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Sustainable Sanitation in Upper Mustang (Nepal) – A Case Study in Lo Manthang Town

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Preface

This thesis is submitted in partial fulfillment of the requirements for the degree of Master of Science in Environment and Natural Resources – Specialization Sustainable Water and Sanitation, Health and Development at the Norwegian University of Life Sciences (NMBU). It is based on background studies and fieldwork undertaken in 2016 and 2017 in Upper Mustang, Nepal, aimed at finding sustainable sanitation options for a local charity school and the wider community. I hereby declare that this thesis is my original work. I sincerely hope it will contribute towards the implementation of holistic sanitation solutions which benefit the local population while helping to protect the fragile Trans-Himalayan environment.

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Abstract

In Upper Mustang, one of Nepal's highest and most remote regions, sanitation infrastructure is undergoing major transitions. The area's inhabitants have traditionally been using dry toilets, perfectly adapted to the semi-arid Trans-Himalayan climate. Excreta are covered with ash from dung fires and reused on fields – the only fertilizer apart from animal manure in a place where about 90% of the people rely on subsistence agriculture and pastoralism. In recent years, however, guesthouses and schools have started building water toilets, which is problematic due to inadequate or non-existing wastewater treatment, posing a health risk and contaminating scarce water resources. Since living conditions in the area are very simple and health services limited, sustainable sanitation is crucial to avoid far-reaching problems.

A charity school in Upper Mustang's capital Lo Manthang is in the midst of these challenges: The school's dry toilets can no longer be used due to a lack of moisture-absorbing materials after switching from dung to gas as a cooking fuel. Meanwhile, the single functioning pour-flush toilet which was built instead is insufficient for the 40 resident students and staff and also causes unsolved issues with blackwater disposal. The objective of this thesis was to develop a sustainable sanitation system in cooperation with the school, aiming at a solution that would be considerate of the environmental conditions and available resources, culturally acceptable, affordable, and directed by local needs for long-term viability. In addition, general suggestions for sustainable sanitary improvements in the area are proposed, based on an assessment of the local context through a combination of social and natural science methods.

Among different options, the school chose to build five urine-diverting dry toilets, henceforth providing separate facilities for girls, boys and staff. When collecting urine and feces separately, only small amounts of amendments are needed to dehydrate and sanitize the pathogen-containing feces before reuse as soil conditioner on fields. The practically sterile, nutrient-rich urine can be applied to crops, for example to increase vegetable production. All materials and expertise for this technology are available in Nepal. For successful implementation, the school will need professional guidance and training of all users. Proper operation and maintenance will require a high degree of commitment, as will the safe handling and reuse of excreta, for which cooperation with farmers might be necessary. Furthermore, to improve the school's sanitary environment holistically, water supply and hygiene measures are essential: The current lack of running water will be addressed with a water storage system, three taps for handwashing, three showers, and an infiltration trench for safe graywater disposal. The water quality of the town's public supply was found to comply with national standards. Through hygiene education and teachers as role models, students are likely to adopt hygiene habits for life.

For Lo Manthang, an awareness-raising program on the links between water, sanitation, hygiene, health and the environment is recommended, including information on the pros and cons of different sanitary options. Local households are advised to keep using dry toilets, and guesthouses may consider returning to dry sanitation as sewage disposal in leaching cesspools is not a long-term solution. Supplying excreta from dry toilets to farmers to cultivate organic produce could strengthen local livelihoods and serve to promote ecotourism. Clean public toilets, with urine diversion and/or solar dehydration, are suggested to reduce open defecation and demonstrate that dry toilets can look attractive – notions of "modernity" being one of the reasons why half of the local respondents prefer water toilets. However, while most welcome the idea of public toilets, only few would pay a user fee to ensure maintenance. To avoid water pollution, an infiltration system or constructed wetland should be built on the terrace of Lo Manthang to treat graywater – and blackwater if water toilets remain in use. The analyzed soils' hydraulic conductivity is low ($2.2\text{-}8.3*10^{-5}$m/s), but purification will be good thanks to their calcium content sorbing phosphorus and pathogens. Judging by the area's heterogeneous layered deposits, infiltration rates at other sites or greater depths will be higher. Effluent from a constructed wetland can be reused for irrigation.

Research challenges included constraints on finances and time in Upper Mustang. Moreover, stakeholder engagement at the school – though so crucial to create ownership – did not happen to the desired extent, probably related to differing expectations and priorities as well as limited experience with the participatory approach on all sides. In Lo Manthang, representative surveys will need to assess various stakeholders' attitudes towards ecological sanitation and wastewater treatment. The elaboration of designs and management schemes will require feasibility studies and further site investigations. However, the most important is the local people's initiative, involvement, and cooperation with sanitation experts.

ནང་དོན་གནད་བསྡུས།

གློ་བོ་ཁུལ་ནི་བལ་ཡུལ་གྱི་ས་བབས་ཆེས་མཐོ་ཞིང་ས་ཐག་ཆེས་རིང་བའི་ས་ཁུལ་ཞིག་རེད། མིག་སྔར་ཁུལ་དེའི་འཕྲོད་བསྟེན་གྱི་རྨང་གཞིའི་སྒྲིག་ཆས་ལ་འཕོ་འགྱུར་ཆེན་པོ་འགྲོ་བཞིན་ཡོད། ཡུལ་མི་ཚོས་སྔོན་ནས་ད་བར་ཏེ་མ་ལ་ཡའི་བྱང་རྒྱུད་ཕྱེད་སྐམ་སའི་གནམ་གཤིས་དང་ཏ་ཅང་འཚམས་པའི་སྲོལ་རྒྱུན་གྱི་ཆུ་མེད་གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་གི་ཡོད། བཙོག་གཙིན་ལྟེ་བའི་གོ་ཐལ་གྱིས་བཀབ་སྟེ། སླར་ཞིང་ཁར་བརྒྱབ་ཀྱི་ཡོད། དེ་ནི་ཡུལ་མིའི་བརྒྱ་ཆ་༩༠ ཙམ་ཞིང་ལས་དང་འབྲོག་ལས་ལ་བརྟེན་ནས་འཚོ་སྐྱོད་བྱེད་པའི་ས་ཆ་དེའི་ནང་སོ་ཕྱུགས་ཀྱི་ལུད་ཕུད་པའི་ས་ལུད་གཞན་གཅིག་པུ་དེ་རེད། འོན་ཀྱང་ཉེ་བའི་ལོ་ཤས་ནང་མགྲོན་ཁང་དང་སློབ་གྲྭ་མང་པོས་ཆུ་གཏོང་བའི་གསང་སྤྱོད་གསར་སྐྲུན་བྱེད་ཀྱི་ཡོད། འོན་ཀྱང་གསང་སྤྱོད་དེ་རིགས་ལ་བཙོག་ཆུ་གཙང་སེལ་བྱེད་པའི་སྒྲིག་ཆས་མི་འདྲེན་བའམ་ཐ་ན་རྩ་བ་ནས་མེད་པར་བརྟེན་ནས་གནད་དོན་ཡང་མང་དག་འཕྲད་ཀྱི་ཡོད་པ། དཔེར་ན་མི་ཕྱུགས་ཀྱི་བདེ་ཐང་ལ་ཉེན་ཁ་ཡོད་པ་དང་། ཆེས་དགོན་པའི་ཆུའི་ནུས་ཁུངས་ལ་འབབ་བཙོག་ཤོར་བ་སོགས་རེད། ས་ཁུལ་དེའི་འཚོ་སྐྱོད་ཀྱི་ཆ་རྐྱེན་ཏ་ཅང་ཞན་པ་དང་། འཕྲོད་བསྟེན་ཞབས་ཞུའི་ཚད་དམའ་བ་སོགས་ལ་བརྟེན་རྒྱུན་མཐུད་ཀྱི་གསང་སྤྱོད་གཙང་སྦྲ་ནི་ཚད་ལས་བརྒལ་བའི་གནད་དོན་ཐོན་རྒྱུ་བཀག་འགོག་བྱ་རྒྱུར་གལ་ཏ་ཅང་ཆེན་པོ་ཡོད།

རྒྱལ་ས་གློ་སྨོན་ཐང་དུ་ཡོད་པའི་ཕན་བདེའི་སློབ་གྲྭ་གཅིག་ནི་གོང་གསལ་དཀའ་ངལ་མང་པོའི་ཁྲོད་དུ་གནས་ཡོད། མི་གཏོང་རྒྱུར་ལྟེ་བའི་ཚབ་ཏུ་སོལ་ཐླངས་བེད་སྤྱོད་བྱས་པའི་རྗེས་སུ་བཞའ་ཚན་འཛིན་བྱེད་ཀྱི་དངོས་པོ་མེད་པས་སློབ་གྲྭའི་ནང་གི་ཆུ་མེད་གསང་སྤྱོད་རྣམས་ལྷུ་མཐུད་ནས་བེད་སྤྱོད་གཏོང་ཐུབ་ཀྱི་མེད། མིག་སྔར་སློབ་གྲྭའི་ནང་དུ་སྲོལ་རྒྱུན་གསང་སྤྱོད་ཀྱི་ཚབ་ཏུ་བསྒྱུན་པའི་ཆུ་ཡོད་གསང་སྤྱོད་གཅིག་པུ་དེས་སློབ་སྦྱོང་སློབ་མ་དང་ལས་བྱེད་མི་གྲངས་བཞི་བཅུར་འདང་གི་མེད་པ་དང་། བཙོག་ཆུ་ཉོག་པོ་གཙང་སེལ་བྱེད་མི་ཐུབ་པའི་གནད་དོན་ཐོན་གྱི་ཡོད། དཔྱད་རྩོམ་འདིའི་དམིགས་ཡུལ་གཙོ་བོ་ནི་སློབ་གྲྭ་དེ་དང་མཉམ་ལས་བྱས་ཏེ་ཁོར་ཡུག་གི་ཆ་རྐྱེན་དང་ས་ཐོག་ཏུ་ཡོད་པའི་ཐོན་ཁུངས་ལ་བདག་སྲུང་ཐུབ་པ་དང་། ཡུལ་སྲོལ་གོམས་གཤིས་དང་མཐུན་པ། འགྲོ་སོང་ཆུང་བ། ཡུན་རིང་འཚོ་གནས་ཐུབ་པའི་ས་གནས་ཀྱི་དགོས་མཁོ་དང་མཐུན་པ་བཅས་ཀྱི་ཐབས་ལམ་ཞིག་འཚོལ་རྒྱུར་དམིགས་ནས་རྒྱུན་མཐུད་གསང་སྤྱོད་ཀྱི་གཙང་སྦྲའི་མ་ལག་ཅིག་གོང་འཕེལ་གཏོང་རྒྱུ་དེ་ཡིན། དེའི་ཁར་སྤྱི་ཚོགས་ཚན་རིག་དང་རང་བྱུང་ཚན་རིག་གི་ཞིབ་འཇུག་གི་ཐབས་ཤེས་ཟུང་འབྲེལ་བྱེད་པ་བརྒྱུད་ས་གནས་ཀྱི་གནད་དོན་ལ་ཕྱོགས་ཡོངས་ནས་དཔྱད་དཔོག་བྱས་པའི་རྨང་གཞིའི་སྟེང་། ཁུལ་དེའི་ནང་རྒྱུན་མཐུད་གསང་སྤྱོད་ཀྱི་གཙང་སྦྲ་ཡར་རྒྱས་གཏོང་ཆེད་གྲོས་འགོ་སྒྲིག་བཏང་བ་ཁག་ཅིག་བཏོན་ཡོད།

ཐབས་ཤེས་མི་འདྲ་བའི་ནང་ནས་སློབ་གྲྭ་དེས་སློབ་ཕྲུག་བུ་མོ་དང་བུ་དང་ལས་བྱེད་རྣམས་ལ་ཁག་སོ་སོར་གསང་སྤྱོད་མཁོ་འདོན་བྱ་ཆེད། བཙོག་གཙིན་ཐ་དད་དུ་དབྱེ་བའི་གསང་སྤྱོད་ཁག་ལྔ་གསར་སྐྲུན་བྱ་རྒྱུ་དེ་གདམ་ག་བྱས་པ་རེད། བཙོག་གཙིན་ཁག་སོ་སོར་བསྡུ་ལེན་བྱེད་པའི་སྐབས་སུ་བཞའ་ཚན་འཛིན་བྱེད་ཀྱི་ཡོ་བྱད་ཤུང་ཤས་ཁོ་ནར་བརྟེན་ནས་བཙོག་པ་སྐམ་རྒྱུ་དང་དེའི་ནང་གི་ནད་རིགས་སྤེལ་མཁན་གྱི་འབུ་ཕྲ་གཙང་སེལ་བྱས་རྗེས་ཞིང་ཁའི་སྟེང་དུ་ས་ལུད་སྐོམས་སྒྲིག་བྱ་རྒྱུར་བེད་སྤྱོད་གཏོང་ཐུབ་ཅིང་། གནོད་བྱེད་འབུ་ཕྲ་ཏ་ལམ་མེད་ཅིང་བཅུད་ཆེ་བའི་གཙིན་པ་དེས་ལོ་ཏོག་གི་སྐང་ལ་བརྒྱབ་ན་འགྲིག། དཔེར་ན་དེ་སྔོ་ཚལ་གྱི་སྐང་ལ་བརྒྱབ་ན་ཐོན་བབ་གོང་མཐོར་གཏོང་ཐུབ་པ་ལྟ་བུ་ཡིན། དེའི་ལག་རྩལ་ལ་མཁོ་བའི་རྒྱུ་ཆ་དང་དེ་འབྲེལ་གྱི་ཤེས་བྱ་ནི་བལ་ཡུལ་ནང་ལ་ཐོབ་བདེ་བ་ཞིག་ཡིན། དེ་བདེ་བླག་ངང་ལག་བསྟར་བྱ་ཆེད་སློབ་གྲྭ་འདིར་ཆེད་ལས་ཀྱི་ཁྲིད་སྟོན་དང་བེད་སྤྱོད་བྱེད་མཁན་ཚང་མར་སྦྱོང་བརྡར་སྤྲོད་དགོས་ལ། ལག་བསྟར་དང་ཉམས་གསོ་འོས་འཚམས་བྱེད་པ་དང་བཙོག་གཙིན་དབོར་འདྲེན་དང་ཡང་བསྐྱར་བེད་སྤྱོད་བྱ་རྒྱུར་ཚད་མཐོ་ཞིང་ཡུན་རིང་འགན་ཁུར་གྱི་ཁས་ལེན་ཞིག་དགོས་པ་ཡིན། ཕལ་ཆེར་དེའི་ཐད་ཞིང་པ་རྣམས་དང་མཉམ་ལས་ཀྱང་བྱེད་དགོས་པ་རེད། དེ་མིན་ སློབ་གྲྭའི་འཕྲོད་བསྟེན་གྱི་ཁོར་ཡུག ཕྱོགས་ཡོངས་ནས་ཡར་རྒྱས་གཏོང་བར་བྱེད་པ་ལ། ཆུའི་མཁོ་འདོན་དང་གཙང་སྦྲ་བྱེད་ཐབས་ཀྱང་ཏ་ཅང་གལ་ཆེན་པོ་རེད། མིག་སྔར་སློབ་གྲྭའི་ནང་ཆུ་ཀ་ལ་མེད་པའི་གནས་དོན་དེར་ཆུ་མཛོད་ཆེན་པོ་མ་ལག་དང་བཅས་པ་ཞིག་བཟོ་དགོས་པ་དང་། ལག་འཁྲུས་ཀ་ལ་གསུམ། གཟུགས་པོ་འཁྲུས་ས་གསུམ། ཏྲི་ཁུ་བདེ་ཐང་དང་ས་འོག་ཏུ་ཐིམས་པར་བྱེད་པའི་ཆུ་སྲུབ་ཅིག་བཅས་བཟོ་དགོས། བརྟག་དཔྱད་བྱས་པ་བརྒྱུད། གྲོང་ཁྱེར་མང་ཚོགས་ཀྱི་བེད་སྤྱོད་པའི་ཆུའི་སྤུས་ཚད་ནི་རྒྱལ་ཁབ་ཀྱི་ཚད་གཞི་དང་མཐུན་ཡོད་པར་ཤེས་རྟོགས་བྱུང་བ་རེད། འཕྲོད་བསྟེན་ཐད་ཀྱི་སློབ་གསོ་སྤེལ་བ་དང་དགེ་རྒན་གྱིས་མིག་དཔེའི་ནུས་པ་བསྟན་ཏེ་སློབ་ཕྲུག་ཚོས་མི་ཚེ་གང་པོར་འཕྲོད་བསྟེན་གྱི་གོམས་གཤིས་ཡག་པོ་ཞིག་ཆགས་པ་བྱེད་དགོས།

གློ་སྨོན་ཐང་གི་གྲོང་ཁུལ་ནང་ཆུ་དང་གསང་སྤྱོད་ཀྱི་གཙང་སྦྲ་དང་། འཕྲོད་བསྟེན། གཟུགས་པོའི་བདེ་ཐང་། ཁོར་ཡུག་བཅས་ལ་སྤྱི་ཚོགས་ཁྲོན་ཡོངས་ནས་ཤེས་རྟོགས་དང་དོ་སྣང་ཡོང་བའི་བྱེད་སྒོ་སྤེལ་རྒྱུའི་འོས་སྦྱོར་བྱ་རྒྱུ་ཡིན། དེའི་ནང་གསང་སྤྱོད་གཙང་སྦྲ་བྱེད་པའི་ཐབས་ཤེས་མི་འདྲ་བ་ཁག་གི་དགེ་མཚན་དང་སྐྱོན་གང་ཡིན་གྱི་ཆ་འཕྲིན་ཕྱུད་དགོས་པ་ཡིན། ས་གནས་དེའི་ཁྱིམ་ཚང་ཁག་ནང་སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་སྐམ་པོ་ལྷུ་མཐུད་ནས་བེད་སྤྱོད་བྱེད་རྒྱུར་སློབ་སྟོན་བྱེད་པ་དང་། མིག་སྔར་བེད་སྤྱོད་བྱེད་པའི་ས་འོག་བཙོག་ཆུ་གསོག་བྱེད་དེ་མིག་རྒྱང་རིང་པོའི་ཐབས་ཤེས་ཤིག་མ་ཡིན་པར་བརྟེན། མགྲོན་ཁང་ཁག་གི་ནང་དུ་གསང་སྤྱོད་སྐམ་པོ་དེ་རིགས་སླར་བེད་སྤྱོད་

གཏོང་རྒྱུར་སྐྱུལ་མ་བྱེད་དགོས། གསང་སྤྱོད་སྐམ་པོ་ལས་བྱུང་བའི་ལུད་དེ་རྣམས་ཞིང་པ་ཚོར་མགོ་འདོན་བྱས་ཏེ་ཐོ་ལྷང་ཟས་རིགས་འདེབས་གསོ་བྱས་ན་ས་གནས་ཡུལ་མིའི་འཚོ་བའི་ཡོང་བབས་མཐོ་རུ་འགྲོ་བ་མ་ཟད། ཁོར་ཡུག་ལ་ཕན་པའི་ཡུལ་སྐོར་ལས་རིགས་གོང་འཕེལ་གཏོང་རྒྱུར་ཞབས་འདེགས་ཞུ་ཐུབ། བསྟོག་གཅིན་ཐ་དད་དུ་དབྱེ་བའམ་ཡང་ན་ཉི་འོད་ལ་བརྟེན་ནས་སྐམ་པའི་སྤྱི་པའི་གསང་སྤྱོད་གཙང་མ་དེ་རིགས་བརྒྱབ་རྒྱུར་གྲོས་འགོ་བཏོན་ན་ཕྱི་ལོགས་སུ་བསྟོག་གཅིན་གཏོང་མཁན་ཉུང་དུ་གཏོང་ཐུབ་ལ། གསང་སྤྱོད་སྐམ་པོའི་རིགས་དེ་བཟླ་དུས་མཛེས་པོ་བཟོ་ཐུབ་པ་དེ་ཡུལ་མིས་མཐོང་བ་དགོས། གང་ཡིན་ཟེར་ན། དེང་རབས་ཅན་ཟེར་བའི་ལྟ་བ་དེ་ནི་བཅའ་འདྲི་བྱེད་སའི་ཡུལ་མི་ཕྱེད་ཙམ་གྱིས་ཆུ་ཡོད་པའི་གསང་སྤྱོད་ལ་དགའ་པོ་ཡོད་ཟེར་ལན་བརྒྱབ་པའི་རྒྱུ་མཚན་ཞིག་རེད། འོན་ཀྱང་མི་རྣམས་ཀྱི་སྤྱི་པའི་གསང་སྤྱོད་ལ་དགའ་པོ་ཡོད་ཀྱང་མུ་མཐུད་ནས་བཟླ་སྐྱོང་དང་ཉམས་གསོ་བྱེད་རྒྱུར་འགན་ལེན་ཐུབ་ཆེད་གསང་སྤྱོད་ལ་དངུལ་སྤྲད་འདོད་བྱེད་མཁན་ཉུང་ཉུང་རེད། ཆུའི་འབབ་བསྟོག་ཐོན་འགོག་བྱེད་པ་དང་། ཆུ་ཡོད་གསང་སྤྱོད་མུ་མཐུད་ནས་བེད་སྤྱད་ན་དེ་ལས་བྱུང་བའི་ཆུ་ཉོག་དང་། དྲི་ཁུ་གཙང་སེལ་བྱེད་པའི་ཆེད་སློ་སྨོན་ཐང་གི་ཞིང་ཁ་ནས་བརྩིས་པའི་ས་མཐོ་སར་ས་འོག་ཏུ་བསྟོག་ཆུ་ཐིམས་བྱེད་མ་ལག་དང་ཡང་ན་མིས་བཟོས་འདམ་ར་གསར་བཟོ་བྱེད་དགོས། ས་ཆ་ཁ་ཤས་ལ་དབྱེ་ཞིབ་བྱས་རྗེས། ས་ཆ་དེ་དག་ནང་ཆུ་སིམ་ཚད་དམའ་པོ་ཡིན་ཀྱང་ ༼སྐར་ཆ་རེར་སྨིད་$2.2\text{-}8.3*10^{-5}$༽ དཀར་རྫས་ཀྱི་རྒྱུ་མང་བས་འོད་ཀྱི་མ་མ་ཞེས་པའི་རྫས་རྒྱུ་དང་གནོད་བྱེད་འབུ་ཕྲ་རྣམས་ཟིན་ཐུབ་པར་བརྟེན། དྲི་ཁུ་དང་ཆུ་ཉོག་གཙང་སེལ་བྱེད་རྒྱུར་ཕན་ནུས་ཆེན་པོ་ཐོན་གྱི་ཡོད། ཁུལ་དེར་ས་རྫོའི་རིགས་ཀྱི་ཕུང་པོའི་རིམ་པར་གཞིགས་ཚེ་ཆུ་ས་འོག་ཏུ་ཐིམས་ཚད་དེ་ས་ཆ་གཞན་དག་གམ་ཡང་ན་གཏིང་ཟབ་པའི་ས་ཆར་དེ་བས་ཀྱང་མྱུར་བ་ཡོད་ཀྱི་རེད། མིས་བཟོས་པའི་འདམ་ར་ནས་ཐོན་པའི་ཆུ་དེ་ཞིང་ཆུར་ཡང་བསྐྱར་བེད་སྤྱོད་གཏོང་ཐུབ།

ཞིབ་འཇུག་བྱེད་པའི་བརྒྱུད་རིམ་ནང་དཔལ་འབྱོར་འགྲོ་སོང་དང་། སློ་སྨོན་ཐང་དུ་སྡོད་པའི་དུས་ཚོད་མི་འདང་བའི་དཀའ་ངལ་འཕྲད་པ་མ་ཟད། ད་དུང་སློབ་གྲྭའི་ནང་ལས་གཞི་དང་འབྲེལ་ཡོད་དགེ་སློབ་ཚང་མས་འཇུལ་ཞུགས་བྱ་རྒྱུ་དེ་ཕྱིས་སུ་བདག་དབང་ཡོང་བའི་ཆེད་དུ་ཧ་ཅང་གལ་ཆེན་པོ་ཞིག་ཡིན་རུང་རང་གི་འདོད་པ་ལྟར་དེ་ལྟར་བྱུང་མེད་པར་སེམས། དེའི་རྒྱུ་མཚན་ནི་ཕྱོགས་གཉིས་ཀྱི་རེ་འདོད་མི་འདྲ་བ་དང་། གལ་ཆེ་ཆུང་མི་འདྲ་བ། ཕན་ཚུན་འབྲེལ་བ་བྱེད་པའི་ཐབས་ལམ་ཐད་ལ་ཉམས་མྱོང་མི་འདང་བ་སོགས་དང་ཕལ་ཆེར་འབྲེལ་བ་ཡོད་སྲིད། སློ་སྨོན་ཐང་དུ་དཔེ་མཚོན་རང་བཞིན་ལྡན་པའི་རྟོག་ཞིབ་དེ་བས་མང་བ་བྱེད་པར་འབྲེལ་ཡོད་མི་སྣ་མི་འདྲ་བའི་ཁོར་ཡུག་ལ་མ་གནོད་པའི་གསང་སྤྱོད་དང་། དྲི་ཁུ་དང་ཆུ་ཉོག་གཙང་སེལ་བྱེད་རྒྱུར་ལྟ་ཚུལ་གང་དང་གང་ཡོད་པའི་ཐད་ལ་དཔྱད་དཔོག་བྱེད་དགོས་ངེས་རེད། འཆར་བཀོད་དང་དོ་དམ་གྱི་འཆར་གཞི་ཞིབ་ཕྲ་ཞིག་བཟོ་ཆེད། ཞིབ་འཇུག་འོས་མཚམས་བྱེད་དགོས་ལ། མུ་མཐུད་ནས་ས་དངོས་རྟོག་ཞིབ་བྱེད་དགོས་པ་ཡིན། འོན་ཀྱང་གལ་ཆེ་ཤོས་ནི་ས་གནས་ཡུལ་མིས་རང་འགུལ་བྱ་རྒྱུ་དང་། འཇུལ་ཞུགས་བྱ་རྒྱུ། དེ་བཞིན་གསང་སྤྱོད་ཀྱི་གཙང་སྦྲའི་རིགས་གཅིག་མཁས་ཅན་དང་མཉམ་ལས་བྱ་རྒྱུ་བཅས་རྣམས་རེད།།

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[1] The funding partners were neither involved in the research set-up nor in the interpretation of the collected data.

Table of Contents

Acronyms and Abbreviations

ABR	anaerobic baffle reactor
ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
(B)CE	(before the) Common Era
BOD	biochemical oxygen demand
BSF	biosand filter
C	carbon
Ca	calcium
$CaCO_3$	calcium carbonate
CAWST	Center for Affordable Water and Sanitation Technology
CBS	Central Bureau of Statistics
CFU	colony forming unit
C:N ratio	carbon to nitrogen ratio
COD	chemical oxygen demand
CW	constructed wetland
DDC	District Development Committee
DEWATS	decentralized wastewater treatment system
DHM	Department of Hydrology and Meteorology
DWSS	Department of Water Supply and Sewerage
EcoSan	ecological sanitation
ENPHO	Environment and Public Health Organization
FEDWASUN	Federation of Drinking Water and Sanitation Users Nepal
FSM	fecal sludge management
GoN	Government of Nepal
GSD	grain size distribution
HCl	hydrochloric acid
HDI	Human Development Index
HMGoN	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
INGO	international non-government organization
IPCC	Intergovernmental Panel on Climate Change
K	potassium
KMTNC	King Mahendra Trust for Nature Conservation
K_{sat}	saturated hydraulic conductivity
l/p/d	liters per person per day
MAAT	mean annual air temperature
m a.s.l.	meters above sea level
MDG	Millennium Development Goal
MLSB	membrane lauryl sulfate broth
MoFALD	Ministry of Federal Affairs and Local Development
MoWSS	Ministry of Water Supply and Sanitation
N	nitrogen
NGO	non-government organization

NH_3	ammonia
NRs	Nepalese rupees (in 2016/17: NRs 100 ≈ US$ 1)
NMBU	Norwegian University of Life Sciences
NTNC	National Trust for Nature Conservation
NTU	nephelometric turbidity units
ODF	open defecation free
O&M	operation and maintenance
P	phosphorus
PAR	participatory action research
SDG	Sustainable Development Goal
SDP	Sector Development Plan
SHMP	Sanitation and Hygiene Master Plan
SWA	Sanitation and Water for All
(T)SS	(total) suspended solids
TU	Tribhuvan University
UD(DT)	urine-diverting (dry toilet)
UMCDP	Upper Mustang Conservation and Development Project
UN	United Nations
UNICEF	United Nations Children's Emergency Fund
VDC	Village Development Committee
V-WASH-CC	Village WASH Coordination Committee
WASH	water, sanitation and hygiene
WHO	World Health Organization
WSP	Water Safety Plan
WSSC	Water Supply and Sanitation Committee
WSSDO	Water Supply and Sanitation Division Office
WUSC	Water Users and Sanitation Committee
WWF	Worldwide Fund for Nature

Some Tibetan (Tib.) terms will be rendered in *Wylie* transliteration.

1. INTRODUCTION

1.1 General Context and Relevance of the Study

For many people in the developing world, safe access to water, sanitation and hygiene (WASH) facilities is still not a given. According to the United Nations (UN, 2015), access to drinking water has greatly improved to 91% in 2015, but more than 40% of the global population experience water scarcity, and that number is expected to rise as an effect of climate change. The situation is much direr in terms of sanitation, with 2.3 billion people worldwide lacking access to basic sanitation services (WHO, 2017b), 40% of them residing in Southern Asia (UN, 2015). Moreover, 90% of sewage in developing countries is not treated before reaching water bodies (Langergraber & Muellegger, 2005; WaterAid, 2011), so that 1.8 billion people's drinking water is contaminated with fecal pathogens (UN, 2015). Such contamination is in fact the world's leading environmental health problem (Landon, 2006).

Bacteria, viruses, protozoa and parasitic worms become a risk to human health as they spread through various transmission pathways (Mara, 2003; Schönning & Stenström, 2004; WaterAid, 2008b). One of the main reasons for WASH-related illnesses such as diarrhea and intestinal worms is the ingestion of contaminated drinking water and food, related to inadequate personal, domestic and agricultural hygiene and/or inadequate quantity and quality of water (Landon, 2006; Prüss, Kay, Fewtrell, & Bartram, 2002; WHO, 2014). Besides, a range of diseases are spread through contact with contaminated water or vectors breeding therein, for example schistosomiasis, malaria and dengue fever (Prüss et al., 2002). Diarrhea is by far the single-most important water-related disease and still the second-leading cause of death in low-income economies (WHO, 2017c). In 2012, 842,000 people are estimated to have died in low and middle income countries due to diarrheal diseases caused by inadequate WASH, making up 58% of the total number of diarrhea deaths in these countries (Prüss-Ustün et al., 2014). Among them are 361,000 children under the age of five, which means that every day almost 1000 young children die because of preventable WASH-related diarrhea (Prüss-Ustün et al., 2014; UN, 2015; WHO, 2017b). The actual number of deaths might be even higher because this estimate does not account for unsafe management of human waste, that is, exposure to fecal sludge and untreated sewage (WHO, 2014). Besides, WASH-related illnesses have further implications such as lower life expectancy due to ill health (also called disability adjusted life years), malnutrition, physical and cognitive development deficiencies, missed school days, lower work productivity and compromised overall well-being (Adams, Bartram, Chartier, & Sims, 2009; Gondhalekar, Nussbaum, Akhtar, & Kebschull, 2015; Landon, 2006; WHO, 2014, 2017b). Nevertheless, the situation is improving: Since 1990, the number of deaths caused by inadequate WASH has dropped by more than half (WHO, 2014). This reduction is partly attributable to better access to health care and oral rehydration of children, but also thanks to improvements in drinking water supply, sanitation facilities and hygiene practices (WHO, 2014). The positive impacts of WASH interventions on public health have long been known (Mara, 2003), and over 30 years ago, a study already indicated that diarrheal diseases could be reduced most efficiently by improving water availability and excreta disposal facilities rather than focusing on water quality alone (Esrey, Feachem, & Hughes, 1985).

On a global level, the importance of WASH was made a priority with the Millennium Development Goals (MDGs) in the year 2000. Under the goal of ensuring environmental sustainability (Goal 7), target C aimed to "[h]alve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation" compared to the baseline year 1990 (UN, 2000). The Sustainable Development Goals (SDGs) adopted in 2015 go even further by making clean water and sanitation a goal of its own with eight specific targets (UN, 2015). The targets strive to "achieve universal and equitable access to safe and affordable drinking water" as well as "adequate sanitation and hygiene for all" by 2030. While hygiene was not part of any MDGs, it is now explicitly mentioned in the SDGs in recognition of its important links with sanitation and public health. It is supposed to be measured by an indicator for domestic hand-washing facilities with water and soap (WHO & UNICEF, 2017). The targets further mention the ambition to "end open defecation, paying special attention to the needs of women and girls in those vulnerable situations" (UN, 2015). Besides, they aim at "halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" in addition to "increasing water use efficiency" and protecting and restoring water-related ecosystems. Of relevance to any intervention in the WASH sector is also the target to "[s]upport and strengthen the participation of local communities in improving water and sanitation management" (UN, 2015). In summary, the SDGs provide ambitious aims to direct efforts towards comprehensive WASH improvements and they recognize inter-linkages between the different components. Such an inclusive approach is particularly important for some of the least developed countries like Nepal where providing sustainable WASH services for all is still a major challenge ahead.

Nepal was a signatory to the MDGs and was therefore supposed to reduce the proportion of people without access to safe drinking water and sanitation by half. In particular, this meant it should have increased drinking water coverage to 65% and sanitation coverage to 59% as its national Millennium Development Targets (WaterAid, 2004). According to an assessment by the United Nations Children's Emergency Fund (UNICEF) and the World Health Organization (WHO), the country surpassed its drinking water target by far and achieved 92% coverage by 2015. However, the sanitation target was not met, and with only 46% coverage, Nepal is still among 47 countries in which less than half of the population have access to improved sanitation facilities (UNICEF & WHO, 2015). Even though that same assessment classified Nepal as having made good progress on sanitation, the persisting shortcomings cannot be overlooked: Thousands of Nepali still die from WASH-related diarrhea annually, open defecation remains widespread in rural areas, and unhygienic environments as well as the limited water availability and quality increase the spread of diseases. These risks are further exacerbated by poverty, illiteracy and misconceptions of the causes of illnesses (Pokhrel & Viraraghavan, 2004). Especially marginalized groups and populations of remote areas lack safe WASH facilities (Sanitation and Water for All (SWA), 2012; WHO, 2012). One such area is the high altitude region of Upper Mustang, located north of the Great Himalayan Range on Nepal's border with Tibet (China).

Upper Mustang is part of Mustang District, characterized by a harsh, semi-arid climate and difficult accessibility. Its remoteness has helped preserve its unique culture and traditional way of life, but also limited the provision of basic government services (Bernet, Pittet, Ambrosi, Kappenberger, & Passardi, 2012; Childs, Craig, Beall, & Basnyat, 2014). For instance, public health care provision is very limited (Banskota & Sharma, 1998; Craig, Chase, & Lama, 2010), and according to the 2001 census, Mustang District was below average in terms of sanitation facilities (WaterAid, 2004). None of the key WASH agencies except the Department for Water Supply and Sewerage (DWSS) had programs in Mustang in 2004 (WaterAid, 2004). Even until 2016, none of Nepal's large WASH partners such as UNICEF, USAid, or WaterAid had extended their program area to Mustang District (GoN, 2016a).

On other levels, changes in Upper Mustang are happening fast, though: A road was completed in 2012 and tourism has increased, as have outmigration of locals for education and labor and the arrival of seasonal migrant workers from other parts of Nepal (Childs et al., 2014). More exposure to and influences from the outside world are transforming the area at a rapid pace, also affecting WASH facilities and habits. Despite limited water resources, guesthouses are replacing the traditional dry latrines with flush toilets, for instance, and institutions such as monasteries and schools are following suit. As this development is very recent and has only taken place over the last few years, the challenges and consequences of (un)safe wastewater disposal are just starting to be considered. Naturally, questions of sustainability arise: Are the newly implemented systems adapted to the local environmental context and do they ensure long-term safe use? Are sewage and fecal sludge properly treated – or is there a risk of "flush and forget," transferring the pollution elsewhere? What are the advantages and disadvantages of the new flush versus the traditional dry toilet system? Are there more sustainable and acceptable alternatives that should be promoted to ensure a safe WASH environment in the future? What notions, attitudes and preferences does the local population have regarding WASH? In an area like Upper Mustang, people's health and survival depend on the intactness of scarce natural resources such as water – "human well-being cannot be seen in isolation from the maintenance of a clean and healthy environment" (Banskota & Sharma, 1998, p. 5). However, the local population must necessarily be at the center of any sustainable development efforts (Banskota & Sharma, 1998).

An opportunity to approach the issue of sustainable WASH in cooperation with local stakeholders presented itself in the fall of 2015: A local charity school in Lo Manthang, Upper Mustang's capital, was looking for consultancy on improving their sanitation system. Kathmandu-based writer Sushma Joshi and Assoc. Prof. Sienna Craig, a long-term friend of the school's headmasters who has been doing ethnographic research in the area for over two decades, facilitated contact with Prof. Petter Jenssen and Assoc. Prof. Manoj Pandey from the Norwegian University of Life Sciences (NMBU). While NMBU's professors did not have the time or funding to travel to Mustang to provide advice, it was decided that a master student should explore sustainable sanitation options together with the local stakeholders. Since the author was familiar with the conditions and language on the Tibetan Plateau and enrolled in the Sustainable Water and Sanitation, Health and Development program at NMBU, she was accepted to assist the charity school in finding the most suitable solutions for improving their WASH situation in the scope of her thesis.

Sanitation in schools is of particular interest and importance due to the influence of WASH on students' education, health and habits. In Nepal, less than two thirds of the schools have toilet facilities, and only one third of those have a separate toilet for girls, even fewer for teachers (GoN, 2010b). This lack of adequate toilet facilities is one of the leading causes of girls dropping out of school during puberty (Adams et al., 2009; GoN, 2010b; Norwegian Church Aid, 2016). Schools with poor WASH conditions also present a high risk environment, especially because children are more prone to getting ill in such circumstances. The risks increase at boarding schools – such as the school in question in Lo Manthang – since the students also eat together, sleep in communal dormitories, use the same toilet and are affected by each other's hygiene practices (Adams et al., 2009). On the positive side, improving WASH at schools has an important multiplier effect, not just because students may act as messengers and initiate positive change in their families and communities, but also because they adopt good hygiene habits at a young age which they tend to keep as adults and pass on to the next generation (Adams et al., 2009). Improving the WASH situation at that Mustangi school, going by the name of Lo Kunphen School, therefore had a range of potential benefits, also because of its unique geographic location.

Even though the Nepali government and numerous non-government organizations (NGOs) are increasingly recognizing improved sanitation as a priority in the country, little has been published in terms of sustainable WASH in mountain areas similar to Mustang. Sanitation projects have largely taken place on the southern, monsoon side of the Himalayas where environmental parameters, the culture and customs differ greatly from the Trans-Himalayan location of Mustang. To achieve greater sustainability of WASH interventions, a number of Nepali and international organizations have promoted ecological sanitation (EcoSan); that is, sanitation that minimizes the spread of pathogens and endorses the reuse of nutrients contained in excreta. However, most of these projects have been implemented in the Kathmandu Valley and there is limited experience of transferring the technologies to a cold, dry mountain climate. Unfortunately, no documentation or reports are available on the small number of EcoSan toilets and alternative wastewater treatment systems that have been built in districts with conditions similar to Mustang, such as Humla and Solukhumbu (Rajendra Shrestha, Director Outreach Division of the Environment and Public Health Organization (ENPHO), personal communication, March 29 and June 16, 2017). Likewise, only limited information could be obtained on how sanitary challenges are dealt with in comparable environments of adjacent countries, such as Ladakh in Northern India.

Regarding Upper Mustang, research conducted in the last decades covers a variety of topics, including assessments of economic and livelihood options, the potential and risks of tourism, outmigration, pastoralism and rangeland management, the role of traditional health care, climate change impacts, and studies on the region's culture, religion, art and history. National statistics capture the coverage of sanitation in the district and list the toilet type households are using, but more detailed data on the challenges and benefits of different sanitation systems has not been published – probably not least because changes in sanitation facilities are a very recent phenomenon. The only sanitation-specific document that could be found is a master thesis evaluating the impacts of ecotourism on the sanitation of local communities in Lo Manthang and two villages in neighboring trekking districts (Pant, 2012). In order to determine the sanitation level of a household, that study categorized toilets into four classes: No toilet received the lowest score, followed by a pit toilet, a pour-flush toilet, and finally a toilet with running water which received the highest score. This ranking is telling because it reflects the assumption that dry toilets are inferior to water toilets, the latter being the predominant and preferred type in most areas of Nepal (Tika Chaudhari, Senior Division Officer of the Wastewater Treatment Section at the DWSS, personal communication, April 6, 2017). By doing so, the author of the study implies that improving sanitation facilities necessarily means flushing excreta with water. Nevertheless, he acknowledges that "toilets [requiring] water can contribute to sanitation problems in communities where water resources are scarce and the knowledge of environmental implications [is] missing" (Pant, 2012, p. 13). He also notes that in Lo Manthang, "creating the 'Western toilet' infrastructure may not be the appropriate method" because it not only leads to a loss of human manure for agriculture but also uses already scarce water resources (Pant, 2012, pp. 34-35).

In line with Pant's (2012) suggestion to consider negative ecological impacts before developing sanitation infrastructure, the thesis at hand will attempt to assess possible WASH improvements from different angles, including environmental sustainability and socio-cultural acceptability. While the main research focuses on sustainable WASH options for the Lo Kunphen School, the thesis also investigates the larger context and possible solutions for sustainable sanitation in Lo Manthang and Upper Mustang in general. The discussed WASH alternatives might thus be of interest and relevance to other high mountain areas with similar climates and constraints, in Nepal as well as in neighboring countries such as India, Pakistan, and on the Tibetan Plateau. The specific objectives and approach as well as the structure of the thesis shall be elaborated below.

1.2 Objectives and Guiding Principles

Upon further communication with the Lo Kunphen School's headmasters in early 2016, the goals of the project – and therefore part of this thesis – were phrased, based on the shared vision to create a sustainable sanitation system which could serve as a model and would have the potential to be replicated across the area: The aim was to improve the sanitary conditions at the school by cooperatively developing a solution that would be adapted to the specific environmental and climatic circumstances, considerate of local resources (including water, soils, and building materials), culturally acceptable, affordable, and directed by local needs and initiative to ensure long-term viability. Reasonable local options would be favored over high-tech appliances which might be expensive and difficult to ob- and maintain. These objectives are consistent with Mara (2003) who emphasizes that the sanitation technologies employed in developing countries must be "appropriate (…), simple, affordable and sustainable" (p. 452). In order to reach these goals, the following guiding principles were considered essential:

1) *Stakeholder participation:* The Lo Kunphen School shall be centrally involved in the development of a solution. This is crucial to create ownership, respect socio-cultural norms and preferences, and design a system that meets the users' requirements, including a sound operation and maintenance (O&M) scheme. Worldwide experience has repeatedly proven that providing "technical" solutions from outside, without active participation of the local people, is unsuccessful and therefore unsustainable in the long run (Bastien, Hetherington, Hatfield, Kutz, & Manyama, 2015; Lambadusuriya, 1993; Nawab, Nyborg, Esser, & Jenssen, 2006; Pokhrel & Viraraghavan, 2004; Rao, Pai, Iyanar, & Joseph, 1997; WaterAid, 2011). Besides, Nepal's Sanitation and Hygiene Master Plan (SHMP) requires greater participation of local communities during planning and implementation of sanitation infrastructure (GoN, 2010b).

2) *Environmental sustainability:* EcoSan principles shall provide guidance and be incorporated to the highest possible extent, though always in consideration of the stakeholders' attitudes and priorities as well as external constraints. From a sanitary engineering perspective the objective is to reduce health risks, prevent contamination of water resources, and ideally promote the reuse of nutrients contained in excreta as fertilizer. In compliance with the SHMP, decentralized sanitation options will be considered and environmental regulations adhered to (GoN, 2010b).

3) *Holistic approach to WASH:* In order to maximize the beneficial outcome, the sanitation concept must address fecal sludge management (FSM) and measures to improve hygiene, both of which need to be planned along with the sanitation infrastructure (GoN, 2010b). Important components are the safe handling and disposal (or reuse) of excreta and/or wastewater, as well as hand-washing facilities. As indicated by the SDGs mentioned above, sustainable projects need to consider the linkages and impacts of WASH on human well-being and the environment rather than focus on separate targets in isolation. Such a larger perspective helps prevent the spread of pathogens and requires awareness of transmission routes (Landon, 2006; Pokhrel & Viraraghavan, 2004). However, comprehensive hygiene education goes beyond the scope of this thesis and will be Lo Kunphen's responsibility.

On the outset it was difficult to predict what system the school would choose to implement due to the participatory nature of the process and many unknown variables, including the status quo, the governing constraints, as well as the stakeholders' expectations and preferences. The author could only vow to take the stakeholders seriously, while trying to promote sustainable solutions and mitigate potential negative environmental impacts.

With the aim of gaining a larger picture and better understanding of the local context, perceptions and attitudes towards WASH, the author planned conversations with key informants in Lo Manthang, including guesthouse owners, health workers and other schools. These interactions during an initial field visit in July 2016 seemed to spark interest in WASH, so that a few months later the local village development committee (VDC) came up with the idea to build a wastewater pipe in town.[2] Partly related to this, the Lo Kunphen School then suddenly appeared to lose interest in developing a sustainable solution together (see *6.2 Difficulties and Methodological Shortcomings*). Half-way into the cooperation, the author therefore decided to widen the research focus beyond the school, in case Lo Kunphen no longer wished to cooperate. An additional goal was set, namely to explore and recommend sustainable sanitation options for Lo Manthang and Upper Mustang in general. Extending the focus required further research. During subsequent fieldwork, more interaction with the wider community in Lo Manthang was planned to deepen insight into a range of WASH-related issues: which toilet types the respondents use and prefer, the reasons for their choices, their awareness of environmental and health impacts of different sanitation systems, their openness to EcoSan and natural wastewater treatment as well as the importance they attach to WASH. Furthermore, an assessment of local soil properties and hydraulic conductivity values was intended to estimate the soil's suitability for wastewater infiltration. Based on these investigations, the thesis reached its current scope and content:

An extensive background chapter (1) provides the context of the three main components of the research: WASH in Nepal, the region of Upper Mustang, and the Lo Kunphen School. Most of the information in this chapter is based on a literature review, supplemented with information from communication with local WASH actors and interview partners. The methodology chapter (3) then explains the research chronology and the used methods, both from social and natural sciences because of the interdisciplinary topic. This is followed by primary research findings (4), including the current WASH situation in Lo Manthang and at the Lo Kunphen School, community members' attitudes towards sanitation and the soil characteristics at three locations in Lo Manthang. Based on these findings, sustainable sanitation options are suggested (5): For the Lo Kunphen School, a selection of possible improvements is presented, followed by a graphic design and specifications of the system the stakeholders ended up choosing. For Lo Manthang, suggestions for improving WASH awareness and different recommendations for private households, guesthouses, public toilets, and potential wastewater treatment are outlined. A separate chapter (6) summarizes the challenges and lessons learned as well as further research needs, so that those interested in similar or follow-up studies have an overview of potential pitfalls, limitations, methodological challenges and further topics to examine. The conclusion (7) is followed by appendices containing more detailed information on interview partners, the question guides for stakeholder and community consultation, a WASH assessment tool, the complete data from water and soil analyses, and the cost estimate for the recommended WASH improvements at the Lo Kunphen School.

[2] E-mail from S. Craig based on communication with Lo Kunphen's headmasters, February 18, 2017.

2. BACKGROUND INFORMATION

2.1 Water, Sanitation and Hygiene (WASH) in Nepal

To set the context in which the research is based, this chapter provides an overview of the current status of water, sanitation and hygiene (WASH) in Nepal. It covers the general WASH situation in the country (2.1.1), sketches the institutional framework, strategies and policies that shape the sector (2.1.2), outlines the budget and fund allocation (2.1.3) and finally highlights some achievements and challenges regarding WASH in Nepal (2.1.4).

2.1.1 General Situation

This first section includes recent statistics on the access to water supply and sanitation facilities in Nepal, the prevalence of hygiene practices, as well as glimpses of persistent health issues and costs attributable to insufficient WASH, the widespread lack of wastewater treatment, and the use of EcoSan.

In terms of access to drinking water, the country has made substantial progress over the last 25 years, increasing the proportion of people with access to improved water sources from 63% in 1990 to 92% in 2015 (UNICEF & WHO, 2015; Figure 1). According to UNICEF and the WHO (2015), "an improved drinking water source is one that, by the nature of its construction, adequately protects the source from outside contamination, particularly fecal matter" (p. 50). Piped water on the user's premises is considered the best category, though public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection also count as improved sources (dark and light blue colors in Figure 1). Increased access to safe water sources has especially taken place in rural areas where over 80% of Nepal's population lives. In urban areas, the proportion of users with access to improved drinking water sources has decreased since 1990, but it must be noted that rapid urbanization has doubled the percentage of people living in cities within the same time period, from 9% in 1990 to 19% in 2015 (UNICEF & WHO, 2015).

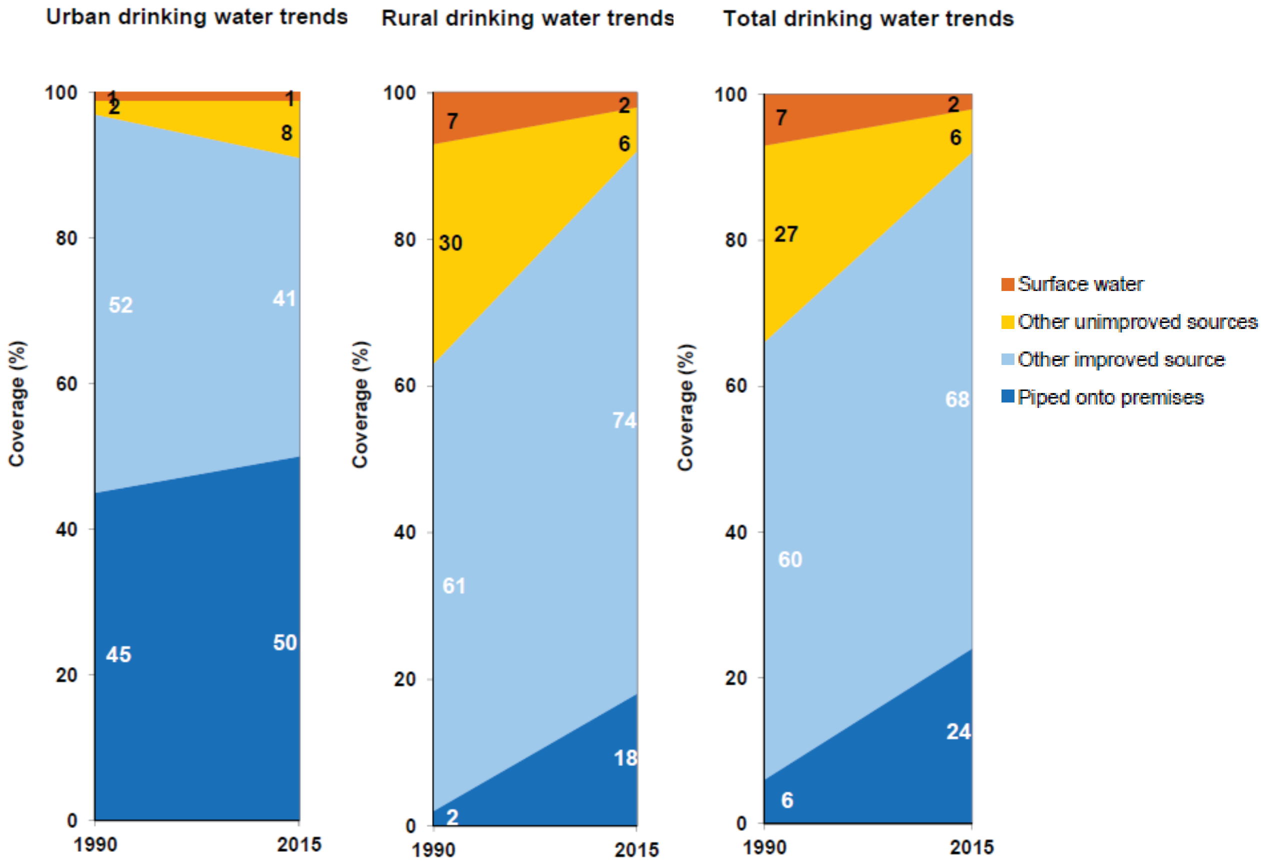


Figure 1: Estimate on use of drinking water sources in Nepal 1990-2015 (UNICEF, 2015)

Even though Nepal met the MDG target regarding access to drinking water, it is important to mention that coverage is neither equivalent with actual functionality nor does it assure adequate water quality. For instance, the Ministry of Water Supply and Sanitation (MoWSS) reports that about one third of over 41,000 piped rural water supply schemes does not deliver water to all taps year-round. Only 25% of the systems function well, while all the others require minor (36%) or major (9%) repairs, need reconstruction and/or rehabilitation to meet the present water demand, or cannot be recovered at all (1%) (MoWSS, 2016). Besides, water quality monitoring is irregular and bacterial contamination of sources, during water transport and storage remains the main quality problem in rural areas (MoWSS, 2016). Whereas national drinking water quality standards were approved in 2005 (GoN, 2005), their implementation is still lagging behind (T. Chaudhari, personal communication, April 6, 2017).

Regarding access to sanitation facilities, coverage has increased remarkably over the last 25 years, both in rural and urban areas. A joint report by UNICEF and the WHO (2015) states that overall, access to improved facilities has multiplied from 4% in 1990 to 46% in 2015 (Figure 2, dark green color). This is not least an achievement considering the country's population growth from 18 to 28 million in the same period (UNICEF & WHO, 2015). However, more than half of the people do still not have access to improved sanitation, meaning a facility "that hygienically separates human excreta from human contact," including a flush or pour-flush toilet to a piped sewer system, septic tank or pit latrine, a ventilated improved pit (VIP) latrine, a pit latrine with slab, or a composting toilet (UNICEF & WHO, 2015, pp. 50, 52). Toilets that are public or shared with other households do not count as improved.

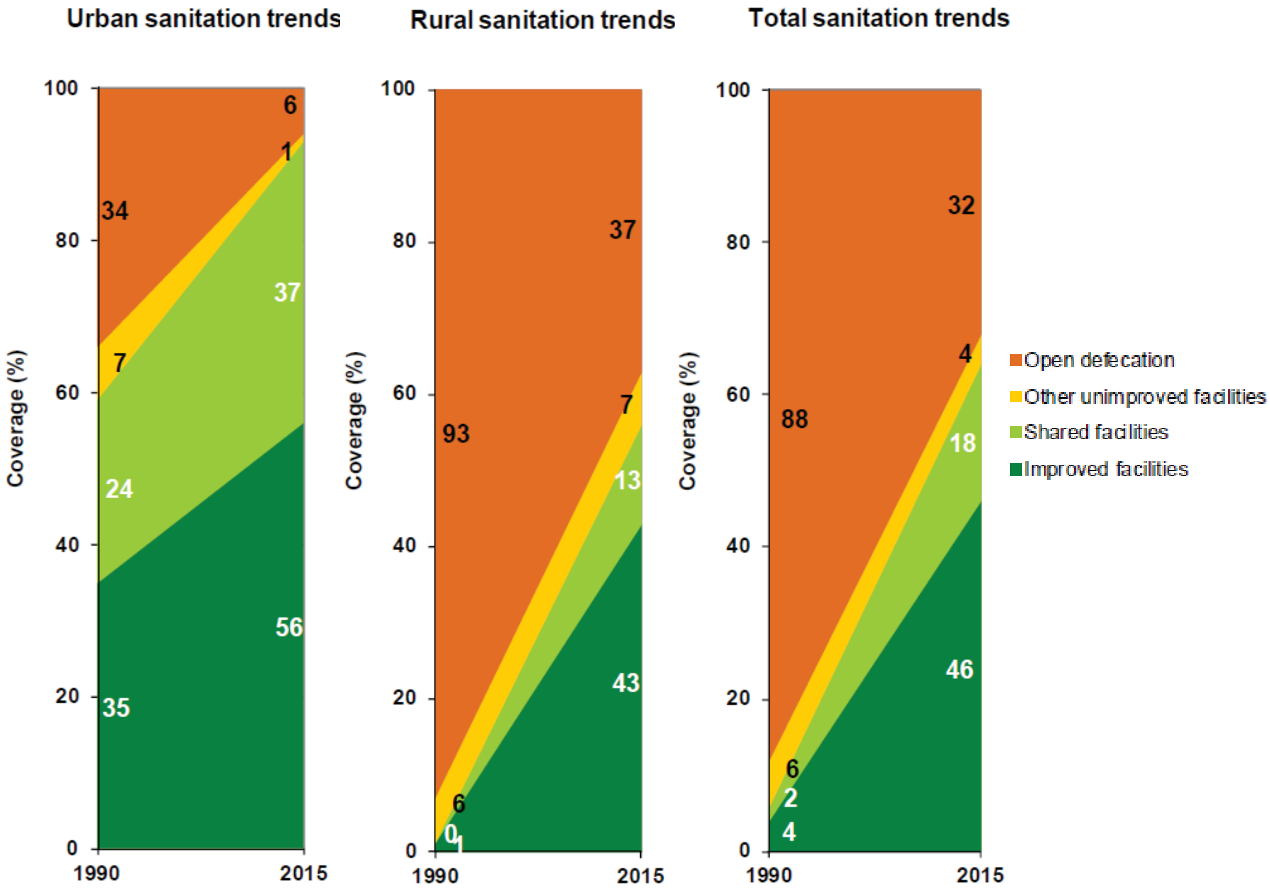


Figure 2: Estimate on use of sanitation facilities in Nepal 1990-2015 (UNICEF, 2015)

Nepal did not reach the MDG target for sanitation, but the country was categorized as having made good progress (UNICEF & WHO, 2015). Improvements have especially taken place since the adoption of the National Sanitation and Hygiene Master Plan (SHMP) in 2010/11, with sanitation coverage increasing by almost 48% (MoWSS, 2016). Access to sanitation varies across the country, though: in the hill region coverage is highest (52%), followed by the mountains (42%) and the lowlands (35%) (GoN, 2010b). Even greater disparities exist between urban and rural areas. Whereas open defecation has been reduced to 6% in cities, it remains high in the countryside where 37% of the people defecate in pasturelands and forests or even in the vicinity of dwellings (Pokhrel & Viraraghavan, 2004; UNICEF & WHO, 2015).

Before the SHMP, sanitation used to be a component of the water supply program and has long been neglected in favor of drinking water coverage, but tendencies are gradually changing (GoN, 2010b; MoWSS, 2016). The government has recognized that a good sanitary environment is equally if not more important for human health, and since the 1990s various programs promoting hygiene and sanitation have been implemented. They have included a range of initiatives, advocacy campaigns as well as school and community approaches to improve toilet coverage. From about 2005 onwards, Community Led Total Sanitation and School Led Total Sanitation programs have aimed to eradicate open defecation (GoN, 2010b). Thanks to a nationwide movement, more than half of all districts, VDCs and municipalities have been declared open defecation free (ODF) in the last decade (MoWSS, 2016).

While sanitation and hygiene programs were initially about awareness raising, they are increasingly shifting towards a behavior change approach (GoN, 2010b). However, despite continued efforts to improve hygiene practices, national estimates indicate that just over half the population (57%) nationwide has access to water and soap for hand-washing (Table 1). 42% have limited facilities (lacking either water or soap), and 1% have no facilities at all. Great disparities between urban and rural areas become apparent again, with the urban population having access to better facilities (WHO & UNICEF, 2017).

Table 1: Hygiene estimates for Nepal, based on data from WHO and UNICEF (2017)

	Urban	Rural	National
Basic facilities (with water and soap)	80%	52%	57%
Limited facilities (without water or soap)	19%	47%	42%
No facilities	1%	1%	1%

Inadequate WASH leads to serious implications for the population and for Nepal as a country. In 2012, 3522 people are estimated to have died from diarrhea (WHO, 2014), among them 982 children below five years of age (WHO & UN-Water, 2017a). WaterAid's estimates vary between 600 and 10,500 annual deaths of children under five caused by WASH-related diarrhea in Nepal, amounting to 18-33% of deaths in this age group (WaterAid, 2008b; WaterAid Nepal, n.d.). The Government of Nepal even reckons infant deaths due to poor hygiene and sanitation to be as high as 12,700 per year, but those estimates also include acute respiratory illnesses in addition to diarrheal diseases (GoN, 2010b). Further unreported cases may exist because many people do not have enough money to travel to a hospital for treatment, especially in rural areas where health posts are often far away (Pokhrel & Viraraghavan, 2004). Besides diarrhea mortality, unsafe drinking water and poor sanitation in Nepal are also causing 72% of the people to suffer from related diseases, and 90% of the people are estimated to have worms at any given time (GoN, 2010b). Health expenditures for WASH-related diseases amount to NRs 2.2-3.6 billion (US$ 21-35 million) per year, and the yearly economic productivity loss attributed to inadequate sanitation is even multiple times higher at an estimated NRs 10 billion (US$ 100 million) (GoN, 2010b).

According to Kelly (1990), the main reason for diarrhea outbreaks are unhygienic environments leading to contamination of the water supply and storage systems. Such unhygienic environments are often related to inadequate disposal of excreta from sanitary facilities; FSM is coming to be seen as a major challenge in improving sanitation (DWSS & MoWSS, 2016b). According to government documents (DWSS & MoWSS, 2016b; GoN, 2010b), observations and numerous interviews with stakeholders and WASH actors in Nepal, FSM is largely unregulated. In rural areas, wastewater from toilets is commonly disposed of directly into streams and rivers without even flowing through a septic tank first. In small towns, emptying of pits and septic tanks depends on households and private service enterprises, without monitoring or control of transportation, treatment and disposal of the sludge. The latter is often dumped on marginal lands, into sewers and drains. Even in cities, most sewage pipes discharge into rivers without prior treatment (ENPHO & WaterAid, 2008). T. Chaudhari and P. K. Shrestha from the Wastewater Treatment and Environmental Sanitation Sections at the DWSS, respectively, stated that this is neither allowed nor desirable, but infrastructure development is lagging behind haphazard urban growth and the government is currently not able to offer an alternative and enforce rules (personal communication, April 6 and June 12, 2017, respectively). It must be noted that the expenses for constructing, operating and maintaining conventional sewers and wastewater treatment plants are a large financial investment even in developed countries (Langergraber & Muellegger, 2005). According to Chaudhari, only one of the centralized treatment systems in Kathmandu – at Guhyeshwori near Pashupatinath – is currently functioning, and incurs high running costs with an annual NRs 3-6 million (US$ 30-60,000) for electricity alone. Due to lacking FSM and wastewater treatment, the contamination of surface and ground water with fecal pathogens is widespread, posing a serious public health hazard and leading to adverse environmental effects (DWSS & MoWSS, 2016b; ENPHO & WaterAid, 2008; WaterAid, 2008a).

The Ministry of Water Supply and Sanitation (MoWSS) as well as the Ministry of Physical Planning and Works (now Ministry of Physical Infrastructure and Transport) have recognized the importance of reducing the pollution of waterways through efficient technologies and affordable, sustainable solutions (DWSS & MoWSS, 2016b; Pant, 2012). Considering the challenges and disfunctionality of centralized treatment plants, decentralized systems with onsite treatment of excreta and wastewater might be a better option in many parts of the country.

Since conventional latrines do not sanitize excreta but often pollute water resources, EcoSan has emerged – or been revived – as an alternative option (Langergraber & Muellegger, 2005; Winblad & Simpson-Hébert, 2004). EcoSan works on the principle of containing excreta (and therefore fecal pathogens), sanitizing them, and reusing their nutrients in agriculture. Not only do EcoSan toilets reduce the risk for environmental pollution, but they also curb the need for flushing water as well as artificial fertilizer. The systems used in Nepal consist of a raised superstructure with an above-ground storage for excreta where urine and feces are collected separately or together, with or without anal cleansing water (Figure 3). Adding soil, ash or other organic amendments to the feces helps pathogen die-off, and in the course of a few months – depending on the climate and user practices – produces odorless compost. (Rajbhandari, 2008; Sijbesma, 2008).[3]

Figure 3: Urine-diverting EcoSan toilet (ENPHO, 2007)

The concept of EcoSan is no novelty in Nepal: indigenous practices of fertilizing fields with human waste, combined with animal manure and kitchen waste, have existed for generations (Adhikari & Poudel, 2015; Rajbhandari, 2008; WaterAid, 2008a). However, modern EcoSan technology started being promoted in Nepal in 2002 under the lead of the NGOs ENPHO and WaterAid Nepal who cooperated with the DWSS and donors such as UN-HABITAT and the WHO. They implemented urine-diverting toilets in peri-urban areas around Kathmandu and worked together with the communities on the treatment and safe use of urine and excreta in agriculture. Local farmers noticed that these human fertilizers increased yields, improved soil condition and enhanced the appearance and taste of vegetables. Nepal being an agricultural economy, EcoSan has the potential to strengthen food security and lower dependency on chemical fertilizers imported from India. Gradually, EcoSan toilet projects scaled up, and by 2015 almost 2,100 such toilets had been installed, not just in private homes but also in schools, at bus stands, and with somewhat modified technology in different parts of the country (Adhikari & Poudel, 2015; Bing, 2014; Rajbhandari, 2008; R. Shrestha, personal communication, March 29, 2017; Sijbesma, 2008; WaterAid, 2008a). The Government of Nepal (GoN) considers EcoSan toilets as "one of the most important and inevitable sanitation options available" (Rajbhandari, 2008, p. 65) and the country's policy framework is favorable to the technology (Adhikari & Poudel, 2015). Nevertheless, EcoSan is predominantly promoted by NGOs, not government agencies, and pour-flush toilets remain the prevailing type (T. Chaudhari, personal communication, April 6, 2017). According to P. K. Shrestha from the DWSS, sanitation practitioners even force locals to build flush toilets in areas where dry toilets have existed for centuries, because these professionals are used to water toilets and consider them a necessary improvement (personal communication, June 12, 2017).

[3] More details on the structure, functioning, maintenance and operational requirements of EcoSan toilets will be presented in sections *5.1.2* and *5.1.3* below.

Despite their advantages, EcoSan systems face a number of difficulties that limit their widespread usage, ranging from people's attitudes and livelihoods to practical and financial challenges. For one, the benefits of the technology are inadequately understood by potential users, and water toilets are erroneously believed to be the best (Rajbhandari, 2008). According to Kabindra Pudasaini from WaterAid Nepal, people are reluctant to see, let alone handle urine and feces after collection. Many are unwilling to reuse human waste and prefer sewage lines that transport excreta elsewhere (personal communication, April 13, 2017). In line with the findings of a report on EcoSan in Nepal (Rajbhandari, 2008), Pudasaini also pointed out that for those who do have EcoSan toilets, the main attraction is not the environmental benefit (cited by 17%) but the availability of fertilizer (cited by 71%). This makes it difficult to encourage non-farming households to use the technology – a problem that increases with urbanization and the disappearance of agricultural land. In urban areas, EcoSan meets with problems of acceptance because there is no immediate use for fertilizer. Even in agricultural areas, the use of urine from EcoSan toilets is limited, possibly due to transportation difficulties and lack of experience with its fertilizer value and production benefits. Practical demonstration of field application is considered essential to convince users of the usefulness of human excreta so that the latter are perceived as a resource rather than waste (Rajbhandari, 2008). EcoSan projects have been most successful in peri-urban areas with farmland and vegetable gardens where artificial fertilizer is expensive and a market for farm products exists. Environmental factors such as water scarcity, rocky soils, high water tables and poor soil fertility also make EcoSan toilets an attractive and suitable option (Sijbesma, 2008). An obstacle for EcoSan systems is their comparatively high initial cost, though, which is only gradually amortized thanks to the value of the gained fertilizer and the saved expenditure for pit emptying and/or wastewater treatment (Sijbesma, 2008). Without subsidies, spontaneous replication is difficult, and the resources mobilized by the government and support agencies have been limited (Adhikari & Poudel, 2015). Further challenges are the space required to build an EcoSan toilet and the need to show visitors how to use is properly. Proper usage and management are also the key to long-term sustainability: The success of EcoSan systems depends on the users' participation and commitment as they not only have to change their habits but also their existing perception, which takes time (Rajbhandari, 2008).

2.1.2 Institutional Framework, Policies and Strategies

Nepal's WASH sector is characterized by a complex institutional setup. The DWSS, established in 1972, is the main agency for planning, implementing policies, O&M of water supply and sanitation systems nationwide. It has division and subdivision offices in all 75 districts, consults with WASH actors and coordinates sector activities (GoN, 2010b; MoWSS, 2016). The DWSS used to be overseen by the Ministry of Physical Planning and Works (Tayler, Scott, & Shrestha, 2005) and the Ministry of Urban Development (WHO, 2015c). In December 2015, it then came under the newly established Ministry of Water Supply and Sanitation (MoWSS, 2016). The responsibility for technical support lies with the Department of Local Infrastructure Development and Agricultural Roads which is a technical unit of the District Development Committees (DDC) in all 75 districts. This unit operates under the Ministry of Federal Affairs and Local Development (MoFALD), another key agency for rural WASH projects working alongside the DWSS (GoN, 2016a; MoWSS, 2016; Tayler et al., 2005). Furthermore, the Ministry of Education is in charge of improving WASH services and hygiene practices in schools, while the Ministry of Health and Population should surveil water quality and respond to emergencies. Environmental issues such as wastewater discharge standards and impact assessments fall under the Ministry of Population and Environment (GoN, 2010b, 2016a). Development partners, including UN agencies, international and domestic NGOs, work with one of the ministries or directly in the districts according to agreements with the government (MoWSS, 2016).

At the local level, DDCs, VDCs and municipalities are responsible for developing, implementing and monitoring WASH programs in their respective areas (DWSS & MoWSS, 2016b; GoN, 2016a; Tayler et al., 2005). These local bodies are supported by WASH Coordination Committees (WASH-CCs) that oversee and harmonize WASH activities at different levels, in line with national policies. For instance, the Regional WASH-CC (R-WASH-CC) helps districts formulate and carry out their own hygiene and sanitation program. The District WASH-CC (D-WASH-CC) helps the DDC coordinate stakeholders' activities and encourages VDCs and municipalities to develop and implement WASH programs. The

Village WASH-CC (V-WASH-CC) is then in charge of overall planning and supervision of WASH activities at the VDC level (GoN, 2010b, 2016a).

Water supply schemes and sanitation programs are run by different entities and community-based organizations at different levels. Urban water supply is managed by government-related utilities and public-private partnerships (WHO, 2015c). In small towns, Water Users and Sanitation Committees (WUSCs) run water supply systems and tariffs collected for the provided services pay for a team of operators. Water supply schemes in rural areas are also managed by WUSCs, in cooperation with village maintenance workers. The WUSCs are supposed to establish a fund for regular maintenance of the systems; for major repairs beyond their capacity they can call on local bodies and sector agencies for support (GoN, 2016a; MoWSS, 2016). However, there is neither an institution for regular monitoring nor a clear procedure for handling technical problems. The Federation of Water and Sanitation Users of Nepal (FEDWASUN), a nationwide association of WUSCs, increasingly facilitates between users and service providers (MoWSS, 2016). While the country relies mostly on the public sector for service provision, private sector involvement is gradually increasing (GoN, 2009). Sanitation programs only started receiving more attention in the 1990s and local government bodies have had limited technical capacity for implementation. Therefore, such interventions have largely been carried out by NGOs of which about 200 are active in the WASH sector (GoN, 2010b; Tayler et al., 2005).

This complex institutional setup has made coordination challenging, led to duplicate work and inefficiencies (Irin, 2013; WHO, 2012). With the new Federal Constitution of Nepal that came into effect in 2015, the current structure is under review and will be subject to major reorganization. WASH sector governance will be increasingly decentralized, and the new federal legislation is expected to clearly define the roles and responsibilities of the involved institutions (GoN, 2016a; MoWSS, 2016). Nepal is now also one of a few countries whose constitutions explicitly state every citizen's right of access to safe water and sanitation and the right to live in a healthy and clean environment (DWSS & MoWSS, 2016b).

A range of more detailed policies concerning water and sanitation have already been enacted over the last decades (DWSS & MoWSS, 2016b; GoN, 2009, 2010b; MoWSS, 2016; Tayler et al., 2005). The first National Sanitation Policy was adopted in 1994, followed by a Rural Water Supply and Sanitation Policy (2004) and an Urban Water Supply and Sanitation Sector Policy (2009), based on the Environmental Protection Act (1997) regarding wastewater disposal. The National Building Code (2003) also includes regulations on wastewater disposal from urban dwellings, besides providing guidelines for toilet construction and plumbing which are relevant for WASH planning in cities. Likewise, the Urban Environment Management Directives (2011) and the Urban Development Strategy (2015) contain passages on sewage, prohibiting the discharge of untreated wastewater into natural water bodies and focusing on sewerage and onsite sanitation systems in urban contexts.

As for specific regulations on sanitation, a wastewater treatment policy has been drafted but not yet approved by the cabinet, so there are currently no binding standards for domestic wastewater and effluent from treatment systems. Before the policy is passed, its content cannot be shared with the public, but in the meantime neighboring countries' standards are used as reference values, for example the Indian Urban Fecal Sludge and Septage Management Policy Draft from 2017 (T. Chaudhari, personal communication, April 6, 2017). An Institutional and Regulatory Framework for Fecal Sludge Management by the DWSS and the MoWSS is also in revision for approval (DWSS & MoWSS, 2016b). The WHO's Sanitation Safety Plan has not been adapted to Nepal's national level yet, but guidelines are under development (K. Pudasaini, personal communication, June 7, 2017).

Regarding drinking water, the legislative framework is more advanced: National Drinking Water Quality Standards were adopted in 2005 (GoN, 2005), and a Water Safety Plan (WSP) in 2013 (GoN, 2013). Regional DWSS laboratories have provided water test kits to each district and started training WUSC members in their use (MoWSS, 2016; S. Joshi and K. Pandey, DWSS, personal communication, April 4, 2017). As indicated in the previous section, regular water quality monitoring is still short of implementation, though. Water quality checks are also intended as part of the WSP which is a "risk assessment and risk management approach that covers all steps in water supply from catchment to consumer" (GoN, 2013, p. 1). Besides verifying water quality, its main objectives are to identify hazards (such as leakages and contamination sources), adopt measures to control them and monitor the effectiveness of those measures (for example the promptness of repairs) (GoN, 2013). So far only around 10% of completed water supply systems nationwide are applying the WSP procedures (MoWSS, 2016).

Policy implementation has generally been slow across the WASH sector: While the existing legislation was deemed satisfactory by an independent assessment in 2011 (SWA, 2014), it has not sufficiently been put into practice because of the above-mentioned fragmentation of the sector, poor local governance as well as the continuing political and social instability (Tayler et al., 2005; WHO, 2012). Even though policies and strategies for WASH improvements are available, as is data for resource allocation and the status and quality of service delivery, that information is not sufficiently used for decision-making (WHO & UN-Water, 2017b). In order to better coordinate the different WASH actors and make interventions more efficient, a comprehensive National Sanitation and Hygiene Master Plan (SHMP) was issued in 2010/11 (GoN, 2010b). It provides clear guiding principles for sanitation and hygiene projects to synchronize the efforts of all stakeholders such as government agencies, local bodies, domestic and international NGOs (INGOs), various community groups, and donors. The SHMP encourages a nationwide inclusive sanitation movement involving people from all regions, ethnicities, classes and ages, with particular emphasis on women and disadvantaged groups. Further essential components are the strengthening of local leadership, community ownership and participation, awareness-raising, mobilization of more funding, public-private partnerships, human resource training, emergency preparedness and response, monitoring and evaluation (Adhikari, 2017; DWSS & MoWSS, 2016b; GoN, 2009, 2010b; MoWSS, 2016; SWA, 2014).

Besides the SHMP, the MoWSS also finalized a National WASH Sector Development Plan (SDP) to streamline sector activities according to a coherent strategy and national priorities (GoN, 2016a). The SDP extends over a 15-year period (2016-2030) and as a rolling plan will be adjusted every five years. It is aligned with the United Nations' SDGs and intends to not just increase coverage of water supply and sanitation, but also to improve service levels and eradicate access disparities. Through the adoption of a single WASH Act and a consistent, national WASH program that will be carried out by one ministry, the plan raises hopes for improved sector governance, transparency and accountability (DWSS & MoWSS, 2016b; GoN, 2016a; MoWSS, 2016).

2.1.3 Budget

In 2016/17, Nepal allocated NRs 25 billion (US$ 250 million) or 2.4% of its national budget to water and sanitation through the MoWSS, the MoFALD and the Ministry of Urban Development, in comparison to 4.6% for health and 11% for education (MoWSS, 2016). The proportion has dropped from 3.7% over the last decade (SWA, 2014), but in absolute terms the budget has greatly increased, by almost US$ 100 million just in the fiscal year 2016/17 (MoWSS, 2016). Even though WASH expenditures continue to increase, they are still reported to be insufficient, amounting to 0.83% of Nepal's GDP or about US$ 6 per capita in 2015 (WHO & UN-Water, 2017b).

The distribution of WASH funding in Nepal is noteworthy in several respects: Whereas less than 20% of the population live in cities, the money is almost equally shared out to urban (51%) and rural (49%) areas (WHO, 2015c). Besides, drinking water is clearly prioritized over sanitation (Figure 4), reflecting the limited attention the latter has received although policy documents state that 20% of the sector budget should be allocated to it (GoN, 2010b). The WHO (2015c) reports only 13% of funds to be used on sanitation, and national estimates are even lower with around 5% (GoN, 2010b). Nevertheless, the government recognized the importance of sanitation and established a separate budget line in 2010/11 (SWA, 2014). Hygiene promotion makes up about 10% of the sanitation budget, while 90% is used for infrastructure and awareness-raising (WHO, 2015a). Infrastructure development also uses a much greater proportion of the total WASH budget than what is spent on O&M – over 90% of financial flows are capital investment. The recurrent (operational) budget only amounts to 6-8%, despite policy commitments to allocate 20% to functionality of WASH services (MoWSS, 2016; SWA, 2012; WHO & UN-Water, 2017b).

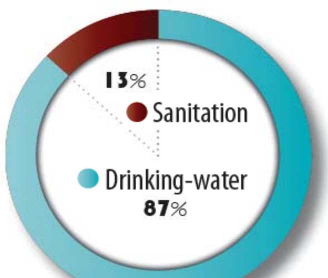


Figure 4: Disaggregated WASH expenditure Nepal, adapted from WHO (2015c)

Nepal cannot cover its national WASH expenditures through domestic sources alone; while the government provides 53% of the funds, 5% of the budget are foreign grants and 42% repayable foreign loans (MoWSS, 2016). The country therefore heavily relies on external aid for its WASH program (WHO & UN-Water, 2017b). Between 2011 and 2013, Nepal received an average of US$ 91.4 million official development assistance for water and sanitation per year (WHO, 2015d). Among the donors are governments providing bilateral aid, various international organizations, and development banks (SWA, 2012). Other WASH funds which do not appear in the national budget are mobilized by (I)NGOs and through local bodies, for example through tariffs and users' contributions (MoWSS, 2016).

In rural areas, tariffs are raised to cover O&M costs of public water supply and sanitation, whereas in small towns, both O&M and capital costs should be recovered through household contributions. On average, a rural household spends about NRs 300 (US$ 3) on water tariffs and an urban household NRs 1,200 (US$ 12), which is reported to cover over 80% of operation and basic maintenance of water supply schemes. Urban sanitation schemes, however, recover less than 50% through tariffs (WHO & UN-Water, 2017b). While people are expected to contribute financially to WASH services (DWSS & MoWSS, 2016b), cost recovery mechanisms may conflict with the necessity to provide affordable services. Thus, as a result of insufficient fund generation, systems may not function well (WHO, 2012) or services to poor and marginalized people may be neglected (GoN, 2009).

Users also contribute to the construction of new water supply and sanitation systems, both through labor and cash. In rural areas, the government provides 80% of the capital cost of water and sanitation schemes while 20% is covered by the population. In small towns, users contribute 15% to the capital cost of sanitation and 30% to water supply projects. In large cities and in Kathmandu, no initial contribution is sought but investments are supposed to be recovered through tariffs (MoWSS, 2016). Regarding government support for sanitation projects, no subsidies are envisaged for toilet construction according to current policies. However, in order to reach ODF status, the D-WASH-CCs can decide to support extremely poor, disadvantaged or disabled community members who are unable to finance toilet construction themselves – provided that the large majority of households already have sanitary facilities (T. Chaudhari, personal communication, April 6, 2017). Even though policies to support vulnerable populations such as the destitute, disabled, or those living in remote areas exist in Nepal, there are no specific measures in the financing plan to target resources to these populations (WHO & UN-Water, 2017b).

2.1.4 Achievements and Challenges

Over the last decades, Nepal's WASH sector has undoubtedly made great improvements, though a number of challenges remain to be tackled. In terms of achievements, access to drinking water and sanitation facilities has increased substantially, and the policy environment is considered conducive to achieving the national goal of full coverage (SWA, 2014; WHO, 2012). The fragmented WASH sector has started a long due harmonization process, undergoing two Joint Sector Reviews (2011 and 2014) and establishing a Sector Efficiency Improvement Unit. This process has led to improved sector coordination and greater political commitments to WASH, not least thanks to the SHMP. The adoption of this strategy has directed more attention to sanitation and hygiene during budgeting and WASH programming (SWA, 2012, 2014; WHO, 2012). Thanks to stakeholders' joint efforts, the sanitation campaign has gained momentum across the country and local bodies are giving high priority to achieving ODF environments. The SHMP has also encouraged cross-sector collaboration, especially with the education and health sectors. For instance, the Ministry of Education has reserved US$ 15 million per year for WASH promotion to achieve the goal of providing basic facilities at all schools in the future (Adhikari, 2017; SWA, 2014). The recently adopted SDP further unifies the sector along a shared vision of how to improve the WASH situation in the country.

The involvement of local people has been key to success and has earned Nepal a high classification regarding the level of community participation in rural and urban drinking water schemes as well as rural sanitation programs (WHO & UN-Water, 2017b). While users' participation in *urban* sanitation programs was considered only moderate (WHO & UN-Water, 2017b), sanitation and sewage treatment in cities and small towns have definitely gained importance for government agencies: T. Chaudhari explained that the number of projects for sewage systems and wastewater treatment has increased from only seven or eight in 2016 to 21 in 2017, and another 102 projects are proposed to the national planning commission for the next fiscal year (personal communication, April 6, 2017). Even though all large projects consist of conventional treatment plants, the DWSS also shows certain openness to alternative (onsite) treatment. According to Chaudhari, consultants are advised to suggest different options and justify their suitability, such as sewerage systems in inner-city areas and decentralized systems with onsite treatment for institutional projects or in peripheral areas where land is available. To improve planning and implementation of sanitation and sewerage projects while reducing negative effects on the environment, legislation and guidelines for sanitation and FSM are under preparation.

Despite accomplishments, the challenges of the Nepali WASH sector have been manifold. The complicated institutional framework, unclear roles and responsibilities, and inadequate coordination among WASH actors have hindered efficient implementation (GoN, 2016a; Irin, 2013; SWA, 2014; WHO, 2012). Besides, beneficiaries may have been over-reported due to the duplication of projects (WaterAid, 2008b). Because of political entities' lack of commitment, policy goals have neither been adhered to applied sufficiently in local level planning (GoN, 2010b; Irin, 2013). The sector urgently needs a simplified structure, joint planning, synchronized activities according to clear guidelines, as well as sector-wide monitoring and evaluation, which the SHMP and the SDP now address (GoN, 2010b, 2016a). Without regulating institutions and due to weak monitoring, funds have been used inefficiently and service delivery has been inadequate, especially in remote areas and to marginalized groups (Irin, 2013; SWA, 2012; WHO, 2012). Therefore, unequal provision of and access to WASH services persist. Projects often target easily reachable communities while the disadvantaged are left out (GoN, 2010b, 2016a; Irin, 2013). For instance, the extremely poor can rarely afford to make the cash or labor contributions required by sanitation projects (WaterAid, 2008b). A lack of control mechanisms has also exacerbated environmental pollution, with far-reaching effects on water resources and public health. Even though environmental impact assessments are required before the implementation of sanitation projects (GoN, 2009), time and monetary constraints limit their scope in practice (Pant, 2012).

Finances and their use are also a crucial factor affecting overall WASH sector performance. Investment is considered insufficient and heavily dependent on external donors, and the distribution of funding has been described as imbalanced and misdirected (GoN, 2010b, 2016a; Irin, 2013; SWA, 2012; WHO, 2015c). Between 2003 and 2008, only 12% of the total WASH budget reached local bodies (DDCs, VDCs and municipalities), making it difficult for them to prioritize WASH even if demand existed. All other funds were budgeted and spent at the ministry level (WaterAid, 2008b). In addition, resource allocation has not matched the institutional capacity to implement programs. While domestic funds are fully used, only about three quarters of foreign capital commitments can be absorbed (MoWSS, 2016; WHO & UN-Water, 2017b). A lack of human resources hinders smooth implementation of WASH programs; there is a shortage of qualified staff and skilled graduates who are willing to work in the WASH sector and in rural areas (SWA, 2012; WHO, 2015c). Nepal has not yet developed sufficient strategies to strengthen human resources through systematic capacity building at all levels (WHO, 2015c). Consequently, limited technical and managerial skills of WUSCs and utilities also hamper the functionality of existing water supply and sanitation schemes (SWA, 2012, 2014; WHO, 2012).

A lack of maintenance and repair often leads to malfunctioning or failure of systems, affecting the continuity and quality of services (GoN, 2009, 2016a). For example, less than a third of over 41,000 rural water supply schemes have maintenance tools and only 4.5% have maintenance funds (MoWSS, 2016). Considering the limited government budget for O&M, financing of repairs becomes a challenge so that communities sometimes request new systems rather than mending the existing ones (Irin, 2013; SWA, 2012, 2014). Moreover, since consistent testing of drinking water quality is still missing in rural and urban areas, safe water supply cannot be assured (SWA, 2012; WHO, 2015c). Regarding sanitation, major maintenance issues are the poorly regulated emptying of full latrines and the treatment of fecal sludge and wastewater (DWSS & MoWSS, 2016b; WHO, 2015c). As the WASH professionals Chaudhari from the DWSS and Pudasaini from WaterAid highlighted, just building toilets is not enough; proper use and maintenance are required for long-term sustainability (personal communication, April 6 and April 13, 2017, respectively). Without follow-up, there is a risk of no one taking full responsibility when a system breaks (WaterAid, 2008b; WHO, 2015b). This lack of accountability might also be connected to limited participation by users during the planning and implementation stages, resulting in low ownership (GoN, 2010b; WHO, 2012, 2015c).

Another shortcoming of the sector has been its predominant focus on water supply and infrastructure while neglecting sanitation and soft components such as hygiene education and training (GoN, 2010b; Irin, 2013; WHO, 2012). Even though sanitation and hygiene have received more attention in recent years, funding does still not reach 20% of the WASH sector budget as stipulated in the SHMP (Adhikari, 2017; GoN, 2010b). Further proof of unfulfilled requirements is the lack of user-friendly toilets in public places and schools, and the continuation of open defecation in areas that have been declared ODF. The provision of sanitary facilities does not automatically lead to behavior change, as is also illustrated by persisting poor hand-washing practices (Adhikari, 2017). As long as communities are only moderately participating in hygiene promotion (WHO & UN-Water, 2017b), the situation is unlikely to change. Few people are aware of the link between unsanitary conditions, disease transmission and ill health, and understanding of the spread of pathogens through human excreta beyond their toilet is insufficient (DWSS & MoWSS, 2016b; GoN, 2010b). With a countrywide illiteracy rate of 37% among the population above six years, sustained and practical hygiene education is all the more important to increase awareness and achieve lasting integration of hygiene practices in daily life (Adhikari, 2017; GoN, 2010b).

While these challenges affect Nepal overall, they multiply and/or present themselves in unique ways in remote and climatically harsh locations such as the mountainous area of Upper Mustang.

2.2 Upper Mustang

2.2.1 Geographic Features and Accessibility

Upper Mustang is a term used for the northern part of Mustang District, one of Nepal's 75 districts (Figure 5). It lies on the northern border of the country, adjacent to what is presently called the Tibet Autonomous Region (T.A.R.) of China. In the south, Upper Mustang transitions into Lower Mustang, and in the west and east it borders the districts of Dolpo and Manang, respectively (Chetri & Gurung, 2004; Pokharel, 2009). The area is located in the Trans-Himalayas, entirely north of the Great Himalayan Range, at an altitude between 3,300 and 6,480 meters above sea level (m a.s.l.), and comprises approximately 2,300 km^2 (Banskota & Sharma, 1998). Its capital Lo Manthang (Tib. *glo smon thang*) lies at about 3,800m a.s.l. and is 84km north of the district headquarters at Jomsom (Banskota & Sharma, 1998). Jomsom, located in the southern part of the district ("Lower Mustang"), is more than a thousand meters lower (2,720m a.s.l.; Shrestha et al., 2015b) and, according to road sign posts, another 158km from Pokhara, the regional metropolis and second largest city of Nepal.

Figure 5: Map of Nepal with Mustang District outlined in red (Foundation Himalaya's Children, n.d.)

Upper Mustang's altitude and its location in the rain-shadow of the Himalayas have created a mostly barren landscape with very little vegetation. It has been described as a high altitude steppe or even desert (Banskota & Sharma, 1998; Bernet et al., 2012; Chetri & Gurung, 2004; Pokharel, 2009), punctuated with cultivated areas that appear like lush oases against an otherwise yellowish-brown backdrop (Figure 6). Even though large parts of the area look uninhabitable, between 40 and 50% of Upper Mustang are actually used as pasture land for animal husbandry, and 1.2% for agricultural cultivation (ACAP & NTNC, 2010; Pokharel, 2009). Agriculture is possible thanks to an intricate system of manmade irrigation channels that distribute water to fields located in the alluvial parts of river valleys (Yi, Ismail, & Yan, 2010). Since access to water and agricultural production are essential for the population, Upper Mustang's roughly 30 settlements developed along the rivers, generally between 3,000 and 4,000m altitude (Banskota & Sharma, 1998; Pokharel, 2009; Verma & Khadka, 2016).

Figure 6: Agricultural fields in an otherwise barren landscape near Lo Manthang, Upper Mustang

Outside agricultural areas, biomass production in Upper Mustang is limited, just like on the Tibetan Plateau of which it is the southernmost extension (Chetri & Gurung, 2004). The plants growing on Upper Mustang's alpine pastures and mountain slopes are suitable for grazing animals and herb collection (Pokharel, 2009), but haymaking is not practiced. Due to the cold and dry climate (see section *2.2.3* below), most vegetation is stunted and hardly any trees grow outside irrigated plantations around settlements, so that fuel-wood is extremely rare (Banskota & Sharma, 1998; Verma & Khadka, 2016).

In terms of access, Upper Mustang is remote but has not been as isolated as it may seem. For many centuries, there has been active socio-cultural and economic exchange along the Kali Gandaki, one of Nepal's major rivers running from its source in Northern Mustang down south to the Indian plains (Banskota & Sharma, 1998; Baumann, 2004; Childs et al., 2014; Craig, 2004; Pokharel, 2009). Until the mid-20th century, the Kali Gandaki trail and the Kore Pass (4,480m a.s.l.) on Mustang's border with Tibet served as a major trade route for salt from the Tibetan Plateau. It is said to be a relatively easy route with the lowest pass for crossing the Himalayas between the two countries (Banskota & Sharma, 1998; Baumann, 2004; Hagen, 2004). However, access to Upper Mustang remains difficult and dangerous at times.

At present, the overland journey from Nepal's capital Kathmandu to Lo Manthang takes at least three days of strenuous traveling. Whereas the distance between Kathmandu and Pokhara can be covered in fairly comfortable six to seven hours by public bus, the onward journey to Jomsom may easily take 12 hours along a bumpy, unpaved road up the Kali Gandaki gorge. Especially during the monsoon season, this road is frequently damaged and blocked by landslides and rock fall so that jeeps and buses can no longer traverse and passengers need to continue their journey on foot (Figures 7-9, all from July 2016). Furthermore, the narrow road cut into steep cliffs is prone to accidents with vehicles tumbling down into the canyon. The dangers of the overland journey can be avoided by choosing a plane ride from Pokhara to the small airport in Jomsom, but flights only take place during clear weather and, according to locals, plane crashes happen every year.

Figure 7: Landslide blocking the road between Pokhara and Jomsom

Figure 8: Rock fall on the same road further up the valley

Figure 9: Public bus stuck in mud between Pokhara and Jomsom

From Jomsom, the road continues up the Kali Gandaki valley between the Annapurna and Dhaulagiri, two of the world's highest peaks above 8,000m a.s.l. It includes numerous steep and narrow passages and crosses several passes above 3,800m a.s.l. before reaching Lo Manthang. The road was only completed in 2012, and during the research period in 2016/17 it was not travelled by buses, only by motorbikes and jeeps. Even the latter needed to be pushed at times or left behind and exchanged for other vehicles beyond particularly dangerous sections (Figures 10-13).

Figure 10: A road section impassable for jeeps between Jomsom and Lo Manthang

Figure 11: Drivers and passengers trying to mend a steep passage through a stream bed

Figure 12: Passengers waiting for their next ride after a section walked on foot

Figure 13: The journey continues

Whereas the distance between Jomsom and Lo Manthang can now be covered within a day by public jeep, it used to take three to five days on foot before the road was constructed (Banskota & Sharma, 1998; Craig, 2004). During the winter, when the water level in the Kali Gandaki is low, trucks and tractors stocking up the supplies of Lo Manthang can avoid the road across high passes and instead drive up the river bed. In spring, however, the water level increases along with snow melt, making such passage more and more difficult. While the road from Jomsom to Lo Manthang and further north to the Tibetan (Chinese) border has facilitated Upper Mustang's north-south connectivity in recent years, the area remains difficult to access from the east and west because of mountain ridges above 5,000m a.s.l. (Banskota & Sharma, 1998; Pokharel, 2009).

2.2.2 Historico-Political Background

Mustang can look back on a long and varied history. Based on archeological evidence, the region was already inhabited several thousand years before the Common Era (BCE; Fort, 2015). In the late 14th century CE, a ruler called Ame Pal (Tib. *a mes dpal*) from Western Tibetan nobility united the fortresses of Upper Mustang and founded the independent Kingdom of Lo (Tib. *glo*) in 1440 CE (Banskota & Sharma, 1998; Baumann, 2004; Craig, 2004; Dhungel, 2002). Lo encompassed approximately the area of what is now called Upper Mustang, and the town of Lo Manthang became its political, economic, social and religious center (Banskota & Sharma, 1998; Craig, 2004).

Lo Manthang was built on a plateau between two rivers running west-east (Figure 14). The ancient town is roughly 300m long and 160m wide, consists of about 200 buildings and is surrounded by a six meter high city wall (Baumann, 2004). This city wall as well as Lo Manthang's fort towers, monasteries and the king's palace testify to the town's rich past (Banskota & Sharma, 1998). Since it has retained its unique traditional appearance into present times, Lo Manthang has been suggested to be listed as a UNESCO World Heritage Site (ACAP & NTNC, 2010).

Figure 14: Lo Manthang, capital of Upper Mustang (seen from the north)

Over the centuries, Upper Mustang became considerably wealthy thanks to its key position along a major Trans-Himalayan trade route (Banskota & Sharma, 1998; Baumann, 2004; Craig, 2004). In 1760, however, the conquest of Lo by the kingdom of Jumla terminated its independence, limited its political power and monopoly position in salt trade (Banskota & Sharma, 1998; Baumann, 2004). Just a few decades later, as Jumla itself was integrated into the newly emerging Nepali Gorkha Kingdom, Upper Mustang became part of Nepal (Banskota & Sharma, 1998; Baumann, 2004; Craig, 2004; Craig et al., 2010; Dhungel, 2002). Nevertheless, until the mid-20th century the region maintained close cultural, religious, economic and to some extent even political connections to Tibet (Craig, 2004; Craig et al., 2010; Dhungel, 2002), and its ruling dynasty has continued into present times: The late King of Lo, Jigme Palbar Bista who passed away in 2016, was the 25th ruler in an uninterrupted lineage (Baumann, 2004; Craig, 2004).

From the mid-20th century onwards, further political changes have affected Mustang's fate. After Tibet came under Chinese rule, the border to Nepal was closed and the hitherto so important salt trade came to a halt in 1959 (Craig, 2004; Hagen, 2004). Besides, Mustangi herders who had previously grazed their animals on the Tibetan side of the border suddenly found their pastures drastically reduced (Hagen, 2004). The political changes in Tibet not only impacted Upper Mustang's economic circumstances, but also isolated the region from its cultural and spiritual home: The so far flourishing exchange between religious institutions on both sides of the border was abruptly discontinued (Craig, 2004). Lo Manthang lost its importance as a central location and became "a remote, 'backward' locale – a sense that is profoundly felt by all generations of people from Mustang […]" (Craig, 2004, p. 17). The region had to reorient itself southward, and from the 1970s, Nepali efforts aimed to integrate Mustang in the attempt to create a Pan-Nepalese identity (Baumann, 2004). Furthermore, Upper Mustang was declared a restricted area due to its sensitive geopolitical location and foreigners were henceforth denied access until the early 1990s (Baumann, 2004; Hagen, 2004; Nepal, 2000).

The area's remoteness left it disconnected from the development elsewhere in Nepal (Baumann, 2004), though tourism and the construction of roads from the north and south have brought fast changes in recent decades. The road from the Tibetan (Chinese) border to Lo Manthang was completed in 2002, a decade before the one from Jomsom, and cheap Chinese commodities started flowing into Upper Mustang (Baumann, 2004). Local people state that the border remains closed most of the time but opens for trade around twice a year. Though the road follows the ancient salt trade route of the yak caravans, Baumann (2004) notes that it no longer promotes an equal exchange but rather a one-sided sale of Chinese goods, not least cheap alcohol. Until the road from the Nepali side to Lo Manthang was completed in 2012, Chinese merchandise outcompeted domestic products as the latter had to be flown to Jomsom and then transported on mules' backs (Baumann, 2004). Now Chinese goods can be found alongside Nepali and Indian products in the stores of Lo Manthang.

The impacts of road connectivity on Upper Mustang are debated, though most locals appreciate it for a range of reasons. Easier transportation means access to more affordable and more varied food, shorter traveling times to Jomsom and Pokhara as well as improved trade opportunities (Craig, 2004; Pant, 2012). As elsewhere in rural areas, it might have a positive impact on education and health, namely by reducing child and maternal mortality rates (Pant, 2012). Besides, farmers and nomads may be able to tap into new sources of income if they can sell local products to visitors and participate in the development of ecotourism (Lama, 2011; also see sections *5.3.2* and *5.3.3* below). Responsible and culturally sensitive tourism could propel a heightened interest in Upper Mustang's traditional culture and lifestyle (Fort, 2015), though the opposite might be the case as well: The influx of imported commodities and easier access by domestic and foreign outsiders could jeopardize the region's unique cultural heritage, bring negative environmental impacts and destroy the region's appeal as a destination for mainly trekking tourism (Craig, 2004). Locals may not share this concern, however, as they perceive little benefit from tourism anyway (Pant, 2012; compare *2.2.7 Tourism Development*). Moreover, many Mustangis welcome modernity and

> neither wish to remain a living example of a medieval culture forever, no matter how well it can be capitalized on, nor carve out a spartan existence full of deprivations, but would rather enjoy the same benefits as the people who tell them that they should continue their traditional lifestyle.
>
> (Baumann, 2004, p. 196).

2.2.3 Climate in Upper Mustang

Though meteorological data for Upper Mustang is scarce, the area clearly experiences a semi-arid, continental climate typical for the Trans-Himalayas, with high temperature variability and very little precipitation (Fort, 2015). The temperature in Lo Manthang ranges from a maximum of 26°C in summer to a minimum of -25°C in winter, with a mean annual air temperature (MAAT) of 5.9°C (Fort, 2015; Pokharel, 2009). According to records from the Department of Hydrology and Meteorology (DHM), the maximum temperature in the years between 1974 and 2005 was most often reached in June or July and averaged 19.8°C, while the minimum temperature in the same period was usually reached in January and averaged -12.4°C (DHM, 1974-2005b). These values indicate that the winters in Upper Mustang (November to March) are severe, while the summers (April to October) are relatively mild (Banskota & Sharma, 1998; Pokharel, 2009).

Since Upper Mustang lies in the rain shadow of the Annapurna and Dhaulagiri ranges, it does not receive the strong monsoon rainfalls as other parts of Nepal and is extremely dry (Banskota & Sharma, 1998; Baumann, 2004; Chetri & Gurung, 2004; Craig et al., 2010; Fort, 2015; Pokharel, 2009; Yi et al., 2010). In fact, Lo Manthang is reported to be the climate station with the least amount of annual rainfall in the country (Marahatta, Dangol, & Gurung, 2009; Figure 15).

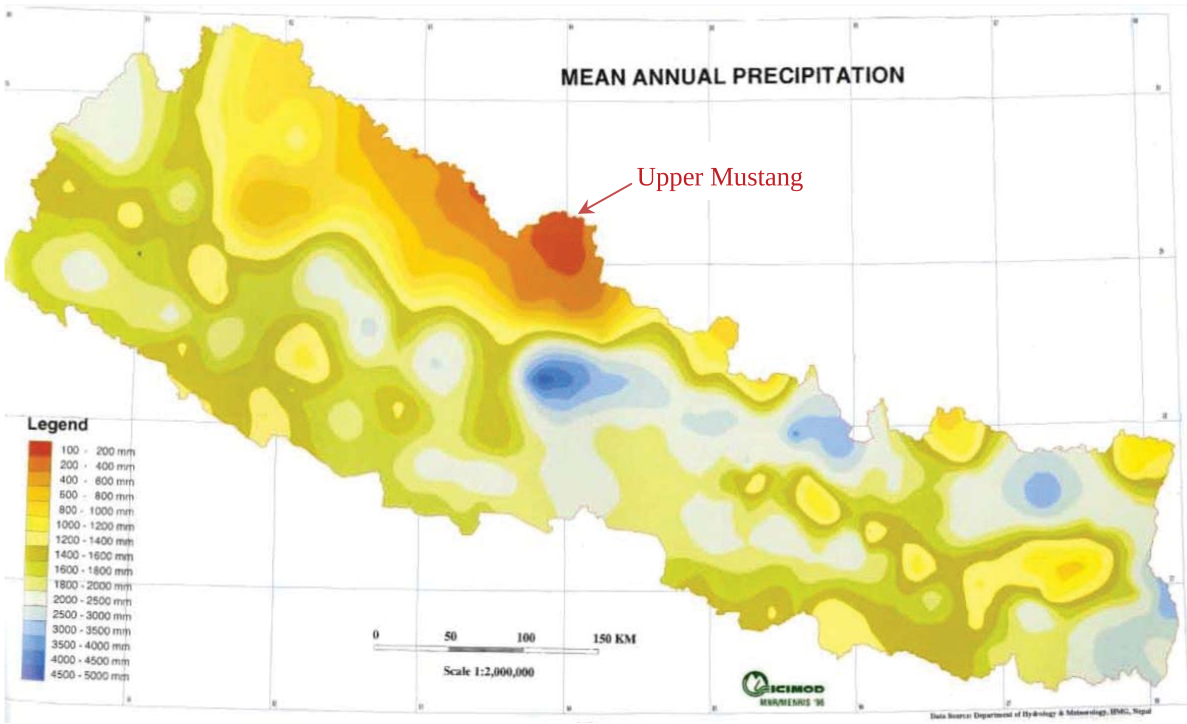


Figure 15: Map of mean annual precipitation in Nepal (Chalise, Shrestha, Shrestha, Thapa, & Bajracharya, 1996), based on data from the DHM. The color red clearly indicates rainfall scarcity in Upper Mustang.

Most sources state precipitation rates between 140 and 250mm per year (Bernet et al., 2012; Chetri & Gurung, 2004; Fort, 2015; Pokharel, 2009; Yi et al., 2010). According to the DHM (2010), recording of rainfall data in Lo Manthang started in 1974. Based on the years with complete records between 1974 and 2000, the town received an average of 161mm rainfall/year (DHM, 1974-2005a). Precipitation follows a clearly seasonal pattern with most of it falling in July and August (Figure 16). The DHM precipitation records show great variations from year to year – for instance, 297mm were recorded in 1978 compared to only 86mm in 1982 (DHM, 1974-2005a). This inter-annual precipitation variability in Upper Mustang has also been observed by Bernet et al. (2012) and Fort (2015), and on a larger scale across the entire Hindukush-Himalayan region by Singh, Bassignana-Khadka, Karky, and Eklabya (2011).

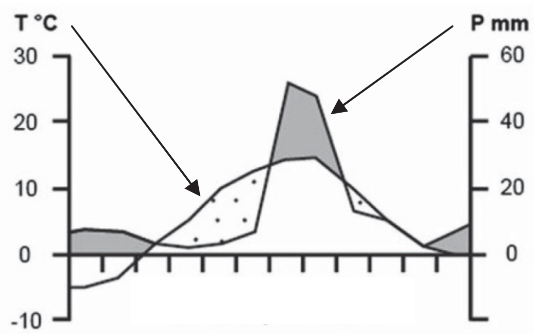


Figure 16: Climate diagram Lo Manthang (Fort, 2015), based on data from the DHM (T = temperature; P = precipitation; stippled area – dry season; grey area – wet season)

Between November and March as well as at altitudes above 2500m, precipitation falls as snow, making up more than half of the total precipitation (Banskota & Sharma, 1998; Chetri & Gurung, 2004; Fort, 2015). Snowfall is difficult to measure, though, and ground data is not available for Upper Mustang (Bernet et al., 2012). Due to snowfall, many mountain passes are blocked and villages become isolated from the rest of the district during the winter (Pokharel, 2009).

In addition to scarce precipitation, Upper Mustang's climate is also characterized by intense solar radiation and winds year-round (Baumann, 2004; Chetri & Gurung, 2004; Fort, 2015; Pokharel, 2009). The strong sunshine on the Tibetan Plateau heats up the soil and causes a low pressure system to arise daily, leading to a pressure gradient between Tibet and India. As a consequence, strong winds blow northwards up the Kali Gandaki gorge, especially in the late morning and afternoon, contributing to desiccation and soil erosion (Bernet et al., 2012; Fort, 2015; Pokharel, 2009).

2.2.4 Global Warming and Its Effects

The people of Mustang have adapted to its climate over centuries, but global warming is now causing increased temperatures and changed precipitation patterns with potentially far-reaching impacts on water resources and local livelihoods. On the Tibetan Plateau, including Upper Mustang, global warming started earlier and has been more profound than on Earth as a whole (Sharma et al., 2009; Singh et al., 2011; Yang, Nelson, Shiklomanov, Guo, & Wan, 2010a; Yao et al., 2012). Concretely, the Plateau already began experiencing a statistically significant rise of temperatures in the mid-1950s (Liu & Chen, 2000) whereas globally it did not start until the mid-1970s (Yang et al., 2010a). The analysis of oxygen isotopes in Tibetan ice cores as well as reconstructed climatic data even indicate a rise in carbon dioxide (CO_2) concentrations and a significant warming trend since the early 1900s (Liu & Zhang, 1998; Yao et al., 2006).

Numerous researchers have attempted to quantify the temperature increase on the Tibetan Plateau over the past decades. According to their findings, the MAAT increase has ranged between 0.2–0.4°C within the last 30-40 years (Jin, Li, Cheng, Wang, & Li, 2000; Wang, Jin, Li, & Zhao, 2000; Zhao et al., 2004) to as much as 0.3°C per decade over the last 50 years – roughly tripling the overall global warming rate (Qiu, 2008; Shrestha & Aryal, 2011). Whereas the Intergovernmental Panel for Climate Change (IPCC) states that the global average temperature has increased by 0.85°C between 1880 and 2012 (IPCC, 2013b), in Tibet it has risen by up to 0.9°C since the 1980s alone (Singh et al., 2011). Even though the values vary, they all confirm clear and significant warming across the entire region since the 20th century (Fort, 2015; Lutz, Immerzeel, Bajracharya, Litt, & Shrestha, 2016; Shrestha & Aryal, 2011; Singh et al., 2011; Yang et al., 2010a; Yao et al., 2006).

Studies also concur that the MAAT rise on the Tibetan Plateau, in the Himalayas and all over Nepal has been more pronounced in the winter compared to the summer (Jin et al., 2000; Liu & Chen, 2000; Sharma et al., 2009; Shrestha et al., 2015a; Singh et al., 2011; Yang et al., 2010a; Zhao et al., 2004). An analysis of observational data from 97 meteorological stations between 1955 and 1996 revealed that the average warming in the cold season (+0.32°C/decade) was twice as much as the increase of the MAAT (+0.16°C/decade) on the Plateau (Liu & Chen, 2000). Besides seasonal differences, warming also varies between locations due to differences in topography and microclimate (Kattel & Yao, 2013), and temperature increases are larger at higher elevations (Eriksson et al., 2009; Liu & Chen, 2000; Lutz et al., 2016; Sharma et al., 2009; Shrestha & Aryal, 2011; Singh et al., 2011).

As for Upper Mustang in particular, the observed warming trends correspond to those found on the Tibetan Plateau in general. According to a study cited by Bernet et al. (2012) temperatures have risen by roughly 1.0°C over the last three decades. Practical Action Nepal found a somewhat lower increase of annual mean temperatures in Upper Mustang of +0.02°C/year between 1976 and 2005. In terms of seasonal mean temperatures, a slightly decreasing trend has been observed during monsoon season, but the opposite is the case for the pre-monsoon, post-monsoon and winter seasons in Mustang (Marahatta et al., 2009). Until the end of the 21st century, Upper Mustang is expected to experience a temperature rise of 6-10°C in winter and 4-10°C during the monsoon, compared to the 1961-1990 average (Bernet et al., 2012; Schmidt & Bauer, 2013). However, due to a lack of long-term reliable data series – not just in Upper Mustang but across the Himalayas – it is difficult to quantify climatic tendencies, and predictions should be taken with a grain of salt (Bernet et al., 2012; Fort, 2015; Kattel & Yao, 2013; Sharma et al., 2009; Singh et al., 2011).

Unlike temperature, precipitation amounts show no clear and significant overall trend on the Tibetan Plateau and in the Himalayan region, including Nepal (Lutz et al., 2016; Shrestha et al., 2015a; Singh et al., 2011; Wang, Bai, Li, & Hu, 2011). On a local scale, some trends are discernible, but with high variability in space and time (Eriksson et al., 2009; Lutz et al., 2016; Marahatta et al., 2009; Singh et al., 2011). For instance, in the southeast, interior and northwest of the Tibetan Plateau, annual precipitation volumes have increased by 4-35% between 1967 and 1997, whereas a slight decrease (-2%) was recorded across large parts of the northeastern Plateau over the same period (Zhao et al., 2004). Even though the precipitation decrease seems minor, a desiccating trend has been noticed through other water-related parameters such as permafrost degradation, increased evaporation, diminishing river runoff, and shrinking wetlands and lakes (Cheng & Jin, 2013; Cui, Graf, Langmann, Chen, & Huang, 2006; Guo, Wang,

& Li, 2012; Wang et al., 2011; Zhang & Chu, 2009). On the contrary, according to the IPPC annual precipitation over the Tibetan Plateau is projected to increase by about 10% until the end of the 21st century, mostly due to moisture winters (+19% median) but little change in the summers (+4% median) (Christensen et al., 2007). However, models used to simulate precipitation changes in the region diverge from each other so that simulations of future precipitation only reach a medium confidence level (Christensen et al., 2013). Higher altitudes are expected to undergo greater changes and inter-annual variability of monsoon rainfalls regarding volumes and timing is likely to increase (Bernet et al., 2012; Sharma et al., 2009).

Since such year-to-year variability has also been observed for Nepal including Mustang, no significant precipitation trend could be identified between 1970 and 2010 (Rohrer, 2012a cited by Bernet et al., 2012; Marahatta et al., 2009). According to a study by Practical Action Nepal, Mustang is experiencing a slightly decreasing trend regarding precipitation in all seasons (Marahatta et al., 2009; Figure 17). This observation is in line with a tendency towards less rainfall on the lee side of mountain ranges affected by the Asian monsoon system which is regulated by the snow cover and surface heating on the Tibetan Plateau (Christensen et al., 2013). Simulations of future monsoon precipitation for Mustang, however, depend on the used model: According to the HadRM2 model (2041-2060), monsoon precipitation is predicted to increase by up to 10%, whereas, according to the PRECIS model (2071-2100) it is predicted to decrease by as much as -10% (Sharma et al., 2009). This variation illustrates the uncertainty about the development of precipitation in the region.

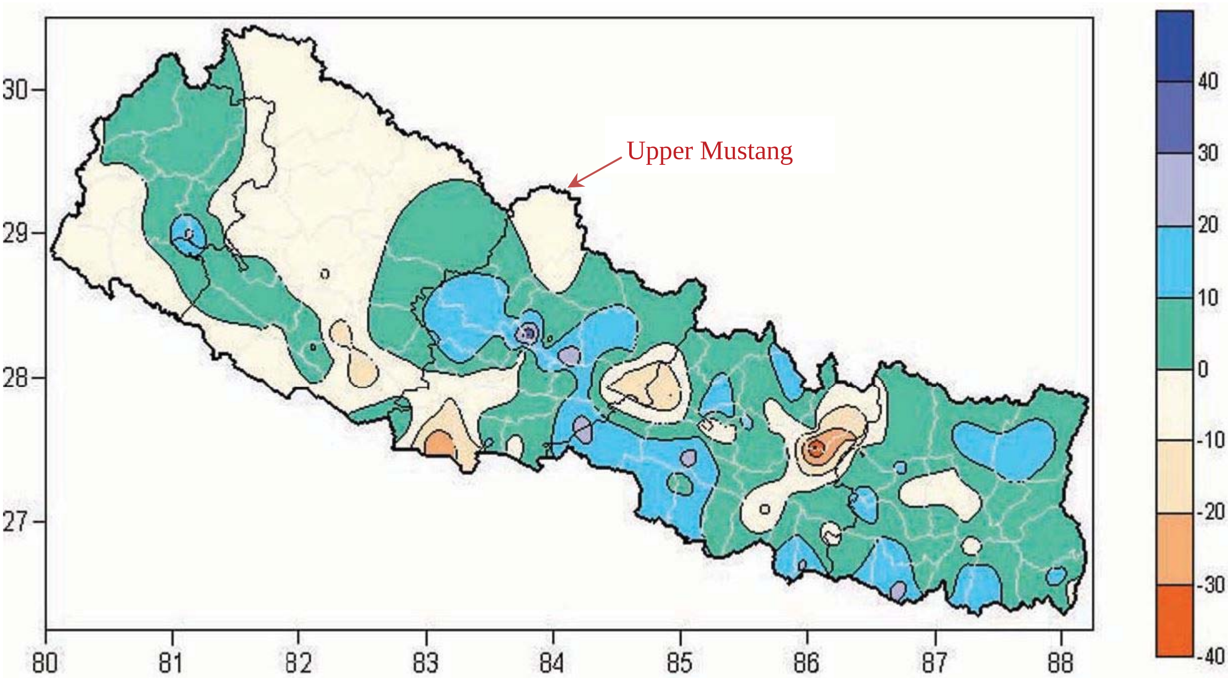


Figure 17: Annual rainfall trend (mm/year) (Marahatta et al., 2009)

Even if precipitation volumes do not change significantly, rising temperatures are affecting the region's hydrology and water availability due to melting glaciers, permafrost degradation and changed snowfall patterns. Global warming has been causing most Himalayan glaciers to experience a significant loss of mass and area over the last century and a half, at rates similar to the global average (Bernet et al., 2012; Bolch et al., 2012; Lutz et al., 2016; Shrestha et al., 2015a). The trends are locally heterogeneous (Bernet et al., 2012; Bolch et al., 2012), but melting glaciers generally increase the runoff initially, followed by a permanent decrease of water flow in the long run (ACAP & NTNC, 2010; Sharma et al., 2009). Whereas in some parts of the Himalayas glacial melt water accumulates behind terminal moraines and poses a risk for sudden glacial lake outburst floods (Mool et al., 2000), such hazards are not a major concern in Upper Mustang because glaciation is already very limited (Fort, 2015).

Besides melting glaciers, global warming is also affecting permafrost, that is, the "ground that remains at or below 0°C for at least two consecutive years" (IPCC, 2013a, p. 1459). In cold climates, hydrological processes and vegetation growth are often governed by permafrost: Since it creates an impermeable layer (aquitard), it limits infiltration of precipitation and surface water, thus influencing the formation, movement and distribution of groundwater as well as the base flow of rivers (Cheng & Jin, 2013; Cheng & Wu, 2007; Wang et al., 2000). Though studies on permafrost in the Hindukush-Himalayas are limited (Fort, 2015; Lutz et al., 2016), monitoring on the Tibetan Plateau has shown that warming temperatures have considerably reduced the areal extent and thickness of permafrost over the last decades (Cheng & Wu, 2007; Cheng, Zhao, Zhou, & Chen, 2012; Fort, 2015; Jin et al., 2000; Lemke et al., 2007; Wang et al., 2000; Wu & Liu, 2004; Yang et al., 2010a). With its area dwindling by one fifth between 1960 and 2000 (Cheng et al., 2012), permafrost on the Tibetan Plateau is thawing much faster than what is reported for Alaska (Osterkamp, 2005 cited by Cheng & Wu, 2007). Not only has the lower limit of permafrost distribution risen (Cheng & Wu, 2007; Wang et al., 2000; Yang et al., 2010a), but the seasonally frozen ground above the permafrost (the active layer) now also thaws to greater depths (Cheng & Wu, 2007; Wang et al., 2011; Wu & Liu, 2004; Wu & Zhang, 2010; Xie, Zhao, Wu, & Dong, 2012; Zhao, Wu, Marchenko, & Sharkhuu, 2010).

These changes profoundly alter the accessibility of water for humans, plants and animals: In Upper Mustang where rain and snow melt used to flow on frozen ground towards the valleys where the villages and fields are located, water now percolates deeper into the ground of hillsides (Schmidt & Bauer, 2013). In addition to reducing the amount of water available for irrigation, permafrost degradation and greater thaw depths also lower the groundwater table, decrease the moisture content of the top soil and leave the ground surface drier than before (Cheng & Jin, 2013; Cheng & Wu, 2007; Wang et al., 2011; Xie et al., 2012; Yang et al., 2004). In places where plant roots no longer reach the water, grassland productivity suffers (Wang et al., 2011; Yang et al., 2010b). Researchers agree that permafrost degradation and associated hydrological changes significantly alter vegetation communities and their distribution (Wang, Li, Wu, & Wang, 2006; Wang et al., 2000; Yang et al., 2004; Yang et al., 2010b; Zhu, Wang, & Farrington, 2009). On the Tibetan Plateau, those shifts typically lead to a succession from alpine swamp meadows to alpine meadows, alpine steppe and ultimately desert steppe (Cheng & Jin, 2013; Wang et al., 2011; Yang et al., 2010b; Zhu et al., 2009). Desertification due to permafrost degradation may then turn into a self-accelerating cycle (Wang et al., 2000; Yang et al., 2004), reducing the amount of ground ice which has served as a source of water in unglaciated areas such as Upper Mustang (Fort, 2015). Furthermore, the reduction of permafrost – along with changes in snow cover and seasonal precipitation patterns – also leads to increased ground instabilities, including earth slides and potential rock avalanches (Fort, 2015; Jin et al., 2000; Lemke et al., 2007; Wang et al., 2000). These hazards may affect settlements and infrastructure such as roads, water pipes and irrigation channels (Fort, 2015).

Changed precipitation patterns are another factor influencing water resources in the Himalayan region. Global warming has caused a tendency towards more rain- and less snowfall, the snowline has risen and the winters have become shorter with snowmelt starting earlier (Bernet et al., 2012; Eriksson et al., 2009; Fort, 2015; Xu, Shrestha, Vaidya, Eriksson, & Hewitt, 2007). In Mustang, the time of snowfall has shifted from winter to early spring and the thickness of snow accumulation has declined, as has the extent and duration of snow coverage (Fort, 2015; Gurung, Giriraj, Aung, Shrestha, & Kulkarni, 2011). Less snow leads to a positive feedback loop by reducing the proportion of solar radiation that is reflected from the surface (albedo), thereby increasing temperatures and accelerating snowmelt – which is an explanation for the higher warming rates over the Tibetan Plateau and the Himalayas (IPCC, 2007). Increasing winds which deposit more sand and dust particles on snow and glaciers further lower the albedo and speed up melt rates. These developments may dry out the soil and lead to a generally more arid climate in Upper Mustang, which is in line with accounts by locals as well as the sight of abandoned agricultural fields (Bernet et al., 2012; Fort, 2015). Although the decline of agriculture has a number of reasons (also see section *2.2.5* below), according to Bernet et al. (2012) "it is very likely that there has been an ongoing reduction of water availability during the last century" (p. 20).

Water availability in Upper Mustang is closely linked to the amount and timing of snowfall and snowmelt, and in turn affects people's livelihoods by influencing flow regimes, agricultural and rangeland productivity (Bernet et al., 2012; Eriksson et al., 2009; Fort, 2015; Sharma et al., 2009; Xu et al., 2007). Since glaciation is limited, river flow is highly dependent on the amount of snowfall in the winter and the release of water at the time of snowmelt. For the rest of the year, surface waters are only fed by emerging groundwater and monsoon precipitation (Bernet et al., 2012). Whereas water used to be stored as ice and snow and gradually released to the ground and rivers, declining snow coverage and shrinking glaciers have made runoff increasingly seasonal (Bolch et al., 2012; Fort, 2015; Gurung et al., 2011; Sharma et al., 2009). As a consequence, the fields and pastures may receive water when the seeds are not ready for sprouting yet, and on the contrary, less water may be available for proper vegetation development during the growing season (Bernet et al., 2012; Fort, 2015; Schmidt & Bauer, 2013).

It is difficult to quantify and predict hydrological changes and water availability due to limited baseline data (Sharma et al., 2009). However, warming temperatures combined with only minor changes in precipitation volumes indicate that water stress in Upper Mustang is likely to increase in the future (Bernet et al., 2012). Unless water can be stored during the agricultural off-season for later use – for instance as artificial glaciers or ice mounds in the winter (Clouse, Anderson, & Shippling, 2017; Safi, 2017) or in ponds during snowmelt runoff in early spring – crops may not receive sufficient water in the future. An extensive study assessing the present and future water challenges in Upper Mustang concluded that the communities of two villages (Samdzong and Dheye) needed to resettle to new locations due to irrigation water shortages (Bernet et al., 2012). Changes in precipitation patterns may not only impact surface waters but also groundwater resources which feed springs (Fort, 2015). It currently remains unclear how and to what extent the groundwater is recharged through melt water and rainfall in Upper Mustang (Bernet et al., 2012). While Bernet et al.'s (2012) study regarding the water situation of Mustangi villages concluded that drinking water supply was sufficient as opposed to irrigation water, Verma and Khadka (2016) cite Nepali newspaper articles claiming that the two above-mentioned villages had to be displaced because of the drying up of drinking water springs.

Besides altering water resources, climate change affects agricultural production and people's livelihoods in a range of other ways, too. For instance, more intensive summer rains may increase soil erosion (Schmidt & Bauer, 2013) and rising temperatures may bring previously unknown diseases, pests and weeds to Upper Mustang (Sharma et al., 2009). On the other hand, a warmer climate may potentially promote the growth of crops and prolong the growing season, but it is questionable whether that could compensate for the negative impacts brought about by water scarcity. Furthermore, heat stress may decrease the quality and quantity of forage for domestic and wild animals, biodiversity may shift, and changes in ecosystem goods and services are likely to happen (Sharma et al., 2009). The people of Mustang may be affected through increased environmental and health hazards, but also socioeconomic impacts because they largely depend on agriculture and animal husbandry for their livelihoods (Sharma et al., 2009). Being a mountain people, they are more vulnerable to climate change than the lowlands because of the fragile ecosystem they live in, combined with unpreparedness and not least limited options for adaptation such as livelihood diversification (Sherpa, 2008; Tiwari, Rayamajhi, Pokharel, & Balla, 2014). To conclude, the region is "one of the world's hotspots in terms of warming trends" (Singh et al., 2011, p. 11), and also one of the most sensitive areas regarding the effects of climate change (Liu & Chen, 2000).

2.2.5 Socio-Cultural Characteristics, Population and Migration Patterns

The people of Upper Mustang, called Loba (Tib. *glo ba*) in the local language, are almost entirely of Tibetan ethnicity (Pokharel, 2009), and according to the Central Bureau of Statistics (CBS, 2014), 98% of the residents of Lo Manthang speak Loke (Tib. *glo skad*), a Tibetan dialect, as their mother tongue. Their culture is essentially Tibetan, and they are among the 10% of Buddhists in Nepal (Banskota & Sharma, 1998; Heredge, 2003; Pradhan & Shrestha, 2005). In fact, Mustang has been called "an important repository of Tibetan Buddhism" (Pokharel, 2009, p. 23). In the 11th century respected religious masters visited the kingdom, and a number of Buddhist teachers and scholars also originated from Mustang (Pokharel, 2009). Buddhism flourished in the area and until the 18th century many monasteries were built (Banskota & Sharma, 1998). Still nowadays, 55 monasteries and temples (Pokharel, 2009) as well as numerous other religious monuments such as stupas (Tib. *mchod rten*), prayer wheels, walls of stone slates with engraved prayers and prayer flags on buildings and mountain passes testify of the importance and influence of religion in the past and present (Figures 18-20). Mustang's rich historic and cultural heritage also includes ancient buildings of unique Tibetan architecture, Tibetan art, monastic rituals, cultural events and festivals that are still observed today (Banskota & Sharma, 1998; Heredge, 2003; Figures 21-24).



Figure 18: Stupa with prayer flags near Chhoser (Tib. *mtsho shar*), a village north of Lo Manthang

Figure 19: Prayer wheels at the base of the ascent to Lo Manthang town from the north

Figure 20: Lone prayer flag pole in the mountains above Lo Manthang




Figure 21: Overlooking the roofs of Lo Manthang towards the King's Palace (red building, under repair because of earthquake damage from 2015)

Figure 22: A cloth scroll (Tib. *thang ka*) of Buddhist master Padmasambhava, displayed during the annual *Tenchi* Festival

Figure 23: Mask dances (Tib. *'cham*) performed by monks during the *Tenchi* Festival

Figure 24: Mask dancers in action

In terms of social organization, Upper Mustang is a blend of traditional structures and Nepali political institutions (Banskota & Sharma, 1998). Due to its ethnic and cultural affiliation with Tibet, Mustang's society is more egalitarian compared to the caste hierarchy and ritual purity concepts prevailing in other parts of Nepal (Pradhan & Shrestha, 2005). Nevertheless, the people are ranked into three main social groups: the *Bistas*, the *Gurungs*, and the *Bishwakarmas* (Banskota & Sharma, 1998; Pokharel, 2009). They are all ethnically Tibetan, though some have adopted Nepali names representing castes that are more highly ranked in the Nepali caste hierarchy. Out of currently 172 households in Lo Manthang, 25 are *Bistas*, the traditional ruling class in the area, which together with the royal family forms the aristocracy (Banskota & Sharma, 1998). About 70% percent of the population belong to the *Gurungs* who are mostly farmers and merchants living inside the city walls, while the *Biswakarmas* are the lowest occupational group and live outside the city wall (Banskota & Sharma, 1998; Pokharel, 2009).

Upper Mustang used to be governed by a king who had considerable control, dictating and regulating agricultural activities and imposing social sanctions on people not following his rules (Banskota & Sharma, 1998). His power diminished over the years, though, and the abolition of the monarchy in Nepal in 2008 also stripped the last official King of Lo of any remaining formal power (Bernet et al., 2012). However, another traditional system of governance continues to exist in Upper Mustang: Every village is ruled by a *mukhiya* or village headman who has considerable influence and decision-making power on various "social, cultural and even economic affairs and customary practices" (Pokharel, 2009, p. 18). The *mukhiya* is elected for one or two years from among the aristocratic families who in this way take turns managing village matters, including rules and regulations about fundraising and voluntary labor. Until present days, the general public usually respects and strictly obeys the *mukhiya*'s decisions (Banskota & Sharma, 1998; Pokharel, 2009).

Besides these customary authorities, formal structures of local governance have also found their way into Mustangi society. As elsewhere in rural Nepal, VDCs used to be in charge of overseeing village affairs until 2017. Since the dissolution of VDCs and elections in the spring of 2017, Village Councils (*Gaunpalika*) are supposed to fulfill a similar function (GoN, 2016a).

Regarding inhabitants, Mustang is one of the least densely populated districts of Nepal, and the population is declining even further (Banskota & Sharma, 1998; Childs et al., 2014). In Tibetan communities across the Plateau, population growth has traditionally been limited by high child mortality and low birth rates due to a large number of unmarried monks and nuns as well as the practice of polyandry (Childs et al., 2014). Since 1981, Mustang District has had around 4 people per square kilometer; about 13,450 people in absolute numbers in 2011 (CBS, 2014; Pokharel, 2009). As for Upper Mustang, its population density is only about half that of the district as a whole, and it dropped from 2.5 to 2.1 people per square kilometer in the decade around the turn of the century (Banskota & Sharma, 1998; Pokharel, 2009). Table 2 below shows how the population of Upper Mustang and its capital Lo Manthang has changed since the 1980s.

Table 2: Population development in Upper Mustang and its capital Lo Manthang over the last decades

Place	Year	Households	No. of people	Data source
Upper Mustang	1983	973	4695	Ojha (1987) cited by Banskota and Sharma (1998)
"	1991	1180	5970	CBS 1991 census (Banskota & Sharma, 1998)
"	2001	1171	5395	CBS 2001 census (Pokharel, 2009)
"	2011	1104	3834	CBS 2011 census (CBS, 2014)
Lo Manthang	2001	180	848	CBS 2001 census (Pokharel, 2009)
"	2011	172	569	CBS 2011 census (CBS, 2014)

While the number of households and therefore inhabitants increased substantially between the 1980s and 1990s, it has been declining since then in Upper Mustang overall as well as in Lo Manthang town. There are fewer households, and the average household size also dropped from 4.6 to 3.5 people between 2001 and 2011 (CBS, 2014). This decrease is not least attributable to the outmigration of children for education (Bernet et al., 2012; Childs et al., 2014; Craig, 2004).

In Upper Mustang, literacy rates are not only much lower than in the nation overall, but they are also lower than in other mountain areas of Nepal and lower than in other parts of the district (Pokharel, 2009). Among 544 people aged 5 and above in Lo Manthang, only about 30% can read and write, with a large gender gap between male (36.6%) female (23.8%) literacy rates (CBS, 2014). In comparison, Nepal's literacy for men and women is 65.5% and 42.8%, respectively, and for mountain regions in particular 56.9% for males and 30.4% for females (Pokharel, 2009). Upper Mustang's low literacy is due to a combination of different factors such as the area's distant location and severe climatic conditions as well as the lack or inadequacy of educational infrastructure and quality teaching (Pokharel, 2009).

At present there are four schools in Lo Manthang: one government school where students can study up to 8th grade, two privately-founded primary schools, and one monastic school. Nevertheless, 75% of children in the age group between 10 and 19 live away from home (Figure 25). While roughly one third (33.8%) of migrant girls and boys aged 5 to 19 study at boarding schools or religious institutions within Mustang District, the majority live further away, in Pokhara, Kathmandu, or India (in about equal proportions; Childs et al., 2014). Many of them reside at one of the successful schools that have been established by exile Tibetans in Nepal and India since the 1960s. About 20 years ago these schools also started admitting Nepali students of ethnically Tibetan origin, which has resonated with Mustangi parents who would like their children to receive an education more in line with their Tibetan identity as opposed to the purely Nepali curriculum (Childs et al., 2014).

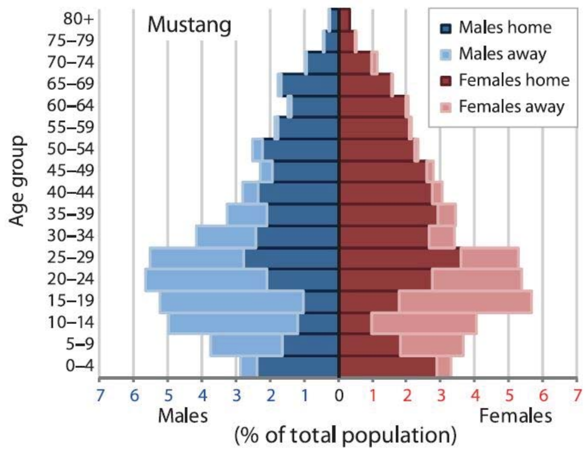


Figure 25: The de jure versus the de facto population of Mustang (Childs et al., 2014), that is, the people who have a right to live there because it is their birth place versus the population actually living there

Sending such a large percentage of children elsewhere for education is exceptional and in the past only occurred in places where children were forcefully separated from their families to assimilate them, as happened for instance to the indigenous populations of North America and Australia (Childs et al., 2014). The current practice in Mustang has far-reaching demographic impacts. For one thing, wealthy and well-connected families have greater chances of finding sponsors to support their children's education outside the area, which leaves a disproportionate number of underprivileged children behind (Childs et al., 2014). Furthermore, few of the children raised outside will return to their villages permanently after finishing their schooling. Not only do they become used to the comforts and lifestyle of urban environments, but if they do move back to Mustang they may also face prejudice and difficulties finding employment that matches their skills (Bernet et al., 2012; Childs et al., 2014; Craig, 2004). Young adults may perceive returning to their villages as a failure: They are no longer familiar with farming and nomadic practices, sometimes do not even speak their local dialect fluently anymore, and the opportunities for salaried jobs are very limited. Many youngsters therefore wish to remain in the cities of Nepal and India or move to even further destinations overseas, which is expected to lead to a drastic population decline (Childs et al., 2014).

Even though permanent outmigration is largely attributable to children and teenagers going for education, adults do leave Mustang, too. Nearly 10% of households in Upper Mustang have outmigrated, a phenomenon not unusual for mountainous regions (ACAP & NTNC, 2010; Childs et al., 2014). In search of wage labor and cash income, young people move to the cities, and many Mustangis now work abroad, in India, Japan, Korea, Arab countries or the United States (Craig, 2004; Craig et al., 2010; Heredge, 2003; Tiwari et al., 2014; Yi et al., 2010). For instance, more than one thousand ethnically Tibetan people from Mustang live in New York these days, which is about 10% of the population of the VDCs where they come from (Craig, 2011).

The consequences of outmigration include abandoned fields, fewer animals, and a lack of labor power. When agricultural fields are not leased to other families but left fallow, they turn barren (ACAP & NTNC, 2010; Craig, 2004) – though not all barren fields have become such because of outmigration but also due to water scarcity and failure of irrigation channels (Banskota & Sharma, 1998; Pokharel, 2009). According to recurrent visitors to Mustang, signs of depopulation were already apparent in 1994, with only about 30% of arable land under cultivation (Shackley, 1995). Without sufficient labor it is difficult to maintain agricultural production and the burden on those who remain in the village increases, which some people associate with more joint pains, arthritis and excessive worrying (Craig et al., 2010). Moreover, a smaller working-age population also jeopardizes social and religious functions of society, which will affect the long-term survival of Upper Mustang's communities. For example, elderly people who used to be looked after by family members in the village increasingly have to move to the cities where their children live if those are not willing to return (Childs et al., 2014; Craig, 2004).

At the same time, remittances from Mustangis living abroad are an important source of income for those who remain in the villages, not just for individual households but also for community development projects and social institutions (Craig, 2011; Tiwari et al., 2014). The availability of more cash improves access to medical treatment in the cities for which farm income alone would not be sufficient (Craig et al., 2010). However, the increasing monetary economy also changes the traditional custom of labor exchange as it allows wealthier households to pay others for agricultural labor, which was unthinkable in the past. Finally, remittances and a few returnees from abroad have boosted some local businesses and initiatives such as tourist lodges and village-based enterprises. Those cases are rare, though, compared to the continuous stream of children leaving Mustang for education (Childs et al., 2014).

While permanent outmigration has become a real concern in Upper Mustang, it seems to be a fairly recent phenomenon: Just twenty years ago a study by the International Centre for Integrated Mountain Development (ICIMOD) noted that "[m]igration is strictly seasonal and little permanent migration is believed to have taken place" (Banskota & Sharma, 1998, p. 26). Seasonal migration, however, has existed for many decades, serving the people of Mustang as a strategy to survive and improve their livelihoods (Pokharel, 2009). In the winter, between 50 and 75% of the population leave Upper Mustang for three to four months and migrate to places south of the Himalayas such as Pokhara, Kathmandu, or India. In this way, not only can they avoid the harsh climate and food shortages in their home villages, but they also engage in seasonal employment or trade to supplement their income (Banskota & Sharma, 1998; Baumann, 2004; Craig, 2004; Heredge, 2003; Nepal, 2000; Pokharel, 2009; Yi et al., 2010). Even the schools with all their students and teachers move to Pokhara, and government services are suspended during the winter (Baumann, 2004). Only the elderly, some women with infants and those who are unable or not in a financial position to migrate remain in Upper Mustang. There they look after the animals and take care of their homesteads until their families return around April when the agricultural season starts again (Banskota & Sharma, 1998; Baumann, 2004; Heredge, 2003; Yi et al., 2010). Since the majority of the population is not there over the winter, even some festivals that used to be celebrated during that time – such as the famous *Tenchi* Festival (see section *6.1.1* below) – have been moved to the spring and summer months so that more people can attend and the rituals can be carried out properly (Baumann, 2004).

2.2.6 Living Standards and Livelihoods

Living standards are made up of various components whose importance may change with the priorities of the people concerned. In the scope of this thesis it is neither possible nor attempted to offer a comprehensive analysis of Upper Mustang's living standards. Instead, a few aspects that figure most prominently in the available literature and seem relevant to the research at hand have been selected: a rough overall assessment of the situation of Upper Mustang compared to other parts of Nepal, the provision of health services, and the availability of electricity and fuel to fulfill energy demands. Besides, the common livelihood strategies of the local people shall be outlined.[4]

As mentioned above, Upper Mustang has been marginalized in terms of development efforts and services provided by the government (Bernet et al., 2012; Childs et al., 2014). A study by the Asian Development Bank found that the investments made towards the development of a region directly correlate with its human development index (HDI; Pradhan & Shrestha, 2005). It is not surprising, therefore, that mountainous districts like Mustang achieve the lowest HDI in Nepal (0.386) compared to the lowlands (0.478) and the hills (0.512). These disparities are not only linked to the mountain regions' remoteness, but also to historical and hierarchical conditions that put minorities at a disadvantage (Pradhan & Shrestha, 2005). Discriminating practices may marginalize minorities in the political and economic arenas, or gradually deprive them of their decision-making power and control over resources (Sharma, 2000). Ethnicities whose first language is not Nepali may face further challenges when dealing with authorities or trying to get employment in the civil service sector because they may lack the required language proficiency and connections to those who have influence (Pradhan & Shrestha, 2005). During the research period, comments by Nepalis from other areas about Mustang's comparatively simple living conditions and lack of infrastructure were not unusual. The author was rather taken aback, however, that even a published report took a patronizing tone by calling the people of Upper Mustang "culturally rich and distinctive" but "economically deserted and socially behind" (Pokharel, 2009, p. 103). Such statements seem to lack respect and recognition for the hardships Mustangis endure to carve out a living and maintain a flourishing culture in an exceptionally harsh environment.

[4] Though water supply and sanitation are also important determinants of human well-being, they shall be discussed in a separate section (*4.1 WASH Situation in Lo Manthang Town*) as those findings are at the core of this thesis and linked to primary research.

Despite hard living conditions in Upper Mustang and widespread associated medical problems, health services are scarce (Banskota & Sharma, 1998; Baumann, 2004; Craig et al., 2010; Pant, 2012; Pokharel, 2009). Although almost every VDC has a government health post, the facilities are often inadequate and lack medicine. Moreover, the staff has limited training and is frequently unavailable, or the health post remains closed altogether, especially in the winter. Cultural differences further deepen the local populations' mistrust of government health providers – the latter are typically from other parts of Nepal where different customs and religious beliefs prevail; they do not speak the local language and tend to have a condescending attitude towards their ethnically Tibetan patients in Mustang (Craig et al., 2010).

A better option for local treatment seems to be the health post opened by the Annapurna Conservation Area Project (ACAP) in 1993/94 (Banskota & Sharma, 1998; Craig et al., 2010; Pokharel, 2009). Not only does it employ local staff, but it also remains open in the winter and has more supplies, which – according to Lhundup Namgyal who works there – may be the main factors making it more trustworthy for the local people (personal communication, May 25, 2017). Even though ACAP health workers' formal medical training is also limited, Namgyal stated that their services were popular and much more frequented than the government health post. This is illustrated by the fact that government health providers bring medicines close to the expiration date to ACAP as they would remain unused and spoil if kept at the government facilities.

While Lo Manthang has no hospital, Ghami, about a third of the way down to the district headquarter Jomsom as well as Jomsom itself each have a 15-bed hospital, funded by an INGO and the Nepali government, respectively (Craig, 2011; Pokharel, 2009). However, there are no critical care facilities in the entire district, and better or more specific treatment requires trips to Pokhara and Kathmandu (Craig, 2011; Craig et al., 2010). Traveling so far for medical care may be costly or even unaffordable for local people, and patients in critical condition may be unfit to make the long journey on bumpy roads (Baumann, 2004). As was observed during fieldwork and also mentioned by Craig (2011), foreign charities also organize medical camps to treat specific physical or dental conditions from time to time.

Whereas the Western (biomedical) medicine offered by the above-mentioned health care facilities has only been available in Mustang for a few decades, Tibetan medicine and ritual healing practices have existed for centuries (Craig, 2011). Many locals still rely on traditional Tibetan doctors (Tib. *am chi*) and healers and only visit biomedical facilities if traditional methods cannot cure their ailments (Pokharel, 2009). For instance, Amchi Gyatso and Amchi Tenzin Bista – the Lo Kunphen School headmasters with whom this research project started – receive patients for diagnosis and treatment in their house daily, and outpatient clinics which they established in several villages are well frequented.[5]

Nevertheless, the general health status of the people of Mustang has been described as lower than the Nepali average, with especially children, pregnant women and old people at risk of malnutrition and livelihood insecurities (Banskota & Sharma, 1998; Pokharel, 2009). On the contrary, a community health expert noted that the health of women and children in Mustang was surprisingly better than in other rural areas of Nepal (Pokharel, 2009). In any case, infant and maternal mortality have traditionally been high, and only few households do not experience illnesses in the course of a year, (Craig, 2011; Pokharel, 2009). The most frequent health issues are diarrhea, gastric problems, respiratory illnesses, jaundice, worm infections and skin problems (Pokharel, 2009; L. Namgyal, personal communication, July 25, 2016). Poor health is not only caused by a severe lack of health services, but also through a range of factors such as inadequate nutrition, water supply and sanitation facilities as well as a lack of awareness. Insufficient health consciousness and illiteracy contribute to limited understanding of the importance of proper nutrition, hygiene and sanitation. In combination with environmental factors, this makes people more vulnerable to air- and water-borne diseases (Banskota & Sharma, 1998; Pokharel, 2009). However, locals do state that overall, health and life expectancy have improved in recent decades (Craig et al., 2010).

[5] These *amchis'* efforts to promote traditional Tibetan medicine and provide health services in Upper Mustang will be described in more detail in section *2.3.1*.

Another aspect affecting human well-being is the availability of electricity and fuel for heating and cooking. In Upper Mustang, electricity is exclusively solar (Pokharel, 2009). A photovoltaic power plant donated by the Chinese government provides electricity to Lo Manthang town (Figure 26). Since there is not always enough electricity, especially on overcast days, some households and institutions also have their own solar panels to meet their demand. In addition, solar energy is used to heat up water for showers in guesthouses. Private homes do not generally invest in solar water heaters as they do not have indoor plumbing and waterproof floors. Besides, using solar water heaters (or any plumbing for that matter) poses a challenge in Upper Mustang because the pipes may burst due to freezing temperatures (Banskota & Sharma, 1998).

Figure 26: Solar power plant in Lo Manthang

Cold temperatures also cause an enormous energy demand for heating purposes (Sherpa, 2008; Verma & Khadka, 2016). Most households use iron stoves (Figure 27) which serve to boil water and cook food while heating up the living quarters. Nowadays gas cylinders imported from Nepal are gaining more and more popularity and are being used alongside iron stoves for cooking.

Figure 27: Dung-fuelled iron stove used for cooking and heating at Amchi Gyatso and Amchi Tenzin's family home

In most other parts of Nepal and in the developing world in general, energy demand is met by firewood, but in Upper Mustang the situation is different: Since plant growth in such a cold, dry and high altitude environment is slow, biomass is extremely scarce. Only between 10 and 20% of the fuel requirements can be met by collecting species such as *Caragana* (Figure 28) and the options to increase biomass production through plantations are limited. The population is therefore forced to rely on animal dung from yaks, cows, sheep and goats to meet up to 90% of their energy needs (Banskota & Sharma, 1998; Sherpa, 2008; Verma & Khadka, 2016). Dung, however, has also become a finite and precious resource. On the one hand, the reduction of livestock herds has led to less dung being produced (Baumann, 2004). On the other hand, dung is not only used for heating, but also to fertilize fields, and some of it must be left on the pastures to maintain grassland productivity (Sherpa, 2008). The lack of fuel is in fact a serious issue in Upper Mustang, and insufficient dung is one of the reasons why a large part of the population leaves the area in the winter (Baumann, 2004).

Figure 28: *Caragana*, a brush species used as firewood in Upper Mustang

In terms of livelihoods, over 90% of Upper Mustang's population depends on agriculture and animal husbandry to varying degrees (Banskota & Sharma, 1998). Around 75% are engaged in subsistence farming – cash crop production is rare – and a study found that 96% of the people identify livestock as their main source of income (ACAP & NTNC, 2010; Chetri & Gurung, 2004; Pant, 2012; Pokharel, 2009). Other important pillars of the local economy are seasonal commodity trade with India and China, wage labor abroad, businesses related to tourism, and salaried jobs with NGOs and in the government sector (Banskota & Sharma, 1998; Childs et al., 2014; Craig, 2004; Fort, 2015; Tiwari et al., 2014; Verma & Khadka, 2016).

Regarding agricultural production, farmers manage to grow a variety of crops in Upper Mustang. On terraced fields they mainly plant barley, wheat, buckwheat, peas and mustard or rapeseed for oil (Figure 29). In kitchen gardens closer to the settlements they grow potatoes, radishes, cauliflower, cabbage, onions and green leafy vegetables, whose cultivation has only become more widespread in recent decades with organizations like ACAP starting to work in the area (Banskota & Sharma, 1998; Pokharel, 2009). Though orchards with apples and apricots are common in Lower Mustang, fruit trees are rare in the upper part of the district.

Figure 29: Buckwheat (pink), barley (light green) and rapeseed (yellow) fields in Lo Manthang

Farming in Upper Mustang is challenging and yields are low due to a number of environmental factors (Banskota & Sharma, 1998; Bernet et al., 2012; Fort, 2015; Heredge, 2003; Lama, 2011; Pokharel, 2009). Snow covers the ground for about five months per year and low temperatures limit the growing period so that only one annual crop can be grown. The agricultural season starts around April when the snow melts and ends after the harvest in September or October. Productivity is affected by water scarcity but also because of the poor quality of soil and insufficient manure to replenish nutrients. Due to low rainfall, the crops mainly depend on melt water from gravity-based irrigation channels. As mentioned among the impacts of climate change (section *2.2.4* above) the availability of irrigation water may be uncertain in terms of quantity and timing. Besides, a member of an expedition to Upper Mustang already noted over twenty years ago that the soils were depleted, probably because dung was being used as fuel rather than returned to the fields (Shackley, 1995). During fieldwork for the present research, several locals confirmed that no chemical fertilizers have been used in Lo Manthang so far, making biological fertilizers all the more important to ensure long-term productivity.

In fact, the local population has become increasingly dependent on imported food (Heredge, 2003), even though the long transportation distances make produce from the lowlands of Nepal multiple times more expensive. For instance, the price for one kilogram of tomatoes or mangoes in Lo Manthang is 250 Nepalese rupees (NRs), while the same quantity costs NRs 60 and NRs 100 in Pokhara, respectively. A large number of households in Upper Mustang do not have enough food from their own production, especially during the winter (Banskota & Sharma, 1998). According to a study by ACAP, year-round food sufficiency is only attained by 13.8% of households, while 9.4% experience food scarcity for over nine months annually (Pant, 2012). Therefore, additional sources of food and income are necessary.

Animal husbandry is another traditional way of making a living in Upper Mustang, thanks to the large areas of otherwise unproductive pastures (Pokharel, 2009). The main animals kept are yaks, sheep, goats and horses which supply people with food, dung, materials for fabric, and income from their sale or transportation services. Until a few decades ago, the main pasturelands used by Mustangi herders lay north of the border, in Tibet. Due to political changes in the neighboring country, however, access to those pastures has been curtailed. This has led to overgrazing on limited pastures in Upper Mustang itself, and the degradation of grasslands has forced nomads to reduce their herd size. Nowadays, the number of nomads as well as income from livestock has declined (Banskota & Sharma, 1998; Baumann, 2004; Heredge, 2003; Tiwari et al., 2014).

Because of such difficulties with traditional livelihood strategies, more and more locals look for alternative occupations; income diversification and remittances have become increasingly important in recent decades (Craig, 2011; Tiwari et al., 2014). Besides trade and foreign employment, businesses and services aimed at tourists visiting Upper Mustang have become a local option to improve the household economy. Since the 1990s, some Mustangis have opened lodges, hotel businesses and curio shops (Pokharel, 2009; Tiwari et al., 2014). Unfortunately, though, tourism has failed to provide many seasonal employment opportunities to local people (Banskota & Sharma, 1998; Nepal, 2000).

2.2.7 Tourism Development

Trekking tourism in the Annapurna area, of which Mustang is a part, started in the late 1960s and has influenced the region ever since. Almost 60% of all trekkers in Nepal visit this area, making it the most popular trekking destination in Nepal (Metz, 1995; Sharma, 2000). While Upper Mustang remained closed for foreign tourists until 1991 (compare section *2.2.2*), the lower and more accessible parts of the district have been frequented by tourists since the 1970s (Baumann, 2004; Craig et al., 2010). On the positive side, economic opportunities and government services in popular trekking areas improved compared to the more remote and restricted Upper Mustang (Craig et al., 2010). However, the development of tourism also led to a wide range of problems because trekking was unregulated and the number of tourists kept increasing rapidly (Sharma, 2000). Among the ecological impacts were forest degradation due to the increased demand for fuel wood, littering and uncontrolled solid waste disposal, as well as water pollution resulting from inadequate sanitation and toilets built at the edge of streams and rivers (Nepal, 2000; Nyaupane & Thapa, 2004; Sharma, 2000). Tourism also affected the local communities by eroding traditional values, changing family and social structures as well as daily life, and commodifying the local culture and art. Furthermore, the exposure to and contact with foreign tourists caused feelings of insecurity, inferiority and loss of self-respect among the local population, and begging developed (Nyaupane & Thapa, 2004; Sharma, 2000). As for economic impacts, only 6% of tourist expenditures actually remained in rural areas and only a small percentage of the population belonging to a few ethnic groups has been directly involved in and benefited from tourism (Metz, 1995; Nepal, 2000). The unequal distribution of wealth was expected to increase tensions within and between communities. Fierce competition between lodge owners led to undercutting of prices, while the cost of essential goods imported from Pokhara and Kathmandu inflated (Nepal, 2000). At the same time, there was a lack of investments in infrastructure and services for the local community such as water supply and sanitation, health, education, and environmental sustainability (Sharma, 2000).

Against this backdrop, the Annapurna Conservation Area Project (ACAP) was created in 1986, in order to develop and manage tourism in line with nature conservation and in consideration of the economic, social and cultural needs of the local inhabitants. The project was set up under a non-profit NGO called the King Mahendra Trust for Nature Conservation (KMTNC; Shackley, 1996; Sharma, 2000). The area it comprises is the largest and most diverse protected area in the country, both geographically and culturally – it is home to nine different ethnic groups with distinct dialects and languages, cultures and religious practices (Nepal, 2000; Nyaupane & Thapa, 2004; Thapa, Basnet, & Khanal, 2015). Using a participatory approach at the grassroots level, ACAP's role is to link local villages with government agencies and provide consultancy and resources for programs that the local people wish to implement. Programs intend to improve their quality of life and reduce the negative environmental impacts of tourism through local capacity building. With ACAP's support and training, communities are strengthened to formulate and carry out their own development and natural resource conservation agendas. Among ACAP's program activities are, for instance, alternative energy promotion, conservation education, sustainable tourism management, women's empowerment, and various community development activities such as trail repairs, greenhouse construction, setting up health posts, schools, and water supply schemes (Nepal, 2000; Sharma, 2000; Thapa et al., 2015).

Although tourism-related problems could not be completely eradicated and continue to exist in the Annapurna Conservation Area (ACA), the project has been considered successful in various aspects and has served as a model for community-based integrated conservation and development efforts elsewhere (Nepal, 2000; Thapa et al., 2015). Therefore, ACAP gradually expanded its activities into Upper Mustang when the government decided to open the area for foreign visitors in 1992, yet with mixed results (Nepal, 2000; Shackley, 1996).

Because of the difficulties to improve agriculture and other economic sectors in Upper Mustang, the government saw high value tourism as a key possibility for development and wanted to make the area a model ecotourism destination (Banskota & Sharma, 1998). Upper Mustang was supposed to provide an alternative and relieve pressure on the existing trekking routes in the Everest and Annapurna regions – and simultaneously generate revenue both for the government and the local population (Shackley, 1996). While its remoteness and inaccessibility may be obstacles to other types of development, for tourism these features, combined with the unique landscape and culture, act as comparative advantages making the area more attractive. Furthermore, trekking and mountaineering, which should be promoted in Upper Mustang, tend to bring more economic benefits to rural areas than other forms of tourism (Sharma, 2000).

Upper Mustang opened in March 1992, but in order to minimize negative impacts, the number of visitors was initially limited and strict regulations were implemented (Banskota & Sharma, 1998): During the first year only 200 tourists were allowed, but due to high demand and pressure by tour operators the quota was increased to 1,000 in 1993 (Heredge, 2003; Shackley, 1996). Nowadays several thousand foreign visitors enter Upper Mustang every year, according to tourist statistics displayed at the ACAP checkpoint in Lo Manthang (2016). Tours have to be organized by an authorized travel agency which needs to obtain a trekking permit from the Department of Immigration in Kathmandu for a minimum of ten days. The cost of the permit used to be US$ 700 per person plus another US$ 70 for each additional day (Banskota & Sharma, 1998; Nepal, 2000; Shackley, 1994). In the meantime the permit fee has been slightly reduced to US$ 500 per person for ten days and US$ 50 for each additional day. The government pledged to return 60% of the permit fee to Upper Mustang for the development of the area, but this has not happened to the promised extent as shall be outlined below. Tour groups had to do camp-based trekking to limit interactions with the local population and reduce pressure on local resources. Staff accompanying trekkers used to come from outside the area as did pack animals. An environmental liaison officer, usually a civil servant, had to join the trek to ensure that the rules and regulations were followed, for example that the groups were self-sufficient in food and energy and that waste was carried out (Banskota & Sharma, 1998; Nepal, 2000; Shackley, 1994). Meanwhile, restrictions have been loosened so that accommodation in local guesthouses is possible, more guides and horsemen are native to Mustang, and instead of liaison officers, licensed tour guides can lead the groups.

Despite these restrictions and regulations, negative environmental and social impacts were already observed eight months after Upper Mustang's opening for tourism. For instance, since tour groups had brought along insufficient kerosene, they required firewood from adjacent areas. The disposal of garbage was inadequate and toilet tents caused smells and pollution because they were set up too close to irrigation channels and streams. Besides, some tourists felt uncomfortable due to the requirement to camp when they would have preferred to stay in lodges. They were further inconvenienced by obtrusive begging from children and mothers' groups and complained about misinformation regarding the availability of locally produced crafts (Banskota & Sharma, 1998; Nepal, 2000; Shackley, 1994).

The problems associated with tourism in Upper Mustang have a variety of causes and consequences, among which the following shall be presented in more detail: (a) the pace of Upper Mustang's opening for tourism, (b) the unclear roles, responsibilities and coordination among actors, (c) the lack of revenue returned to Upper Mustang, (d) the limited benefits for the local community, and (e) the socio-cultural impacts of tourism.

a) The pace of Upper Mustang's opening for tourism

In the past, Mustang's population had been in contact with the outside world due to trade, but the scope of interactions was limited. With the opening for tourism, the whole population suddenly became exposed to foreign visitors (Nepal, 2000). The abrupt opening hit the local population completely unprepared. There was not enough time for the KMTNC or ACAP to raise awareness about the purpose and potential of tourism development, let alone conduct capacity building training and ensure the local population's full participation and taking-on of responsibility (Hagen, 2004). The KMTNC strongly recommended that Upper Mustang should not be opened for three years in order to build on the proven approach used by ACAP. The NGO intended to train local people and establish basic infrastructure, including drinking water facilities, waste management systems, and alternative energy sources, warning that tourism might otherwise be destructive and jeopardize the sustainability of the area's development. However, the government disregarded the KMTNC's advice and carried on with the opening of Upper Mustang (Gurung, 1998). Only nine months *after* the arrival of the first trekkers did the KMTNC launch the Upper Mustang Conservation and Development Project (UMCDP) with an office in Lo Manthang (Gurung, 1998; Nepal, 2000). UMCDP staff then started rapport-building with the local population as well as environmental awareness activities. They provided medical support to the community and assisted with irrigation and agriculture. Moreover, the UMCDP cooperated with local committees to build basic infrastructure such as a health post, schools, bridges, and supported the renovation of historical buildings. These activities helped create mutual trust between the community and the project, but the UMCDP would have needed more time to develop a strong foundation for environmentally and culturally sensitive tourism before visitors started coming in increasing numbers (Gurung, 1998).

For the first few years after Upper Mustang's opening, only a few hundred trekkers visited the area annually. Therefore, in the mid-1990s, researchers predicted that the limit of 1000 tourists per year would not be exceeded as the novelty effect of Upper Mustang seemed to wear off and the high permit fee to deter more visitors (Shackley, 1995). There were also warnings, though, that without control mechanisms, visitor numbers might grow significantly and that more than 1000 tourists a year would come with social and cultural costs for the local population (Heredge, 2003; Shackley, 1994). Since then, the quota of 1000 visitors per year has been dropped and the number of permits issued for foreigners has risen to 4146 in 2014, despite the retention of the permit fee (ACAP statistics displayed at checkpoint in Lo Manthang, 2016). Such an increase in tourism has undoubtedly come with side effects and has been difficult to manage sustainably.

b) Unclear roles and responsibilities

One big challenge in Upper Mustang has been the lack of clarity about which organization is in charge of coordinating development activities. This uncertainty not only concerns ACAP and the KMTNC – now called National Trust for Nature Conservation (NTNC) –, but also international aid agencies, some of which have cooperated with UMCDP while others worked independently. As a result, there have been issues of duplication, conflicting approaches and rivalry to win over the community. Besides, government offices approved of development projects without informing the KMTNC, and as an NGO the latter had no authority to enforce rules and regulations (Gurung, 1998).

On top of it, local politics and internal conflicts among community members have hindered development efforts in Upper Mustang. While the people used to be united by the king and follow his advice, for example on how to settle water and land use disputes, the local community is now split into different political factions who let conflicts escalate if it favors their goals. In such a situation it is difficult for UMCDP to actively engage the local people without being dragged into local quarrels (Nepal, 2000; Shackley, 1996).

Another problem is that no long-term strategy has ever been defined for tourism development in Upper Mustang. Its activities in Upper Mustang are considered inadequate, and limited due to a lack of resources (Banskota & Sharma, 1998; Heredge, 2003; Shackley, 1994, 1996).

c) The lack of revenue returned to Upper Mustang

The financial situation of development projects in Upper Mustang is also linked to the minor return of tourism income – the government never provided the promised 60% of permit revenue (Craig, 2004; Gurung, 1998). In the first year of Upper Mustang's opening (1992), around 41% were returned to the KMTNC and UMCDP; in the year after the percentage had already dropped to 25% – out of a total of over half a million US$ revenue from permit fees. Despite the increasing number of permits issued over the following years, the returned proportion dropped continuously to only 4.5% in 1997 (Banskota & Sharma, 1998; Gurung, 1998; Shackley, 1996). Negotiations by local citizens and ACAP to reclaim tourism revenue from the government met with limited success. Apart from aid agencies, the revenue from permits is the only funding source for tourism development. Without it, ACAP has to use its own funds to finance UMCDP's programs, which explains the restrained scope of activities it can implement (Gurung, 1998; Pant, 2012; Shackley, 1996).

Due to the broken promise, conflicts have arisen between the local people, the Ministry of Tourism, ACAP management and different NGOs. Many Mustangis understandably feel resentment, which finds expression in some locals' negative remarks about tourism: "We don't want outsiders coming and intruding while we don't get anything out of it," Pant (2012) was told by one of his respondents. Especially older people worry that the increasing influx of foreigners could upset local protector deities and cause their wrath, leading to natural calamities such as droughts, famines and illnesses (Baumann, 2004; Shackley, 1995). In general, the local population perceives hardly any benefits of tourism (Banskota & Sharma, 1998; Pant, 2012).

d) Limited benefits for the local community

The direct benefits of tourism to the people of Upper Mustang are not only limited because of the withheld permit fee, but also because of the type of tourism that is promoted and lacking linkages with the local economy. With trekking as the predominant form of travel, foreigners generally book full package tours through travel agencies abroad or in Kathmandu or Pokhara. Tourism earnings therefore leak outside the area, for example as salaries paid to non-local staff and goods purchased and brought in from other parts of the country (Banskota & Sharma, 1998; Heredge, 2003; Sharma, 2000). Even though trekking groups usually pay more for their trips than independent travelers, they spend only little money locally (Nyaupane, 1999). Tourism in protected areas such as Upper Mustang does not spontaneously benefit the local population and create employment without strategic planning to involve local communities (Nepal, 2000; Sharma, 2000). Even if some control is in the hands of local lodge owners and travel agents, benefits tend to concentrate among the existing social elites and do not spread much to the wider community (Heredge, 2003; Pokharel, 2009). As in other parts of the ACA, the wealth gap is increasing, as are social tensions and the prices for essential goods (Shackley, 1995; Sharma, 2000). The majority of Mustangis do not benefit from tourism, not least due to the lack of linkages with the productive sector, that is, they do not make any income from the sale of locally produced food (Banskota & Sharma, 1998; Nepal, 2000; Sharma, 2000). ACAP and NTNC (2010) suggest that benefits for the local community could be maximized by changing Upper Mustang's restricted area status and letting more visitors come. However, such a strategy might again only benefit a few, unless specific interventions would address the connection of tourism with agriculture and enhance the trickle-down effect.

On the positive side, tourism may improve living standards through infrastructure development which might otherwise not happen at the same pace in such remote areas (Sharma, 2000). In Upper Mustang, the arrival of tourists was followed by the construction of new facilities such as new water pipes and tap stands, works on irrigation channels and tree plantations. Furthermore, a greater variety of imported foods and drinks became available in shops. The local people welcomed such progress (Shackley, 1995), but of course the exposure to new products, consumption patterns and habits – the "demonstration effect of tourists" (Sharma, 2000, p. 354) – has also had an impact on the local community and culture (Pant, 2012).

e) Impacts on society and culture

Mountain cultures like the one in Upper Mustang have been preserved for centuries thanks to remoteness and inaccessibility. Change used to take place slowly, but with tourism this process accelerates (Sharma, 2000). Among the changes happening in Mustang are gradual westernization, a decline of traditional culture, but also an increased interest and pride of locals in their cultural heritage (ACAP & NTNC, 2010; Heredge, 2003; Shackley, 1996; Sharma, 2000). Especially young people tend to be attracted to and imitate foreigners' behavior, clothing style, eating habits, and lifestyle in general. A change of traditional value systems may, among others, lead to the deterioration of the local customs and language, the commercialization of art, cultural and religious events, and changes in traditional architecture towards more cement and concrete, especially if there is unregulated expansion of hospitality infrastructure. Change does not have to be negative, though: Culture tourism and more visitors may also encourage locals to value and maintain the uniqueness of their culture and way of life, and interaction with outsiders may expand their knowledge and interest in innovation (Sharma, 2000).

Though a decline of local traditions has been observed in Upper Mustang (Gurung, 1998; Shackley, 1994), this is not only attributable to tourism. Increased mobility – for example due to seasonal migration and the construction of the road –, education in and outside the area, and the media have all contributed to people's exposure, influencing their values and lifestyles. While tourism has indisputably had an impact, it is also one among very few options to improve people's well-being (Banskota & Sharma, 1998; Heredge, 2003). For tourism to be sustainable, though, the focus should not be on quick gains at the expense of the environment and community cohesion. A long-term vision needs to include all stakeholders to prevent the degradation of natural resources and protect Mustang's cultural heritage (Gurung, 1998). As Sharma (2000) puts it, the people of Mustang have to try and "search for an identity that can integrate the traditional norms, values, and ways of life with the demands and needs of the modern world" (p. 363).

2.3 The Lo Kunphen School and Mentsikhang

Not in the tourism sector, but in education and health care, the Lo Manthang-based initiative Lo Kunphen has been trying to simultaneously maintain traditional knowledge and create future prospects for young locals through its program described below. Unless otherwise noted, the information in this section is compiled from Lo Kunphen's website and brochure (Lo Kunphen School and Mentsikhang, n.d.-a, n.d.-b), annual school magazines (Lo Kunphen, 2014, 2015), its five-year development plan 2008-2013 (Lo Kunphen School and Mentsikhang, 2008), and from conversations with the organization's founders during the research period.

2.3.1 Lo Kunphen's Educational and Health Care Services

The Lo Kunphen School and Mentsikhang (house of medicine and astrology) is a local non-profit organization in Upper Mustang, focusing on education, training in traditional Tibetan medicine, and health care services. In terms of education, Lo Kunphen runs boarding schools in Lo Manthang and Pokhara that benefit around 50 students at any given time, offering primary school education and the option of vocational training in traditional Tibetan medicine for students in higher grades. Besides, the organization has started a network of small Tibetan medicine clinics in several villages in Upper Mustang and provides medical treatment to 2,000-3,000 patients annually (Lo Kunphen, 2014, 2015). The herbal medicine used in these clinics is partly produced by Lo Kunphen in a small medicine-making facility inside the school in Lo Manthang.

The organization was founded by two brothers, Amchi Gyatso and Amchi Tenzin Bista, who are Lo Manthang locals. They are both doctors of Tibetan medicine, continuing the family tradition of their highly respected forefathers who were the Mustang royal family's physicians (Craig, 2007). While Amchi Gyatso has a family, Amchi Tenzin is a monk and therefore not married. Besides overseeing the schools they have established, the brothers still treat patients and pass on their medicinal skills to older students. Furthermore, they actively promote traditional medicine through the Himalayan Amchi Association in Kathmandu and during lecture and study trips abroad.

The brothers' vision for Lo Kunphen – *kun phan* meaning "benefitting all" in Tibetan – is two-fold: On the one hand, they would like to preserve and promote the ancient wisdom of traditional Tibetan medicine in Mustang. This aim shall be achieved through standardized training of young *amchi*, providing medical services to local communities, and producing high-quality medicine, which also requires the conservation of medicinal herbs. On the other hand, Amchi Gyatso and Amchi Tenzin would like to offer culturally appropriate primary education for underprivileged children from Upper Mustang and other mountain areas of Nepal. There did not use to be a school in Lo Manthang except the monastery school which only taught traditional subjects, Nepali and English and only admitted male students. Lo Kunphen wanted to bridge the gap by offering an overall education including modern subjects such as social and natural sciences and also giving girls an opportunity to study.

In 2000 they opened the Lo Kunphen School in Lo Manthang and got it officially registered as a primary school at the District Education Office in Jomsom two years later. While the school started out with 15 students, the numbers increased over the years but were intentionally kept to a manageable few dozen. The limit on student numbers was also decided on because of the specialized nature of Tibetan medical training Amchi Gyatso and Amchi Tenzin envisioned for older students. In cooperation with the Himalayan Amchi Association and Nepal's Council for Technical Education and Vocational Training, the brothers developed a curriculum aiming to formally qualify successful students as community medical assistants. In 2006, Lo Kunphen became the first and only institution in Nepal that can certify students who have accomplished the first level of training in traditional Tibetan medicine, called *kangjenpa* (Tib. *rkang rjen pa*). Traditionally, those skills had only been passed down through family lineages or apprenticeships and rigorous study of Tibetan medical texts with experienced masters.

The benefits of Lo Kunphen's work are manifold: Not only does it offer educational and professional opportunities for local children and youth, but by promoting *amchi* medicine it also helps preserve Mustang's cultural heritage and improves health care for underserved communities. In Upper Mustang's context of outmigration, providing education and vocational training locally is vital, not least to balance out opportunities and improve the social mobility of otherwise disadvantaged children. Besides, Lo

Kunphen's education is unique in that it gives students the chance to study their mother tongue and use it to acquire vocational skills. Nepali government schools do not teach Tibetan (Craig, 2012) – which is required to study Tibetan medicine – and the monastery, albeit teaching Tibetan language at a high level, does not have the authorization to offer medical training. Lo Kunphen is in a position to do both and has attained good learning outcomes, with several of its students scoring highest in district-level exams and later earning the *kangjenpa* certificate. The Ministry of Education recognized the school's achievements in 2009 by offering an award to the principal. Lo Kunphen's success has proven that an alternative to the government school system is possible, which has increased local families' interest in culturally appropriate education.

For the continuation of Tibetan medicine, such appreciation is crucial: Even though it is becoming more popular and renowned in Nepali cities and internationally, the number of traditional *amchis* in Mustang has plummeted over the last decades. Lo Kunphen attributes this decline to "a shift towards a more cash based economy associated with the outmigration of young people from Mustang for work, [the] introduction of development programs that have not valued indigenous knowledge, and the impacts of western medicine" (Lo Kunphen School and Mentsikhang, 2008, p. 6). Without countermeasures, generations of pharmaceutical knowledge and indigenous healing practices in Upper Mustang are at risk of being lost. The traditional Tibetan science of healing (Tib. *gso wa rig pa*) has developed over thousands of years, using naturally available substances from the Himalayas to restore the balance of the body's three humors wind, bile and phlegm. Well-being is seen as an interaction between body, spirit, mind and the physical environment, with concepts of pre-Buddhist (Bön) and Buddhist philosophy influencing the ways patients are diagnosed and treated (Craig, n.d.). The holistic approach of Tibetan medicine is not only deeply rooted in the local culture, environment and belief system, but it also remains crucial in Upper Mustang as there are few alternative options for medical treatment (compare section *2.2.6* above). Through its training program and clinics, Lo Kunphen addresses the population's need for health care and, in accordance with its name, is determined to benefit the remote communities of Mustang and other mountain districts.

The organization is based on the *amchi* brothers' private initiative and has not received any government support (Craig, 2007). Instead, it has depended on donations from international foundations and individual sponsors. Three of the main foreign funding partners have been the British charity Kids in Need of Education, the American non-profit organization Drokpa and the German charity Aragua. Their funds have supported the construction of the school buildings and village clinics as well as continuous operating costs. The students are not charged any school fees, but their families contribute in kind, such as by supplying barley flour, butter and cooking fuel. Some of the poorest households cannot afford to make any contributions, though. Therefore, a scholarship scheme generates resources to cover the students' food and accommodation, their uniforms, textbooks, as well as the teachers' salaries. To ensure equality, individual students do not receive any money directly, but the school manages and allocates the annual funds. In order to supplement international funding, Lo Kunphen also produces and sells herbal teas and incense sticks made from local ingredients. Besides, a Japanese sponsor supported the creation of an exhibition room on Tibetan medicine in the *amchis'* home (Figure 30) which tourists may visit for an entrance fee. However, these local income-generating activities only cover a minor part of the running costs, and securing sufficient funding to keep the school and clinics running has been a challenge in recent years.

Figure 30: Exhibition room on Tibetan medicine

The school building in Lo Manthang was constructed on land belonging to Amchi Gyatso and Amchi Tenzin's family, on the northwestern side of town. It is located diagonally across from their family home and is partly in- and partly outside the ancient city wall. The main entrance on the outer side of the school is directly facing a sandy road running along the city wall (Figure 31), while on the inner-city side a second entrance opens into a narrow alley (Figure 32). On the remaining two sides, the school is attached to neighboring buildings. Inside the school premises, there are two courtyards, one outside and one inside the city wall (Figures 33 and 34). Six classrooms, two student dormitories, a staff room, meeting room, kitchen, eating hall and storage rooms are arranged on two floors around those courtyards which are connected by a passage through the city wall. The dormitories and classroom are sparsely furnished and equipped, as are the dining hall and kitchen (Figures 35-38). The architecture is according to the traditional local style with unburned mud bricks and rammed earth. To reduce dust and facilitate cleaning, the floors of both courtyards were cemented in the spring of 2017. At the same time, a team of hired workers also erected an inclined corrugated iron roof above the school to prevent rain and snowmelt from damaging the traditional earthen flat roofs and walls (Figure 39). Leaking had become a problem in the year before, not just because of unusual rainfall in the summer but also because no one remained at the school in the winter to clear snow off the roof before it could melt and infiltrate.[6]

Figure 31: The Lo Kunphen School (white building) seen from the *amchis'* family home

Figure 32: Alley on the inner-city side of the school, school entrance indicated by arrow

Figure 33: Courtyard with classrooms outside the city wall

Figure 34: Students during morning assembly in the courtyard inside the city wall

Figure 35: Boys' dormitory

Figure 36: First graders with teacher in their classroom

Figure 37: Students having their afternoon tea in the dining hall

Figure 38: Cook in the school kitchen

Figure 39: Amchi Gyatso with the newly roofed school in the background (spring 2017)

The school in Lo Manthang only runs from April to October, providing a home and primary education to around 30 students aged six to fifteen. They all live at the school, in separate dormitories for boys and girls. According to the headmasters, boarding allows students to efficiently use the time before and after

[6] Snow needs to be removed from the traditional flat roofs because it otherwise percolates into the unsealed mud and eventually damages the roof structure.

class for studying and reduces distractions from domestic chores they would be expected to do if they lived at home. Except for longer holidays twice a year, the students do not generally return to their families during the semester. They are taught in classes from first to sixth grade based on their education level; due to their different age at enrollment there might be a range of ages in the same class. Each class has its own classroom, and the teachers move around to teach their specialist subjects (Figures 40-42). In 2016, three female and four male teachers were in charge of the then enrolled 17 girls and 14 boys. Most of the teachers were themselves Lo Kunphen graduates aged in their twenties and early thirties; four of them from Amchi Gyatso and Amchi Tenzin's extended family. Three of the teachers also lived at the school all the time, not only teaching the students during class hours but also supervising them during self-study time and daily life.

Figures 40, 41, 42: Science, Nepali and English classes at Lo Kunphen

In the winter, Upper Mustang is too cold to hold lessons in Lo Manthang, so all primary students and teachers move to the outskirts of Pokhara where a branch of Lo Kunphen was constructed in 2008 (Figure 43). The hostel in Pokhara also houses Lo Kunphen's older students (middle and high school age) who live there year-round. This arrangement is based on practical reasons – also because of limited space at the school in Lo Manthang – and to maximize the students' educational outcome.

Figure 43: Lo Kunphen hostel outside Pokhara

Lo Kunphen's specialty is its dual education system, following the standard Nepali curriculum while also integrating typically Tibetan subjects and offering vocational training to older students. The primary school in Lo Manthang mainly teaches the nationally required courses, but adds Tibetan language and traditional culture such as legends, music and dance to the program (Figure 44). During observed lessons, the teachers and students were highly engaged and motivated. An advantage is that the teachers hail from Mustang themselves, which allows them to explain the content of math, science and social studies classes in the students' mother tongue even if the text books are in English. Furthermore, whereas teacher-centered instruction prevails in most Nepali schools, some of Lo Kunphen's teachers were seen to use pedagogically diverse methods to make the content more relevant and graspable to the students. For instance, during an unannounced visit to a science class for grade six, the teacher had prepared an experiment for the students to practically investigate the theoretical knowledge they had read about in the textbook (Figure 45).

Figure 44: Students and teachers practicing traditional songs for a performance at the *Tenchi* Festival 2017

Figure 45: Sixth graders experimenting in science class with the dissolution and evaporation of sugar and salt solutions

The older students in Pokhara attend a nearby Tibetan school as day students where they continue with the Nepali curriculum plus Tibetan. This allows them to take externally marked examinations after grades eight and ten and obtain the national school-leaving certificate upon completion of their secondary education. In the evenings, they return to the Lo Kunphen hostel where they can take introductory classes in Tibetan medicine. Those who have the necessary aptitude and desire to make it their profession have the option to do the *kangjenpa* vocational training program simultaneously to their regular grade 9 and 10 schooling. Those classes are taught in the students' free time by Amchi Gyatso and Amchi Tenzin as well as other traditional doctors hired by the school (Craig, 2007). The training consists of a variety of subjects such as classical Tibetan, medicinal theory, anatomy, physiology, methods of diagnosis (such as pulse reading and urine analysis) and treatment of illnesses. It also includes the use and production of herbal medicine for which students learn to identify and gather medicinal plants as well as the manufacturing process of medicine pills. Such practical experience is an essential component of the *kangjenpa* course, as is a nine-month apprenticeship under the supervision of a qualified *amchi* at the end of two years' formal learning (Craig, 2007). Through this combination of theoretical studies with clinical practice as well as the balance between traditional and modern scientific knowledge, *kangjenpa* students acquire the skills to provide basic health care services to the community. In the meantime Lo Kunphen has developed a subsequent accredited course called *durapa* (Tib. *bsdus ra pa*), so that successful *kangjenpa* graduates can continue to study Tibetan medicine for another two years while also attending class 11 and 12 which are required for university level studies. The *durapa* degree is equivalent to a health assistant, "the nearest to a doctor found in many Nepali rural areas" (Lo Kunphen School and Mentsikhang, 2008, p. 6). Some of Lo Kunphen's graduates now work as *amchi* assistants at one of the rural clinics established by the organization in Upper Mustang. However, the school founders have not been able to encourage all graduates to use their skills and provide service to the community for at least two to five years in return for their free education and training.

Amchi Gyatso and Amchi Tenzin opened the first outpatient clinic in Lo Manthang in 1993. This was a novelty as Tibetan medicine used to be practiced only at the doctor's or patient's home. From now on, anyone could visit the clinic for consultations during its opening hours. Currently, the clinic opens daily except Saturdays from 8:00 to 9:30 and again from 16:30 to 18:00, that is, before and after school hours. While the senior *amchis* practice in their family home, three of Lo Kunphen's teachers take turns staffing the clinic, treating patients and prescribing medicine (Figure 46). In 2004, Lo Kunphen opened three additional clinics in other villages of Upper Mustang to improve health care provision closer to the people. These clinics also offer clinical practice opportunities for students working towards a *kangjenpa* degree.

Figure 46: Lo Kunphen Clinic in Lo Manthang

Traditionally, *amchi* services have no set fee but the patients pay what they can afford. In Upper Mustang, such voluntary donations may be very low. Even though the region is more and more influenced by a monetary economy, cultural expectations and the *amchis'* ethics prevent them from charging for their time (Craig, 2007). For medicine, a nominal fee is raised to cover the cost of supplies, but not to generate profit. Lo Kunphen manufactures about 70% of their medicines themselves, although only about half of the required herbs can be grown in Lo Manthang or collected in the wild. The remaining ingredients are not available in Upper Mustang and need to be imported from Nepal or abroad. Likewise, about 30% of the medicines used at Lo Kunphen are purchased ready-made from larger Tibetan medicine manufacturers in Kathmandu. The cost of raw materials and ready-made medicines amounts to about NRs 100,000 (US$ 1000) each year (Craig, 2007), and it is rising: Due to climate change impacts, overharvesting and grazing practices, it has become increasingly difficult to get medicinal plants, so that more ingredients need to be imported. Between 2007 and 2010, organizations such as ACAP, the Worldwide Fund for Nature (WWF), and the United Nations Development Programme provided financial support for Lo Kunphen's efforts to cultivate medicinal plants, thereby preserving Upper Mustang's biodiversity and ethno-botanical knowledge. However, without external project funding and due to lacking manpower, Lo Kunphen has only been able to grow few plants in its small herbarium in Lo Manthang in recent years (Figure 47).

Figure 47: Amchi Gyatso with a medicinal plant in Lo Kunphen's herbarium

2.3.2 Intention to Improve Sanitary Situation

Despite the achievements of Lo Kunphen in the fields of education and health care, the organization is still struggling with some problems. For example, at the school in Lo Manthang shortcomings regarding water, sanitation and hygiene facilities on the premises have become apparent: There is no running water, and the headmasters are aware that the toilets are inadequate both in numbers and functioning. Thus the idea to improve the school's WASH situation arose.

After initial contacts with S. Joshi, S. Craig, P. Jenssen and M. Pandey, Amchi Tenzin met S. Joshi in Kathmandu to clarify the school's requirements. The meeting revealed Lo Kunphen's interest in an alternative solution and its intention to "build a model of a cold weather sewage system […] which can be replicated by […] Upper Mustang inhabitants" (S. Joshi, personal communication, November 1, 2015). This aspiration was confirmed by both *amchis* on several occasions in 2016 and 2017: The recommended solution should not just be suitable for the Lo Kunphen School, but also for the wider community. One of the reasons for this desire is that Lo Kunphen has acted as a role model for others from its inception. For instance, Amchi Gyatso mentioned that they were the first secular school to open in Lo Manthang, after which another charity school was founded and a monastic school started accepting boys *and* girls. Other schools also followed Lo Kunphen's example to move to Pokhara in the winter to extend their annual teaching session rather than completely suspend classes during the cold season (Lo Kunphen School and Mentsikhang, 2008). The headmasters would like to build on their reputation as a model school and continue to encourage positive change in their surroundings.

During those early stages of the cooperation, talks were about P. Jenssen himself visiting Lo Manthang as early as spring 2016 to assess the situation and design a system for the school. Amchi Tenzin was hoping to receive a design, a list of required materials and a cost estimate from the cooperation, after which he would fundraise for the budget himself. However, Lo Kunphen would not be able to cover a consultant's airfare and travel costs. Due to time and financial constraints, P. Jenssen proposed that a student would cooperate with the Lo Kunphen School instead, which would take more time but reduce the costs. As a result, the author then became involved in the communication with Lo Kunphen's headmasters.

In early 2016, the author contacted Amchi Gyatso as more information was needed about the current sanitation problems at Lo Kunphen and the headmasters' expectations regarding the cooperation. Besides roughly describing the WASH situation at the school, Amchi Gyatso expressed his hope that the author would assess the suitability of different toilet types in the local context, so that they could then choose the most appropriate system. During the same interaction, the nature and time frame of the cooperation were discussed and the objectives and approach defined by mutual agreement as stated in section *1.2* above and described in more detail in the methodology chapter below (section *3.1 Overall Research Approach and Chronology*).

Over the following weeks, the author then drew up a more detailed proposal and shared it with the Lo Kunphen headmasters, specifying the different steps, anticipated schedule and involvement of the cooperation partners (see methodology sections *3.1*, *3.3* and *3.6*). In addition, further communication between Amchi Tenzin, the author, P. Jenssen and S. Joshi clarified the travel arrangements, funding responsibilities and limitations of the cooperation. In the scope of her thesis, the author would accompany the project up and until the final planning stages for improving the school's sanitation system, but Lo Kunphen would then be in charge of implementation.

3. METHODOLOGY

3.1 Overall Research Approach and Chronology

To reach the goal of designing a suitable sanitation system with the Lo Kunphen School while following the principles of stakeholder participation, ecological sustainability and a holistic WASH approach, the most suitable method seemed participatory action research (PAR). PAR is "an approach in which the action researcher and members of a social setting collaborate in the diagnosis of a problem and the development of a solution based on the diagnosis" (Bryman, 2012, p. 397). The method has been used in a variety of fields worldwide, mostly in the social sciences, but also for WASH interventions and health promotion, which made it particularly relevant for this study (Bastien et al., 2015; Fals Borda, 2001; Nawab et al., 2006). PAR differs in its intention and approach from methods used in positivist science, which makes it necessary to point out some of its special features.

The term "action research" appeared in the first half of the 20th century and the method has been further developed and applied increasingly since the 1970s (Berg, 2008; Fals Borda, 2001; Susman & Evered, 1978). Its initiators rejected the custom of using research and fieldwork mostly to boost one's academic career. Instead, they postulated that research should not create abstract scientific theory only read by researchers themselves, but be relevant for practitioners dealing with real-world problems. PAR aims to address practical concerns of the people while generating knowledge, developing praxis skills and competence that will improve future problem-solving (Berg, 2008; Fals Borda, 2001; Susman & Evered, 1978). It treats issues in a specific situational context and attempts to create solutions tailor-made to the local circumstances to increase sustainability and effectiveness (Bastien et al., 2015; Nawab et al., 2006; Susman & Evered, 1978) – defying the "global trends towards uniformity which are harmful to people's culture and the environment" (Fals Borda, 2001, p. 33). Direct involvement between the researcher and local partners combines academic knowledge with popular wisdom and experience of the setting in which a problem is to be solved. PAR aspires to transcend the barrier between intellectuals, grassroot leaders and common people and the subject-object relation commonly present in research situations. It is an empathic approach, recognizing that the participants have different backgrounds but interact with mutual respect and appreciation. The researcher and local partners are both considered experts in their own right and try to understand each other's perspective. This approach does not leave room for scholarly arrogance; partners are not objects of inquiry but human beings with the ability to think, reflect and act on their own situation (Berg, 2008; Fals Borda, 2001; Susman & Evered, 1978).

Contrary to positivist science, an action researcher cannot be a detached, neutral, objective observer vis-à-vis his or her clients (Susman & Evered, 1978). Instead, PAR relies on close collaboration between interdependent partners to incorporate different sources of knowledge, stakeholders' preferences and capacity (Bastien et al., 2015; Berg, 2008; Nawab et al., 2006; Susman & Evered, 1978). The cooperation process moves in a cycle (Figure 48) from diagnosing a problem to action planning and action taking, followed by evaluating the action and learning from the outcome as well as the process in order to tackle other problems. Not all PAR projects involve the researcher and local partners in all steps; sometimes – as in this thesis – the collaboration only encompasses the diagnosing and action planning stages (Susman & Evered, 1978).

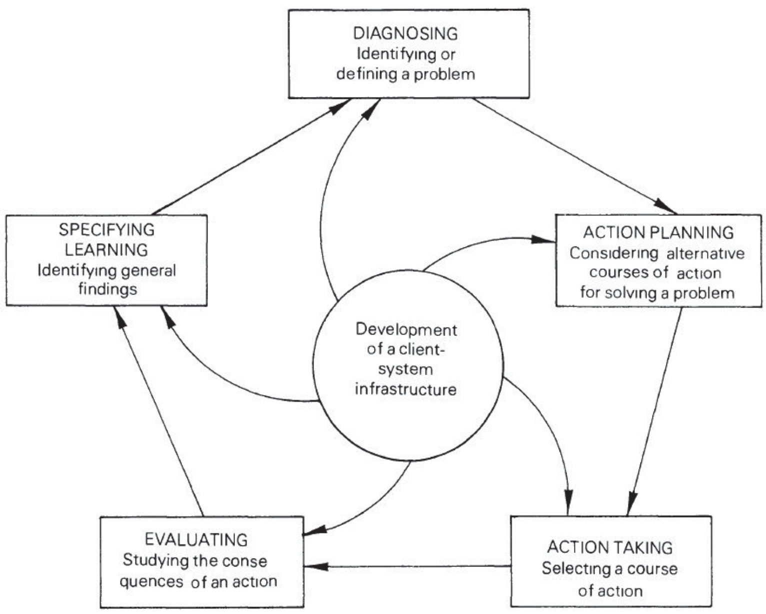


Figure 48: The cyclic process of action research (Susman & Evered, 1978)

During the first step, the researcher assists the stakeholders with analyzing their situation, identifying the problem, setting their priorities and formulating the desired future change (Berg, 2008; Susman & Evered, 1978; Swantz, Ndedya, & Masaiganah, 2001). An assessment done by the researcher alone is contrary to the purpose of PAR and might lead to inappropriate interventions. For the participatory process to work properly, it is important for the local partners to understand that the researcher will not tell them what to do but requires their inputs and involvement. This approach might be new to participants as it differs from conventional top-down community development where external agents decide how to change a situation and locals passively accept (Swantz et al., 2001).

The diagnosis and the action-planning steps both involve data collection. Since PAR follows a holistic approach, it combines data from different disciplines acquired from different sources and through different techniques. The research can be qualitative and quantitative, including questionnaires, observation, interviews, records and reports (Bryman, 2012; Fals Borda, 2001; Susman & Evered, 1978). PAR mixes methodologies and links different academic and technical fields, actors and communities (Fals Borda, 2001) – as the variety of methods described in the following sections demonstrate. The process itself determines the objectives and methods as well as the direction the research will take, depending on the needs and competencies of everyone involved. Susman and Evered (1978) point out that the action researcher must recognize that "the consequences of selected actions cannot be fully known ahead of time" (p. 590). This is contradictory to the positivist paradigm to predict and control, and some academics have criticized PAR for lacking rigor and "being too partisan in approach" (Bryman, 2012, p. 397). However, PAR's approach is also its strength as it offers opportunities for innovation and for scientific research to become more pertinent. Not outside "experts" define problems and impose solutions, but the concerned people themselves explore and select alternative actions together with the researcher (Bryman, 2012; Susman & Evered, 1978). Such cooperation can not only bring about improvements in the local situation, but it also engenders sharing of knowledge and learning on both sides (Bastien et al., 2015; Susman & Evered, 1978).

The action researcher as well as the local partners develop techniques and know-how that are necessary for and supportive of the PAR process (Fals Borda, 2001; Susman & Evered, 1978). For instance, the action researcher may improve his or her ability to deal with unexpected and unplanned situations, to revise the course of action without clear existing guidelines, and to adapt his or her language for effective communication in the local context. Local partners may increase their problem-solving skills and thereby become more self-reliant and empowered to tackle future challenges. For such learning to happen, it is necessary to evaluate a completed action and its consequences. This contributes to the creation of new theory – theory based on action – which can then serve to guide subsequent interventions. However, since every research situation has specific actors and circumstances, the outcome may not be the same and the theory will again have to be revised. In PAR, earlier experiences are used as models to "learn from and improve upon" (Susman & Evered, 1978, p. 600).

For successful PAR, several aspects are crucial. It requires all participants' commitment to a long-term collaboration; researchers and local partners must consider themselves essential parts of the process, even if not all actors engage in all the conducted research to the same degree. People need to define the problem themselves and contribute to the research, which may lead to development in several dimensions (Swantz et al., 2001). Success also depends on the researcher's understanding of the local partners' values which influence their choice of and commitment to a solution (Susman & Evered, 1978).

The many potential benefits of PAR seemed to justify its use for the cooperation with the Lo Kunphen School in Lo Manthang, even though it was clear from the beginning that the author would only be part of the diagnosis and action-planning phases of the project. During the very first interaction between the author and Amchi Gyatso in February 2016, this participatory approach was proposed and agreed on. The author then elaborated the procedure and timeline on the next page (Table 3), aiming for a multistep consultancy in accordance with PAR and following the example of Nawab et al. (2006).

An initial assessment in Lo Manthang, involving the local stakeholder as well as the author, was planned for July 2016. In conversation with Amchi Gyatso, the author highlighted the need to integrate Lo Kunphen's local knowledge, experience, and preferences in order to find a sustainable solution. Besides, the assessment was intended to provide information about the current state of sanitation at the school and the wider context that needed to be considered for suggesting improvements. Such an analy-

Table 3: Timeline and planned activities for research cooperation with the Lo Kunphen School

	Research Chronology	**2016**			**2017**				**2018**
		March - June	July / Aug.	Sept. - Dec.	Jan. / Feb.	March	April - June	July - Dec.	Jan. - May
	Location / **Main Activities**	Norway (NMBU)	Nepal / Mustang[1]	Norway (NMBU)	Outside of Nepal[2]	Kathmandu Pokhara & Mustang		Outside of Nepal	
Preparation	1. Project proposal								
	2. Fundraising for research expenses (travel, permit)								
	3. Literature review (Mustang, WASH in Nepal, EcoSan systems for cold arid climates)								
	4. Development of research methodology								
Diagnosis of Problem	5. Multidisciplinary assessment to collect data on the school's WASH situation including technical information, constraints, stakeholders' preferences, cultural, socio-economic, and environmental context								
	6. Definition of desirable change and exploration of potential solutions								
	7. Evaluation of collected data, consultation with experts								
Action Planning	8. Development of different sanitation system alternatives; file including strengths, weaknesses, cost, O&M for each								
	9. Consultation process: adaptation, refinement and choice of concept								
	10. Design (dimensioning, materials, budget, O&M)								
	11. Continuous documentation, writing of thesis								
	12. Fundraising for implementation								
	13. Implementation								

= Author
= Lo Kunphen & Author
= Lo Kunphen

1) Due to permit requirements and limited funding, the time in Upper Mustang was 10 days in 2016 and a total of 23 days split into two separate trips in the spring of 2017. In between, the author was based in Pokhara. The timing could not be freely chosen but depended on the availability of tour groups for permit sharing.

2) The maximal allowed stay in Nepal is five months per calendar year. This period was scheduled for the spring/summer 2017 when the Lo Kunphen School would actually be in Upper Mustang. "Outside of Nepal" means the author was in adjacent countries or Europe.

sis is not only an essential part of PAR (Berg, 2008), but also required by Nepal's SHMP: "The choice of technologies and investment for sanitation infrastructure should be based on proper assessment of local (financial, technical and institutional) capacities and site-specific needs for design, construction and operation of the systems" (GoN, 2010b, p. 27). Subsequently, the author would develop different alternatives for sanitation systems and other WASH upgrades during the fall and winter 2016/17. Further cooperation in Lo Manthang in the spring of 2017 would then give the opportunity to discuss and modify the improvement options according to Lo Kunphen's requirements.[7] Finally, Lo Kunphen's preferred choice would be elaborated with a more detailed design and particulars. Amchi Gyatso fully approved of the suggested process, emphasizing that they were excited about the cooperation and very eager to find the best solution for Upper Mustang, in harmony with the environment.

However, as priorities shifted and the study focus had to be expanded half-way into the project (compare sections *1.2* above and *6.2 Difficulties and Methodological Shortcomings* below), the methodologies described below not only reflect the research conducted for and with the Lo Kunphen School, but also with the wider community in order to recommend sustainable WASH solutions for Lo Manthang and Upper Mustang in general. They include methods from the social and natural sciences.

3.2 Data Collection

To assess the WASH situation in Lo Manthang and the possibility for improvements from different angles and in a wider context, data was collected in a variety of ways as described in the following sections.

3.2.1 Meetings with Government Offices, NGOs and WASH Experts

Government offices, NGOs and individual WASH experts were contacted in order to get data on environmental aspects of the project area and to find out about WASH interventions – especially decentralized sanitation projects – that had taken place in Upper Mustang or elsewhere in Nepal. Networking with practitioners and learning from their experience was intended to help find viable solutions and potential cooperation partners for the Lo Kunphen School and Lo Manthang town. A list of the most relevant meetings with experts in Nepal can be found in Appendix A, Table 10.

Department of Hydrology and Meteorology (DHM): The DHM was approached for meteorological data to assess Upper Mustang's climate and climate change trends which are likely to influence water resources. However, the lack of climate records poses a challenge to present reliable temperature and precipitation data. Compared to other parts of the country (that is, the lowlands, lower and middle hills), the number of meteorological stations in the high mountains is limited (Marahatta et al., 2009). The DHM possesses climate records of Lo Manthang starting in 1974, from a station established at 3,705m a.s.l. (coordinates 29°11'N, 83°58'E). The available data is utterly incomplete, though; many months and sometimes almost entire years lack measurements as other authors have also noted (Bernet et al., 2012; Fort, 2015). The temperature values presented for Lo Manthang in this thesis are based on data from 1974-2005, but no records exist for the years 1992 and 1995-2002. Similarly, precipitation data is based on records from between 1974 and 2000, though only 20 years within that period had complete data series. After the year 2000, precipitation records are incomplete, and the DHM could not provide any records for either temperature or precipitation in Lo Manthang after 2005. In the attempt to present a more reliable picture of Upper Mustang's climate, data obtained from the DHM was compared and complemented with values from the literature in section *2.2.3*.

The section on global warming and its effects (*2.2.4*) partly relies on a literature review conducted by the author for a term paper on permafrost degradation on the Tibetan Plateau (Karli, 2015).

Survey Department: Contact to the Survey Department in Kathmandu was established by Assoc. Prof. Iswar Man Amatya from the Department of Civil Engineering at Tribhuvan University. The aim was to obtain a large scale topographic map of Lo Manthang as well as geological and pedological maps for an assessment of the underground, including the rock and soil types. However, the sheets in question did not exist, neither in print nor electronically, and the only map of the area that could be purchased was a 1:50,000 hardcopy land use map of Upper Mustang.

Department of Water Supply and Sewerage (DWSS): As the main government agency in charge of water supply and sanitation, the DWSS was contacted to learn about policies and standards related to WASH, the status of interventions in Upper Mustang, the responsibilities of government organs at the local level, and the developments regarding water quality control, wastewater treatment and (ecological)

[7] This action-planning stage will be described in more detail in *3.6 Developing Sustainable Sanitation Options.*

sanitation. Interviews were conducted with staff from the Water Quality, Wastewater Treatment and Environmental Sanitation Sections. Those respondents then facilitated contact with the chief of the Water Supply and Sanitation Division Office (WSSDO) in Jomsom (Mustang District) and with chemists at the DWSS laboratories in Kathmandu and Pokhara. From these connections the author could obtain more specific information about public water supply projects in Upper Mustang and perform water quality tests with the official test kit at two water supply locations in Lo Manthang.

Environment and Public Health Organization (ENPHO): ENPHO is a Nepali NGO founded in 1990, focusing on sustainable WASH technologies for communities and the environment. The organization has been pioneering the development and implementation of innovative systems such as EcoSan toilets and constructed wetlands (CWs) for wastewater treatment in Nepal. ENPHO's approach is scientific and at the same time applied as it is involved in numerous community development projects. The organization has grown to employ 275 people and is a hub of expertise on WASH-related issues (ENPHO, 2018). The author had several meetings and phone calls with the director of the Outreach Division who offered valuable insights into possibilities and challenges as well as practical advice for EcoSan at the Lo Kunphen School and in Lo Manthang.

WaterAid Nepal: WaterAid is an INGO that was founded in the U.K. in 1981 to improve access to clean water, sanitary toilets and good hygiene in the developing world. In Nepal, the organization has been active since 1987, working with the government and communities in rural and urban areas of the country. WaterAid is committed to appropriate and affordable WASH solutions and, like ENPHO, has been at the forefront of promoting EcoSan toilets and decentralized wastewater treatment systems (DEWATS). So far, Mustang has not been included in WaterAid's activities, but according to Kabindra Pudasaini, manager of the Recovery and Resilient WASH program, the district will be a target of the organization's efforts in the coming years. Several meetings and e-mail exchanges took place with Pudasaini and D. R. Chitrakar, another program officer. They showed great interest in the author's findings on the status and gaps of WASH in Upper Mustang. Furthermore, they facilitated contact with the Water Supply and Sanitation Committee at Nala, a peri-urban VDC in the Kathmandu Valley that had implemented a CW for community wastewater treatment in cooperation with ENPHO, WaterAid and other WASH partners. Through a visit at Nala the author hoped to gain insight into the community's experience and challenges with DEWATS, in case a similar system would be considered for Lo Manthang.

Federation of Drinking Water and Sanitation Users Nepal (FEDWASUN): FEDWASUN is an umbrella organization for users' committees, mainly in rural areas, to build capacity for WASH governance at the local level, including advocacy for users' rights, facilitation between users and government service providers, interaction with VDC secretariats, training on WASH governance and awareness, project management, monitoring, book-keeping, etc., support for better implementation of policies, and lobbying for policies according to the users' issues. They also organize public hearings, hygiene training, exposure visits for learning and skill sharing, advocating appropriate technology (for example, rainwater harvesting). 60 out of 75 districts are covered by FEDWASUN. In each of the 60 districts, FEDWASUN is a member of the DWSS, and also cooperates with different NGOs, for instance with ENPHO for water quality tests and with UNICEF on the WSP. FEDWASUN was approached to find out about the structure and functioning of the organization and whether its network includes communities in Mustang – which unfortunately it does not. The interview was conducted with a program manager and a senior program officer.

THE SEWA Nepal: THE SEWA Nepal is an NGO founded in 2009 by dedicated EcoSan activist Shreerendra Pokharel from Chumlingtar, a village along the road between Kathmandu and Pokhara (Bing, 2014). Shreerendra used to work as a teacher and organize successful EcoSan and WASH awareness campaigns for children, which earned him the attention of WASH actors across the country. He then received funding from ENPHO and the WHO and scaled up his EcoSan promotion, leading to the construction of 750 urine-diverting (UD) toilets in Darechowk VDC (Bing, 2014). Furthermore, Shreerendra established a resource center in his home village where he continues to conduct EcoSan training (Adhikari & Poudel, 2015). Being an expert on urine-diversion, Shreerendra was contacted for advice on practicalities regarding the implementation of UD toilets at the Lo Kunphen School.

Annapurna Conservation Area Project (ACAP): As mentioned above, ACAP is a non-profit NGO that started working in 1986 with the aim to manage tourism in the area in line with environmental conservation efforts and sustainable community development (Sharma, 2000). The author met twice with two consecutive chiefs of ACAP's Unit Conservation Offices in Jomsom and Lo Manthang to inquire about their program activities in general, but especially regarding sanitation and hygiene promotion in Upper Mustang.

In order to collect further background information on WASH in Upper Mustang, the author also had meetings at ICIMOD and the WWF whose country director in Nepal is a native of Upper Mustang. However, neither of the organizations is involved in WASH projects in Upper Mustang as their thematic focus lies elsewhere. Lastly, the head of a Tibetan medicine clinic in Kathmandu was consulted to learn about traditional views and rules on water, water pollution and related health issues based on Tibetan medicinal texts and Buddhist scriptures.

3.2.2 Semi-Structured Interviews with Lo Manthang Residents

Semi-structured interviews, a standard investigative approach in qualitative research (Almedom, Blumenthal, & Manderson, 1997), were one of the methods chosen to get a better understanding of Lo Manthang residents' practices, preferences, and awareness surrounding sanitation and wastewater. The method was used for conversations with key informants during the initial assessment in Lo Manthang in July 2016, as well as for more extensive and specific interviews on WASH conducted with a larger number of respondents in the spring of 2017.

The process of selecting interviewees differed between key respondents and further community members. Since the author had not been to Upper Mustang before the initial assessment, she had to rely on contacts recommended to her as entry points into the community by researchers and development partners with long-standing connections in the area. The initial four key informants included two guesthouse owners, a health worker at ACAP and the vice principal of the second charity school in Lo Manthang. When the research focus expanded in 2017, additional respondents were sought out among Lo Manthang residents, aiming at a similar number of men and women from a range of ages, occupations and education level. Those respondents were found through casual interactions while walking around town and spending time in the *amchi* household and at the Lo Kunphen School. For instance, some interviewees were met at the tap stand or when heading to the fields for soil analyses. Further respondents were referred to the author by earlier interview partners, and yet others were members of the extended *amchi* family or teachers at the Lo Kunphen School. After meeting a potential respondent for the first time, several other brief interactions usually happened before an interview was scheduled in order to get acquainted. All in all, 15 interviews were conducted with Lo Manthang residents in the spring of 2017. Six of the respondents were women and nine men, aged between 24 and 65. All but one were of Tibetan ethnicity; one was Nepali from Pokhara. In terms of education and occupation, they have between none and eighteen years of formal schooling and make a living as guesthouse owners, teachers, politicians, farmers, NGO workers, a tour guide and a carpenter. Their detailed demographics can be found in Appendix B, Table 11, from which it becomes clear that they were by no means a representative sample of the general population of Lo Manthang. The unbalanced selection is a result of the short fieldwork period in Upper Mustang which restricted the time for rapport building, as well as a number of challenges in finding residents who were willing and available for a conversation on WASH (see *6.1.2 Limited Access to the Community*).

Interviews were generally conducted in the respondent's home, guesthouse or office and took about an hour. While Berg (2008) mentions that interviews should take place in a location without any risk of the respondent being overheard or seen, other people such as relatives, friends or co-workers were present during almost half of the interviews. This did not seem to inhibit the respondents, though, but rather put them at ease, possibly providing a sense of support in an otherwise unfamiliar situation. The interviews were held in Tibetan language in which all respondents and the author were conversant enough to understand each other.

The interview procedure followed guidelines provided by Almedom et al. (1997) and Berg (2008). The author introduced herself, offered some personal information and explained the purpose of the interview. In adherence to ethical standards, the respondents were assured that their participation was voluntary, that information they provided would only be used for research and academic purposes, and that they would remain anonymous unless they agreed to being cited by name. In order to create a comfortable atmosphere and establish rapport, the conversation started with some informal chatting and introductory questions about the respondent's background, family, and work. As sanitation is a potentially sensitive, private matter (Almedom et al., 1997; Nawab et al., 2006), it was approached slowly by first inquiring about water supply, a topic which is easier to talk about, neither embarrassing nor taboo. Gradually the conversation was then directed towards the more sensitive topics of wastewater and toilets.

The key informant interviews during the initial assessment in 2016 were intended to provide an overview of WASH-related issues in Lo Manthang. Following Almedom et al.'s (1997) advice, the author had prepared a few guiding questions but let the respondents take the lead of the conversation to get an idea of what *they* considered relevant in terms of WASH. The author inquired broadly about the respondents' thoughts and concerns regarding water and sanitation in Lo Manthang in general as well as problems they had encountered in their specific work environment, that is, at their guesthouse, school, or health post. In the course of the interaction the topics became more specific: With guesthouse owners and the school leader, the author asked about the reasons for building flush toilets and the type of wastewater treatment system, including its functioning and maintenance issues. With the health worker, WASH-related public health concerns and hygiene practices in the past and present were addressed.

For interviews with Lo Manthang residents in 2017, a more detailed interview schedule (see Appendix C) was developed according to Almedom et al. (1997) and Berg (2008) and translated into Tibetan by the author. The translated version was proofread and discussed with two native Tibetan teachers who helped adjust the terminology where necessary to convey the intended meaning in a simple, understandable way. The interviews were conducted in a semi-standardized interview (Berg, 2008), meaning the order of questions wasn't strict and the author followed up on cues given by the respondent to make the conversation flow naturally. The wording of the questions was also flexible and adjusted to the circumstances. As Craig et al. (2010) have noted,

> [f]ormalizing the structure of interview schedules can allow for consistency in data collection around a particular issue (…). However, (…) working within the confines of such a tool can also hinder communication, disrupt narrative flow, and reinforce social differences between interviewers and interviewees in ways that informal interviewing and participant-observation tends to minimize (…). [I]nterviews that elicited the most nuanced narratives were the ones in which interviewers did the least amount of talking and in which specific questions were put into dialogue with the interviewees' response to initial prompts in each section of the template, rather than those interviews that proceeded in a more methodical, checklist-like fashion. (pp. 14-15)

Therefore, the author tried to listen without interrupting the respondents, encouraging them to elaborate on what they were sharing. The respondents' behavior during the interviews varied with their character; some were more inhibited and only replied while others were very engaged, freely offering information and asking questions in return. When talking about alternative toilet systems (EcoSan) and wastewater treatment – which most respondents were unfamiliar with – it was challenging not to ask leading questions which aimed at a certain answer. The author tried to remain non-judgmental and reassure the respondents that she was truly interested in their views and opinions, that whatever they shared was valuable information even if they did not approve of the new technologies they were learning about. In order to visualize different toilet systems and natural wastewater treatment, the author had brought along pictures and sketches which raised great interest. The respondents invariably became more involved and eager as soon as the photos were produced.

Despite the flexible, participatory interview structure, the author tried to navigate the topics so that all questions would be addressed with all interviewees to maintain a degree of comparability. She recorded all their answers on print-outs of the interview schedule and used a notebook for additional information that was provided. At the end of the interview the respondents were thanked for their participation and encouraged to get in touch again if they had further questions or information to share. When evaluating the data, the author looked for trends in the responses and particularly valuable insights or comments, but due to the low number of interviews and non-representative selection of respondents no statistical analysis was done.

3.2.3 Participant Observation

Participant observation is a method to gain firsthand experience of one's research area, community and topic by living among and interacting with the people in everyday situations (Becker & Geer, 1957; Ritchie & Lewis, 2003). The researcher accumulates a wide range of impressions and information by observing the surroundings, listening to and engaging in casual conversations with people in their natural environment. Such an approach helps minimize bias so that the researcher is in a position to "understand and explain observed phenomena as accurately as possible" (Almedom et al., 1997, chapter 3).

Participant observation has many advantages because it provides a larger background picture and subtle understanding that cannot be acquired through isolated, scheduled interviews (Becker & Geer, 1957). The researcher gets acquainted with daily habits and customs, has the possibility to find out how and why things are done a certain way, how people interact with each other, how vocabulary is used and not least how non-verbal communication functions in a particular setting (Ritchie & Lewis, 2003). Spending time with the people can also make the researcher aware of issues or facets of life that are not reported in an interview – either because the respondent does not share everything with the researcher or because it does not occur to either the researcher or interviewee to comment on or inquire about certain matters (Becker & Geer, 1957). Participant observation allows the researcher to gain greater understanding of and insight into the context, which makes it easier for him or her to accurately interpret information gathered through interviews as opposed to relying on inference alone (Almedom et al., 1997). The researcher will be more likely to understand hints from interviewees, put their accounts into perspective and discover distorted perception caused by respondents' bias. Interview data therefore gains reliability if accompanied by participant observation. Furthermore, incongruities between interview statements and observed practices can be noticed, and the researcher becomes more aware of linkages between topics and implications of circumstances that would otherwise remain unexplained (Becker & Geer, 1957). In PAR, participant observation and the understanding arising from it make it easier for the researcher to share his or her knowledge and experience in a way that is useful and accepted by the local partners (Susman & Evered, 1978). Participant observation has been considered the best method to gain in-depth knowledge of a study field (Almedom et al., 1997) and has also been used in WASH interventions elsewhere (Nawab et al., 2006).

During the research period in Lo Manthang, the author engaged in participant observation while living in a local household (with the *amchi* family), spending time at the Lo Kunphen School and around town on a daily basis. Casual conversations took place with family members, school staff and students, as well as local men and women at the public tap stand, near drainage channels and streams, while walking through Lo Manthang's alleys and around agricultural fields. Not only did these interactions give the author the opportunity to learn about daily (WASH) routines in the domestic and public sphere, but it also allowed her to identify potential interview partners and mention the purpose of her stay in Upper Mustang. Information on WASH-specific issues was recorded and supplemented with observations at home and from walks around town, along irrigation channels and rivers, and on several hikes to the water supply intake in the mountains above Lo Manthang. These excursions familiarized the author with the water supply and drainage system of the town as well as the waste disposal practices. Sanitation-specific information was obtained by visiting several local households, guesthouses and schools where the functioning of different toilet systems could be observed and experienced. Some of these visits were systematic, while others happened incidentally, complementing the data gathered through other methods.

3.2.4 Literature Search

An in-depth literature study was conducted, covering topics related to Mustang, WASH in Nepal, sustainable sanitation options, and research methodologies. The used resources include journal articles, books, government documents, reports by local and international organizations, textbooks, construction manuals, case studies of PAR projects, and websites of organizations working in the WASH sector. While plenty of documentation exists regarding WASH, literature on Mustang is very limited, which was also observed by Pokharel (2009) who did an analysis of socio-cultural, economic and livelihood options of the people of Upper Mustang. Therefore, the information presented in this thesis regarding WASH in Upper Mustang is almost exclusively from primary research.

3.3 WASH Assessment at the Lo Kunphen School

3.3.1 Engagement of Stakeholders

Previous studies have pointed out the need for a good rapport with and understanding of the stakeholders' views and preferences for successful WASH interventions, especially where new technologies are involved (Bing, 2014; Nawab et al., 2006). At the Lo Kunphen School, the two headmasters, seven teachers, and students participated in the assessment of the current situation and the quest for a solution, though to varying degrees. As the headmasters had been part of the cooperation from the start and bear the responsibility for the school, their engagement was crucial. In order to obtain information about the current WASH situation at Lo Kunphen, their ideas how to improve it, the requirements and constraints governing potential solutions, and perceptions surrounding WASH in general, a detailed question guide (Appendix D) was prepared. The questions were not posed in the form of a formal, structured interview, but blended into conversations and explored in the course of joint site visits, sanitation walks around town and discussions in the *amchis'* family home during the initial assessment. Besides the headmasters themselves, Amchi Gyatso's eldest son Lhundup also turned out to play a central role during these investigations as he is not only a teacher at Lo Kunphen but has also taken on the position as principle and is centrally involved in the day-to-day management of the school.

The teachers' opinions were gathered through individual interviews. Those were meant to be held in the meeting room at school one day after class, but at short notice the headmaster decided that they were going to take place in their family home instead. Each interview took about twenty minutes and the teachers came over from the school one after the other. During all but one interview with a female teacher, Amchi Gyatso's son Lhundup was also present; the interviewee sitting between him and the author on one of the beds in the living room. The interviews started with the author introducing herself and the purpose of consulting with the teachers. The latter were then asked about their names, age, hometown, how long they had been teaching at Lo Kunphen and what subjects, and how many years of schooling they had had themselves. After that, the conversation proceeded according to the interview schedule in Appendix E. While questions about the school's water supply were subsidiary in the question guide for the headmasters, by the time the teachers were interviewed it had become clear that the lack of water at the school was actually a major issue. It was therefore included in the interview schedule and also provided a smooth entry into the topic. The procedure was more structured than during the meetings with other Lo Manthang residents (section *3.2.2* above). The questions were phrased in the same way and in the same order for all teachers. Nevertheless, the conversations were casual and flexible enough to accommodate clarifying follow-up questions and the respondents' queries. The author took notes during the interviews.

Direct student involvement only happened during the action-planning part in the spring 2017 when different WASH improvement options were presented to the school. Since participation of all students would have been impractical and not possible time-wise, it was decided to do focus group interviews, a method that has been used for other WASH interventions (Nawab et al., 2006). A focus group is a number of people of similar backgrounds who discuss the topic the researcher would like to investigate (Almedom et al., 1997). Such discussions are useful to get an idea of the diversity of ideas on an issue and learn about the reasons for the participants' opinions. Oftentimes, focus groups are used at the beginning of a study to find out what topics should be investigated (Almedom et al., 1997). At the Lo Kunphen School, focus group interviews were organized to prevent overlooking important concerns when choosing a certain sanitation system and to integrate the students' views into the decision-making.

Compared to regular interviews where participants are asked to answer questions in turn, focus groups have several advantages (Kitzinger, 1995). The interaction happens not just between the researcher and the participants, but also among the participants who complement each other's accounts and discuss ideas and experiences. Observing this exchange allows the researcher to gain greater understanding not just of the number of people who hold a certain opinion but also of why and how opinions are shaped. Besides, focus group interviews encourage people who would be too shy or feel uncomfortable expressing their views if interviewed individually. The method also motivates people who feel they have nothing to contribute – in focus group interviews the participation of others may trigger their interest so that they also start engaging. However, the group composition must be such that the participants feel comfortable around each other.

Most focus group projects have commonalities in the way they are organized (Morgan, 1997): They include three to five groups which are made up of six to ten homogeneous participants, and the moderator (researcher) guides the discussion in a structured way. However, these are not strict guidelines but rather an observation of how focus groups are often formed. At the Lo Kunphen School, there were three groups; two with girls of different ages (13 and 15 years old, respectively) and one with boys aged 12 to 15. Segmentation is usually done according to sex and age as mixed groups would inhibit the participants, especially girls (Almedom et al., 1997; Morgan, 1997). Furthermore, it is important to gather their specific inputs as they have different needs and possibly different preferences with regard to WASH. Various WASH experts and practitioners mention the significance of involving girls and women in order for projects to be successful (Langergraber & Muellegger, 2005; Nawab et al., 2006; Pokhrel & Viraraghavan, 2004; WaterAid, 2008a). Female-friendly sanitation facilities, including separate toilets for women, are also known to promote dignity and girls' school attendance (WHO, 2017b). Among the girls, age groups were made, which is common when older and younger participants have different experiences with a topic (Morgan, 1997). One of the female teachers had pointed out that some of the older girls already had their periods which might influence their preference of toilets and hygiene facilities. Age difference was also one of the reasons, besides differences in status and authority, why the students were consulted separately from the teachers and headmasters. Had they been together, the participants might have felt uncomfortable talking about toilets and hygiene in front of each other. Regarding the number of participants, there were only two girls in each group, which is an unusually small size. However, participation was voluntary and most girls, especially the younger ones, did not have the interest or courage to join. The boys' group consisted of six active boys and two silent bystanders. Not surprisingly, the girls' discussions did not gain as much momentum due to the small number of participants, but each girl got the space to talk. On the contrary, the boys' discussion was livelier but also more difficult to oversee because of multiple contributions at once and group dynamics that tend to evolve with more participants (Morgan, 1997).

The focus group interviews were scheduled for a Saturday, the students' day off, as they were usually too busy on other days. The meetings with the girls were held in one of the classrooms at the Lo Kunphen School, whereas the boys' discussion took place outside, in front of the school entrance where they had been playing soccer on the road. As is commonly done with focus groups (Morgan, 1997), the author led the discussions according to the same pattern with all groups. After introductions, the purpose of the meeting was explained so that the students understood clearly that all their opinions would be valued and there would be no right or wrong answers (Almedom et al., 1997). The author then used a funnel strategy as described by Morgan (1997), starting with general questions about WASH issues they had at the school and asking the students to talk about the problems they perceived as well as their ideas for improving the situation (see Appendix E for the detailed interview schedule). This part also generated more information on current hygiene practices at the school and the students' awareness of pathogen transfer. The discussion was then channelized with more specific questions about their views on a proposed sanitation technology, that is, urine-diversion. The technology was illustrated with pictures, which sparked the students' curiosity and invigorated discussions. Pictures have proven to be a useful tool for focus group discussions on sanitation and hygiene issues as they provide good starting points into rather sensitive topics (Almedom et al., 1997). The meetings were wrapped up when the topic seemed sufficiently discussed, after about 20 minutes for the girls and half an hour for the boys' group.

3.3.2 Site Visits, Observations and WHO Assessment Checklist

In addition to the stakeholder interviews, the author evaluated Lo Kunphen's WASH situation through repeated visits of the school grounds, observations of WASH-related activities, and an assessment checklist. A first systematic inspection with Amchi Gyatso's son Lhundup provided a general overview and first impressions of the sanitation infrastructure. Subsequently, the toilets and excreta storage spaces were examined in more detail, the dimensions measured and relevant floor plans sketched. The author inquired about the approximate conduit of pipes for graywater from the kitchen – so-called graywater – as well as underground connections to a drainage ditch, a water channel and the school's cesspool for blackwater (fecally contaminated toilet wastewater). That ditch and water channel were then followed through town to their outlet to see where they ended up. In order to gain an understanding of WASH in everyday school life, the students' routines and behavior regarding water-fetching, personal hygiene, dish-washing, and toilet cleanliness were observed. These observations were complemented by asking teachers and students situative questions about their practices. Findings were documented by taking notes and pictures. Besides, the WHO assessment checklist for schools in low-cost settings was used to identify the school's standing with regard to international WASH guidelines (Adams et al., 2009; Appendix F, applicable sections of guidelines 1-7). Where observations alone were insufficient, indicators were cross-checked with information obtained through conversations and interviews with the local stakeholders.

To develop solutions for safe and adequate WASH at the school and in Lo Manthang, including the treatment of graywater and potentially blackwater, further investigations were required to assess the underground and the water available from the public tap stand. These environmental conditions were assessed through hydrogeological studies and soil tests (section *3.4*) as well as water quality analyses (section *3.5*) before sustainable improvement options could be elaborated (section *3.6*).

3.4 Hydrogeologic Assessment

Lo Manthang's hydrogeological situation was assessed through a combination of different methods, including the study of scientific literature, field observations, and field tests. The two main objectives were (1) to get an idea of the location of the groundwater table to estimate the potential for drinking water extraction and the contamination risk from wastewater infiltration, and (2) to determine the soil's suitability for natural wastewater treatment, that is, an infiltration system or a constructed wetland.

3.4.1 Evaluation of Lo Manthang's Geologic and Pedologic Context

The geology and pedology of Lo Manthang was evaluated by consulting maps and scientific articles, interpreting the topography, identifying rock samples and analyzing the soil texture at three sampling sites. In terms of cartographic resources, there is a dearth of detailed thematic maps for Upper Mustang (compare section *3.2.1*). For the geology, small scale overview maps of the Himalayas and Nepal were used along with relevant literature on the geology of Mustang. The formation of the topography around Lo Manthang was deduced from the study of Google Earth Pro images and repeated investigative walks on the terrace of Lo Manthang, along the river valleys and on the surrounding hills. The hillsides along the road and a three-meter deep construction pit in the town center provided opportunities for – very localized – assessments of the layering of deposits. From the construction pit a soil sample of the fraction <5cm was taken at a depth of 1.9m to do a grain size distribution as described below. Rocks in the area were roughly classified on site and two small samples brought back to Norway for more detailed identification with the help of professional geologists at NMBU. The analysis included the use of 10% hydrochloric acid (HCl) to determine whether one of the rocks was a limestone or dolomite – bubbling when HCl is applied to the rock indicates a reaction with calcium carbonate ($CaCO_3$) which is present in these rock types. However, these two samples only provide a glimpse of the variety of rocks around Lo Manthang and not a comprehensive picture.

For soil sampling and infiltration tests, three locations on the terrace of Lo Manthang were chosen, all of them east of town along the natural incline of the landscape to ensure that wastewater conveyance would not require any pumping uphill (Figure 49). Based on the interpretation of landscape features, the groundwater level was estimated to be several dozen meters below the plateau so that potential infiltration of wastewater at these sites should not create a contamination risk (see section *4.4.1* below). The choice of sites was also limited by the availability of water for infiltration tests – they had to be near irrigation channels – as well as ongoing agricultural activity such as plowing, sowing, and fencing. To avoid disturbing currently used farmland and causing conflict with land owners, sampling and tests were done on plots used for storage of mud bricks and rocks (sites 1 and 3, respectively) and outside the rock wall boundary of the cultivated area (site 2). While site 1 was surrounded by fields, sites 2 and 3 were located on the south eastern and north eastern edge of the terrace, just before the slopes down to the ravines Drokpolo Khola and Chhorak Drokpo Khola, respectively (Figure 50).

Figure 49: Soil sampling and infiltration test sites, seen from a hill southwest of Lo Manthang town

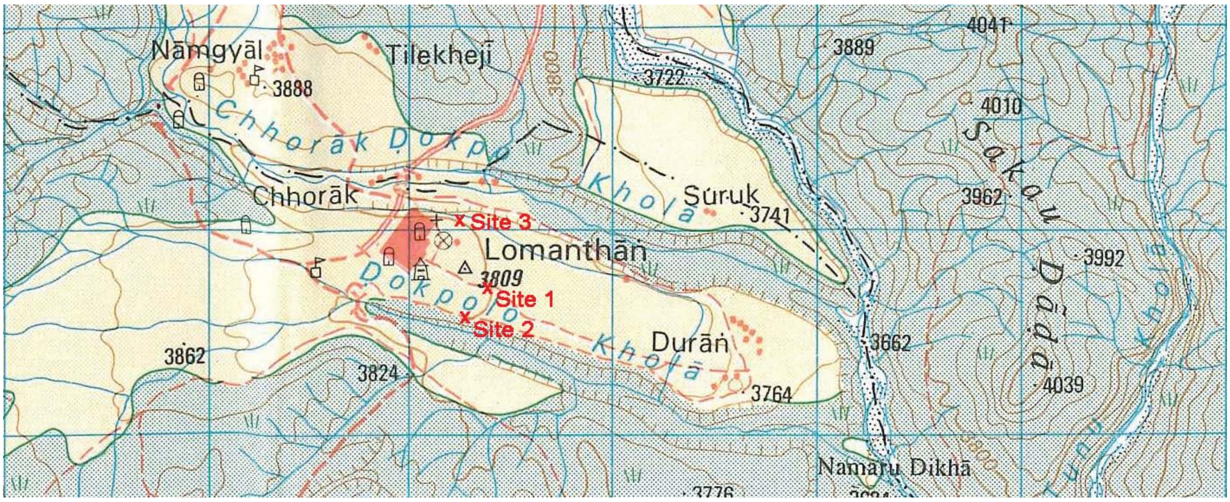


Figure 50: Map of Lo Manthang with approximate location of test sites (grid size: 1km²); yellow indicating cultivated area (HMGoN, 2001)

The altitude and exact coordinates of the locations were determined by GPS (Table 4).

Table 4: Location and GPS data of soil sampling and infiltration test sites

Site 1	Site 2	Site 3
		
3,809m a.s.l 29°10'55.5'' (N) 83°57'39.7'' (E)	3,812m a.s.l. 29°10'46.4'' 83°57'35.1''	3,815m a.s.l. 29°11'03.0'' 83°57'34.4''

At each site, soil samples of about one kilogram were taken from a depth of 50cm to estimate the textural class, measure the pH, determine the organic matter content by loss on ignition, and conduct a complete grain size distribution analysis. The texture class of the soils was assessed in two ways according to the guidelines for soil description by the United Nations' Food and Agriculture Organization (FAO, 2006, pp. 26-28). The first way was a practical field method that gave a rough estimate and involved feeling the constituents of the fine earth fraction (<2mm) in a slightly wet state. The second way was based on entering the sand, silt and clay percentages obtained from the grain size distribution (see section *3.4.2* below) into a texture class diagram. For the coarser constituents, the different sand fractions (fine, medium, coarse) were also distinguished to determine the subclass of the sand. The pH and organic matter content were analyzed in the soil science lab at NMBU, according to the methods described by Krogstad and Børresen (2015). For pH measurements, three replicates from each sampling site were prepared with deionized water, and the electrode was calibrated with buffer solutions of pH4 and pH7. To determine soil organic matter, the soils first had to be dried for six hours at 105°C to remove water from the samples. Loss on ignition then resulted in the organic matter content as a percentage of the dry matter. However, in mineral soils this figure needs to be corrected for clay content because clay keeps water bound up to higher temperatures, so the measured loss on ignition might not just be organic matter but also water (Krogstad & Børresen, 2015). The clay content of each soil sample was known from the grain size distribution described below.

3.4.2 Grain Size Distribution (GSD)

A grain size distribution (GSD) is a method to determine soil texture, that is, the relative fractions of sand, silt and clay. It can be used to estimate a soil's hydraulic conductivity (K_{sat}), a measure of how easily a fluid can pass through a porous medium (Schwartz & Zhang, 2003). K_{sat} is one of the most important hydraulic characteristics of a soil and is expressed in distance per time, for example meters per second [m/s] (Stibinger, 2014). Knowing a soil's K_{sat} can serve as an indicator of its suitability for wastewater infiltration, a treatment method that makes use of natural processes in the soil to remove contaminants from wastewater. Wastewater infiltration is a particularly relevant option in places like Upper Mustang where building a conventional wastewater treatment plant would be too costly, difficult to operate and maintain properly, and therefore unsustainable for economic, environmental and health reasons. Before an infiltration system can be considered in Lo Manthang, an assessment of the local soils was required to clarify whether they would have the capacity to continuously infiltrate wastewater at a sufficient rate.

The GSD procedure involves several steps: drying the sample, separating it into different grain size fractions through dry and wet sieving, determining the texture class, and finally creating and interpreting a grain size distribution curve. The soil samples were first dried for 24 hours at 35°C because their moisture content could falsify the results. They were then individually poured into a stack of sieves with decreasing mesh size from 19mm to 2mm which is the threshold diameter for sand. The sieves were placed on a vibratory sieve shaker by Retsch® at a moderate vibration speed (50) for 5 minutes, but the soil aggregates did not disintegrate sufficiently, so the vibration speed was doubled and shaking continued for another 5 minutes. However, many particles still stuck together as small aggregates, which would have distorted the results. Therefore, when separating the sieves, the aggregates were crushed with a pestle so they would pass through the mesh. The soil remaining in each sieve was then weighed and recorded as percentage of the total sample.

To distinguish the different fractions smaller than 2mm, a GSD analysis by pipette method and wet sieving was carried out according to Krogstad and Børresen (2015). One deviation from the mentioned procedure was that no HCl was added during sample preparation because the pH measurement had shown that the soils were alkaline. HCl breaks up the carbonates which are part of every soil with a pH higher than 6.5 or 7 (Tore Krogstad, personal communication, August 30, 2017). Since the aim of the GSD was to get a picture of the soils in their natural state in order to estimate their hydraulic conductivity, dissolving the carbonates with HCl would have altered the actual soil conditions.

While the soil samples from the three infiltration test sites were analyzed at NMBU, the sample from the construction pit was analyzed at Tribhuvan University (TU) in Kathmandu. The method was the same, except that the mesh sizes of the sieves at TU had different grading, and sieving was done down to 0.063mm, the threshold between sand and silt. The soil from the construction pit was not analyzed by pipette method and wet sieving as it was considerably coarser than the others and only had a negligible fraction below 0.063mm.

In order to create cumulative GSD curves, the relative amounts of the different grain size fractions were then plotted by using an Excel template (Kitch, n.d.). The shape of the resulting curve indicates how well sorted a soil is: In a well-sorted soil where a large percentage of soil constituents belongs to the same grain size fraction, the curve shows a steep incline, whereas gradually inclining curves represent poorly sorted soils made up of many different grain sizes. For well-sorted soils, a probable range of the K_{sat} can be estimated by interpreting the properties of the dominant grain size fraction or texture class. A guide by the United States Department of Agriculture (USDA, n.d.) was used for approximate K_{sat} ranges based on texture class. An alternative is to apply empirically derived formulae called pedotransfer functions (Ibrahim & Aliyu, 2016; Schwartz & Zhang, 2003; Stibinger, 2014). However, such correlation methods, based on predetermined relationships between soil texture and K_{sat}, are often inadequate and only applicable under certain conditions (Odong, 2007). The GSD does not take the soil structure into account, that is, the size, shape and interconnectedness of pores which are crucial for a soil's K_{sat} (Stibinger, 2014). Especially in poorly sorted (heterogeneous) soils with a wide range of different grain sizes, K_{sat} is difficult to approximate and some empirical equations cannot be used (Odong, 2007). For instance, the soil samples from Lo Manthang were not suitable to apply the pedotransfer function by Hazen (1911, cited in Schwartz & Zhang, 2003, p. 53):

$$K = C * d_{10}^2$$

Where
K – hydraulic conductivity
C – constant for loose sand
d_{10} – effective grain size: 10% of the grains smaller, 90% coarser than this diameter

Hazen's formula is based on the assumption that $d_{60}/d_{10} < 5$, which was not the case for any of the assessed soils as they were more heterogeneous. Besides, the d_{10} value of the samples from the three infiltration test sites could not be determined with the used pipette method: It only distinguished the fractions down to 0.002mm (clay), but the clay content was greater than 10%. Therefore, a different pedotransfer function by Krumbein and Monk (1943), cited in Schwartz and Zhang (2003), was used to estimate the hydraulic conductivity. This calculation was done in two steps: First, the permeability k was calculated with

$$k = 760 * d^2 * e^{-1.31\sigma} \qquad \text{(Schwartz \& Zhang, 2003, p. 53)}$$

Where
k – permeability (darcys; 1 darcy = $9.87*10^{-13}m^2$)
d – mean grain size (mm); d_{50}
σ – log standard deviation of grain size distribution (standard deviation = $d_{84} – d_{50}$)

Thereafter, K was calculated using the following equation:

$$K = \frac{k*\rho*g}{\mu} \qquad \text{(Schwartz \& Zhang, 2003, p. 53)}$$

Where:
ρ – density of water: $1000kg/m^3$
g – gravity: $9.81m/s^2$
μ – viscosity of water: 0.0015 kg/(s*m) at Lo Manthang's MAAT of 5.9°C and 0.0011 kg/(s*m) at 15°C, the approximate temperature of the water used for infiltration tests (Engineering ToolBox, 2004)

This formula was used to estimate K_{sat} at all four sites. However, due to the associated uncertainties, the research in Lo Manthang *combined* correlation methods based on textural analysis with in-situ infiltration tests. Such an approach enhances the understanding of the site-specific circumstances – hydraulic methods may validate the estimates or provide more accurate K_{sat} results.

3.4.3 Infiltration Tests

Hydraulic methods to determine K_{sat} include laboratory tests as well as small- and large-scale field tests (Stibinger, 2014). For Lo Manthang a small-scale field test – a falling head pit infiltration – was chosen, based on the Danish instructions for simple drainage tests (Rørcentret, 2012, pp. 25-29) and the modified inverse auger-hole method, also called Porchet's method (Stibinger, 2014). This method reflects the soil of a larger area than laboratory methods which use undisturbed soil cores of only $100cm^3$ (Krogstad & Børresen, 2015). Furthermore, it has the advantage of not requiring much equipment. Even though the constant head method by Mariotte infiltrometer is supposed to produce more reliable results than a simple pit infiltration (Solheim, 2017), the remote location and difficult accessibility of Lo Manthang did not allow for such instrumentation to be transported. The only devices used were a cubic sponge (0.25m*0.25m*0.30m) with a cylindrical hole in the center, a measuring stick and a stop watch to assess the infiltration rate.

Before the tests could begin, a two-leveled infiltration pit had to be dug at each site. The outer pits were about 0.60m*0.60m large and 0.30m deep; the inner pits 0.25m*0.25m large and 0.24m deep (0.54m from the surface) (Figure 52). The inner pits should have been sized so that the sponge fit tightly, thereby supporting the side walls to keep the geometry of the hole standardized. In practice, however, exact dimensions were difficult to dig due to compact soil and a rusty shovel as the only available tool. Especially at site 3, the upper few centimeters around the sponge had to be backfilled as the inner pit had been dug slightly too large at the top. At site 2 digging was further complicated by about 15% rocks between 5 and 10cm diameter (Figure 51). Furthermore, the sponge protruded 0.06m above the inner pit at all three sites, instead of the recommended 0.05m.

Figure 51 (above): Stones dug out from infiltration pit at site 2

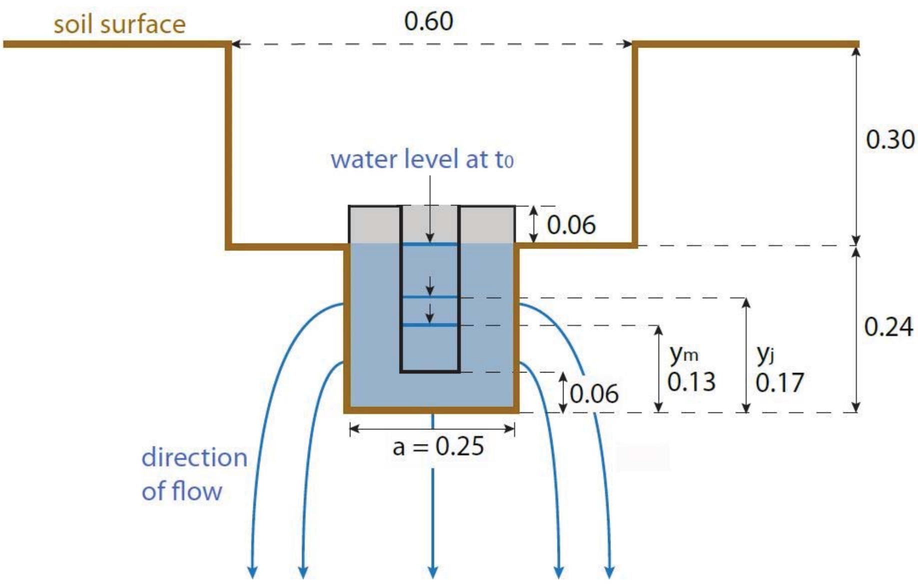


Figure 52 (left): Cross-section of infiltration pit (design adapted from Stibinger (2014); dimensions in meters)

Once the pit was prepared, the soil surrounding the infiltration surface had to be saturated. Without saturation, the measured infiltration rates would be fast at the beginning and getting slower as the soil pores fill up. To avoid such irregular measurements and allow the infiltration rate to stabilize before the actual experiment, about 30 liters of water were poured into the pit through the cylindrical opening of the sponge over a period of 30 minutes (Rørcentret, 2012). Water for saturation as well as the subsequent tests was fetched in buckets from nearby irrigation channels. While the water was reasonably clear at sites 1 and 2, the only available water at site 3 was very turbid (Figure 53) and smelled like sewage.

Figure 53: Turbid water used at infiltration site 3

After saturation, the infiltration test was performed three times at each site. For that purpose, a wooden measuring stick was placed vertically in the cylindrical opening of the sponge and the inner pit filled to the top with water (Figure 54). Then it was recorded how much time it took the water to sink centimeter by centimeter. Due to the design of the sponge it was only possible to read the water level clearly down to 13cm above the pit bottom, that is, a depth of 41cm. Before each consecutive run there was a 1-2 minute gap during which water was fetched from the nearest irrigation channel to refill the inner pit and start measuring the head decline again.

Figure 54: Running infiltration test at site 1

The data was plotted in Excel (Microsoft Office 2010) in two different ways: 1) The continuous drop in water level [cm] per time [min] and 2) the infiltration rate [cm/min] per time [min]. While the first graphs only serve illustrative purposes and are displayed in Appendix I (Figures 176-178), the infiltration rates are presented in a single combined graph among the primary research findings in section *4.4.3* (Figure 140). To calculate the infiltration rate, the last 5cm of each run were used along with the corresponding times. In the graph, each run is therefore depicted by a single value representing an averaged infiltration rate of the last 5cm of the experiment. K_{sat} at each site was then calculated in m/s for the third run (which would be closest to the steady state, that is, saturated soil conditions). However, simply expressing the water level drop per time overestimates K_{sat} as it considers vertical infiltration only, whereas in reality water also infiltrates through the pit sides.

In order to account for the total infiltration surface, K_{sat} was therefore also calculated based on the geometry of the pit (Figure 52), including the submerged side walls as the water level goes down. As before, the last 5cm of the third run at each location were used along with the corresponding times, according to the following formula:

$$\frac{a^2}{2a}\ln\left[\frac{y_j+\frac{a^2}{2a}}{y_m+\frac{a^2}{2a}}\right]=K\left(t_m-t_j\right)$$ modified from Stibinger (2014, p. 49)

Where:
a = edge length of the sponge [m]
y_j, y_m = water level at times t_j and t_m, measured from the pit bottom [m]
K = saturated hydraulic conductivity [m/s]
t_j, t_m= time j and m after starting the infiltration test [s]

Based on the thus obtained K_{sat} as well as the GSDs, the soils' suitability for wastewater infiltration was assessed for all three infiltration test sites. Since the infiltration of wastewater leads to clogging, the loading rate must be lower than the soil's K_{sat} for clean water (Jenssen, 2016). The wastewater loading rate that a soil can sustain in the long run varies with the initial K_{sat} of a certain soil type. For instance, coarser soils have a larger reduction factor than more finely grained soils which have a lower K_{sat} to begin with (Jenssen, 1986).

Therefore, loading rate recommendations have been established for different soils depending on their GSD and K_{sat} for clean water. Such recommendations are based on a soil's mean grain size (d_{50}) and a term reflecting how well sorted it is (d_{60}/d_{10}). These properties are combined in a so-called grain size / sorting diagram (Figure 55). The diagram has been divided into four different sectors according to infiltration properties. Sector 1, for instance, represents finely grained and poorly sorted soils such as tills, silts and clays for which K_{sat} is generally low and cannot be determined from the GSD. Sectors 2-4 represent better sorted sands and gravels which generally have a higher K_{sat} that *can* be estimated from the GSD (Jenssen, 2016). The loading rate recommendations determined for different soil types and sectors vary between authors, two of which are presented in Table 5.

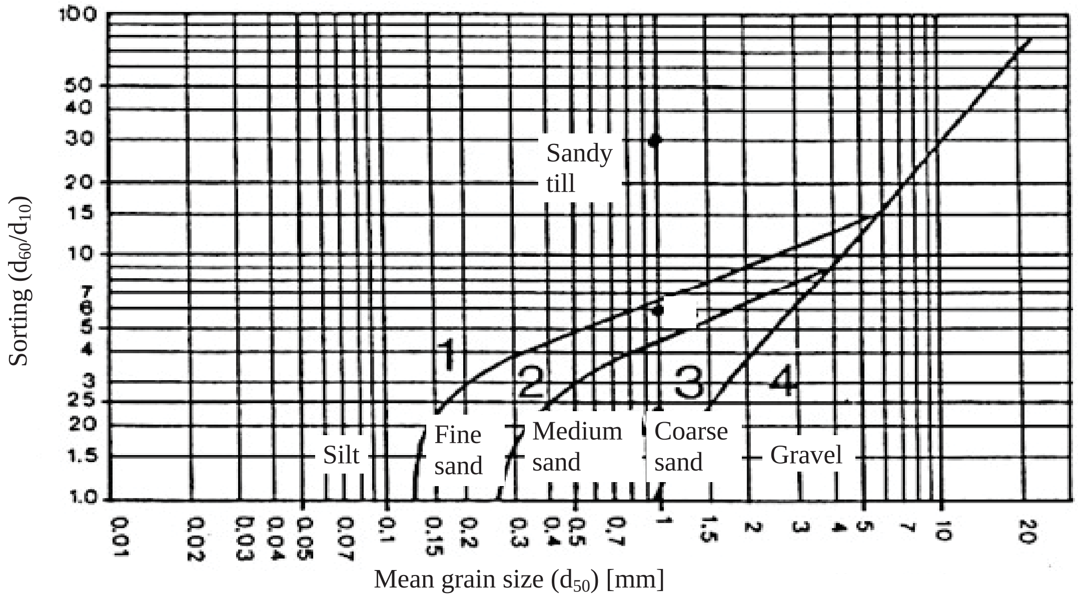


Figure 55: Mean grain size / sorting diagram (based on Jenssen, 2016)

Table 5: Recommended wastewater loading rates (LR) based on soil types and K_{sat} for clean water (compiled from Jenssen, 2016)

		Jenssen, 1986		Norwegian guidelines	
Sector	**Soil type**	**K clean water [m/d]**	**LR wastewater [cm/d]**	**K clean water [m/d]**	**LR wastewater [cm/d]**
1	Sandy till	0.05	1	>5.0 2-5 1-2	2.5 1.0 0.6
	Coarse silt	1	1		
2	Fine sand	5	1	No specifications	2.5
3	Medium sand	30	1-2		5.0
	Coarse sand	70	5		
4	Gravel	>400	>10		No specifications

3.5 Water Quality Tests

3.5.1 Sampling Locations and Sample Taking

Time constraints limited sampling and field testing to two locations which were chosen according to Lo Manthang's and the Lo Kunphen School's water supply. The sampling procedure was the same for both locations. The first sample was taken from the public tap near the jeep stand at the entrance of Lo Manthang town, reflecting public taps throughout town which are all fed by the same water supply scheme (see section *4.1.1*). The Lo Kunphen School uses water from two of the public taps. The second sample was taken from a black pipe on the southwest corner of Lo Manthang where locals commonly do laundry (Figure 56). This pipe carries water from a bog about 15 minutes' walking distance uphill to the west.

Figure 56: Second sampling location (arrow indicating pipe)

Before sampling, the mouth of the tap and pipe were sterilized with methanol and the sampling vessels and instruments rinsed several times with water from the respective source. For comprehensive chemical analyses at the DWSS regional laboratory in Pokhara, a sample of one liter was taken from both locations. A lack of man power in the DWSS laboratory led to a two-month gap between sample taking and chemical analyses; the samples were refrigerated but not chemically preserved during storage.

3.5.2 Wagtech® Field Tests: Physical, Chemical, Microbiological Analyses

Due to Lo Manthang's remote location and long traveling times to the laboratory in Pokhara, certain parameters had to be assessed on the spot. For this purpose, a Potatech® portable water quality test kit by Wagtech® WTD (Figure 57) was used, provided by the DWSS subdivision office in Jomsom and brought to Lo Manthang by Prakash Subedi, chemist in charge of water quality analyses at the DWSS in Pokhara. In accordance with the National Drinking Water Quality Standards (GoN, 2005), the parameters evaluated in Lo Manthang included turbidity, pH, and *E.coli* bacteria as described below. Though the Potatech® kit is also equipped to measure free residual chlorine, this test was unnecessary as Lo Manthang's water supply has never been chlorinated.

Figure 57: Components of the Potatech® drinking water field test kit (Wagtech® WTD, n.d.-b)

Turbidity and pH analyses were quick procedures. For turbidity, a glass tube graduated with nephelometric turbidity units (NTU) and a yellow disc with a cross at the bottom was used. If the water is clear (≤ 5 NTU), the cross at the bottom is visible when the whole tube is filled with water (Figure 58). With greater turbidity the water level needs to be lowered until the cross becomes visible and the degree of turbidity can be read from the NTU scale on the tube. For measuring pH, a digital pH meter by HANNA™ was immersed into a sampling cup filled with water. The reading was taken after the measurement had stabilized.

Figure 58: Turbidity test tube with visible cross at the bottom

Microbiological analysis was a more complex procedure requiring various preparation steps and incubation. First, the sampling cup as well as a petri dish and its lid were sterilized by burning small quantities of methanol inside them. As for the cup, it was covered with the filter funnel (that is, the top part of the filtration unit) while the methanol was still burning and left to burn for another 2-3 minutes. Anaerobic combustion of methanol produced formaldehyde, thereby ensuring complete sterilization (Wagtech® WTD, n.d.-a).

Following sterilization, a Whatman® filter membrane of 45µm pore size and the absorbent pad contained in the filter package were placed in the filtration unit and the petri dish, respectively. After that, the sterilized filter funnel was screwed tight and filled to the 100ml mark with water from the sampling cup. The water was then pumped by hand through the filter paper which would catch any *E.coli* bacteria present in the sample (Figure 59).

Figure 59: Pumping water sample through a 45µm filter paper

As is commonly done, *E.coli* was used as an indicator organism for fecal coliforms, and bacterial contamination was assessed by counting colony forming units (CFUs) of *E.coli* after incubation. Ideally, the water sample is processed as quickly as possible; if two or more hours pass between sampling and incubation, the sample needs to be chilled down to 4°C. A delay of more than 6 hours, even with a chilled sample, leads to questionable results that rarely reflect the initial bacteriological conditions (Wagtech® WTD, n.d.-a). In Lo Manthang, the samples were prepared for incubation immediately after sampling. In order to create optimal conditions for *E.coli* growth, the absorbent pad on the petri dish was saturated with membrane lauryl sulfate broth (MLSB) serving as *E.coli*'s culture medium (Figure 60). MLSB contains lactose as a carbon (C) source and phenol red as an indicator to make *E.coli* CFUs visible after incubation through a color change. The color change happens because *E.coli* utilize lactose and produce acid which then reacts with phenol red, turning it yellow (Wagtech® WTD, n.d.-a). The filter paper was placed on the absorbent pad, the petri dish closed and labeled with the name of the location, date and time of sampling. The prepared petri dish was then left for about half an hour to allow the bacteria to resuscitate before incubation. Without resuscitation, there is a risk of *E.coli* dying from shock by suddenly being exposed to excessively favorable conditions (food and optimal temperature); they need gradual habituation (P. Subedi, personal communication, April 25, 2017). After the resuscitation period, the petri dish was placed in a battery-powered incubator within the Wagtech® field test box for 24 hours at 44°C. While the minimum incubation period is 14 hours, Subedi mentioned that 24 hours are commonly used for field tests performed by the DWSS regional office in Pokhara. After that time lapse, the petri dish should be removed from the incubator and the yellow CFUs counted – the count representing the number of *E.coli* per 100ml sample.

Figure 60: Saturating absorbent pad on petri dish with lauryl sulfate solution for incubation of *E.coli*

The incubator in the Wagtech® field test kit also offers a setting to incubate total coliforms at 37°C, but it is not possible to incubate samples at different temperatures at the same time. Due to time constraints, the water samples in Lo Manthang could only be analyzed for *E.coli*.

3.6 Developing Sustainable Sanitation Options

A number of steps were undertaken to find sanitation solutions for the specific conditions and constraints at the Lo Kunphen School as well as for Lo Manthang in general. Since the main focus was initially on the school, the process of developing sustainable options shall be described in more detail. The two main phases were the elaboration of different alternatives, followed by a consultation process with the stakeholders at the school. During the first phase, primary research data from the initial assessment was evaluated and considered in combination with background information on Mustang and WASH in Nepal. This was accompanied by a literature study on EcoSan options suitable for the environmental, geographic and socio-cultural context, and local WASH experts were consulted to find out about similar projects that had been implemented in the past. Furthermore, the case was presented to and discussed with dozens of professors, practitioners and fellow students from the fields of environmental and civil engineering, development cooperation, social anthropology, Tibetology, and public health. In consideration of the circumstances at Lo Kunphen, potential options for improving the toilets and creating water supply and hygiene facilities were elaborated – a challenging task due to the range of site-specific limitations. But as Nawab et al. (2006) have pointed out, "it is important that the general principles of ecological sanitation models are adapted to local conditions, rather than introducing universal, specific technologies developed under different conditions" (p. 245). While developing the different alternatives, care was taken to suggest solutions that would be feasible to implement and maintain in the local context. As the WHO's WASH standards for schools in low-cost settings advise, the choice of technology must be considerate of the stakeholders' capacity for maintenance and repair, besides being durable and requiring neither specialist skills nor equipment (Adams et al., 2009).

In the spring of 2017, these options were then presented to the stakeholders for consideration. Along with oral explanations, the school received a two-page file with pictures or simple sketches for each alternative, with a brief explanation of the suggested changes, the required construction and materials, O&M needs, benefits as well as shortcomings and challenges of the system. The costs were not specifically included yet, mainly for two reasons: 1) The above-mentioned WHO guidelines state that

> local constraints, such as lack of funding (…), should not be taken into consideration at this stage. The aim is first to define appropriate targets required

> for providing a healthy school environment in a particular setting, then to seek ways to meet those targets, rather than defining limited targets that are insufficient.
>
> (Adams et al., 2009, p. 11)

2) The author was much less familiar than the *amchis* themselves with the local prices for sanitary appliances, construction materials and labor. During the short period of the initial assessment it was also not possible to inquire about the prices of all materials mentioned in the different alternatives as those were only elaborated over the following months. Therefore, expenses were only included where known.

During a consultation process on the ground, the proposed concepts were then supposed to be adapted according to the stakeholders' wishes, drawing on Nawab et al. (2006)'s experience that the local partners "neither totally rejected nor accepted any of the models but wanted to pick from (...) two models and combine and adapt [them] to their culture and environment" (p. 238). The teachers' and students' preferences and requests were integrated in discussions with the headmasters about the choice of improvements regarding the toilet design and the availability of water and space for personal hygiene. This process was intended to enable the stakeholders to make an informed decision, as stipulated by the Nepali government as well as (I)NGOs working in the WASH sector (DWSS & MoWSS, 2016b; GoN, 2010b; WaterAid, 2011; Werner et al., 2003). The headmasters then chose the option they considered the most suitable. This was meant to be followed by cooperative refinement of the system design and practicalities such as the dimensioning, materials, O&M requirements and responsibilities. In practice, the further elaboration of the improvements was done by the author alone. It included additional consultation with local WASH experts and contact with suppliers of sanitary appliances in Pokhara and other required materials. Based on the gathered information, designs for toilets and washing facilities were sketched and later redrawn digitally using Adobe Illustrator® CS4. Furthermore, a material list including a cost estimate was drafted, giving different options such as more expensive versus cheaper appliances and optional features and fittings.

In addition, a detailed contact list was created for the Lo Kunphen School to be able to get in touch with suppliers and local WASH experts willing to provide advice and training before, during and after implementation. According with WHO guidelines, the author also planned to discuss and define the requirements and responsibilities for O&M as well as the budget for recurring costs (Adams et al., 2009).

Upon further consultation with the headmasters in Lo Manthang, the designs, material list and cost estimate were adjusted based on their requests and the quotation amended with further costs for construction materials, transportation and labor. Along with the contact list, the author explained the importance of getting in touch with the indicated Nepali WASH experts to ensure proper implementation and long-term sustainability. To facilitate Lo Kunphen's fundraising efforts for the required budget, the author also wrote up a handout with an outline of the intended improvements for distribution at the *Tenchi* Festival as well as a more detailed summary for dissemination among potential donors by e-mail.

The improvements were to be carried out and financed by Lo Kunphen; the author was only involved during the problem diagnosis and action planning stages of the PAR cycle (compare section *3.1* above). At the end of this process, all relevant documents were given to the school on paper and in electronic form, including the different improvement options, the designs, material list, and cost estimate of the chosen system, the contact list as well as the project summaries for fundraising. This thesis, containing the complete research documentation, will also be provided to the local stakeholders.

The solutions for sustainable sanitation in Lo Manthang in general could not be developed to the same depth and detail as for the school and no further community consultation could take place to discuss the proposed options. The recommendations are based on information obtained through the literature review, community interviews, and the assessment of the surroundings and soils described above. They focus mainly on sanitation and are presented in different sections for raising WASH awareness, suggestions for local households, guesthouses, public toilets, and wastewater treatment. Ideas for improving the water supply are not included as this would have gone beyond scope of the thesis. Besides, the government is already planning a new system with household connections (see section *4.1.1* below), so the public supply is expected to undergo substantial change in coming years.

4. PRIMARY RESEARCH FINDINGS

4.1 WASH Situation in Lo Manthang Town

Whereas water supply (*4.1.1*) is a straightforward topic, sanitation is a large field encompassing the "collection, transport, treatment and disposal or reuse of human excreta, domestic wastewater and solid waste, and associated hygiene" (DWSS & MoWSS, 2016b, p. 6). In this thesis, sanitation will be split into separate sections dealing with excreta and their fate (*4.1.2*), wastewater from the kitchen, bathing, and laundry (known as graywater; *4.1.3*), wastewater disposal (*4.1.4*), and hygiene practices (*4.1.5*).

4.1.1 Water Supply and Drinking Water Quality

Compared with most other parts of the country, Mustang District's water supply coverage is high. In 2010 it had 82% drinking water coverage, and the percentage rose to 83% in 2012 and 95% in 2014 (GoN, 2014). In 2016, Mustang was one of only five districts in Nepal that had achieved a coverage rate of 95-100% (MoWSS, 2016).

As for Lo Manthang, the current domestic and institutional water demand is met by snowmelt from the mountains southwest of town. The water intake is located about 6km uphill at 4,300m a.s.l. where nomads herd their sheep, goats and yaks in the summer (Figures 61 and 62). Water is diverted from a mountain stream and led by gravity down to Lo Manthang. According to WSSDO Chief Bijay Yadav in Jomsom, this supply scheme was built in 2007/08 with support from the DWSS (personal communication, May 27, 2017). A local nomad further specified that the current intake was built in 2012 after a flood had destroyed the previous pipe (personal communication, July 24, 2016). The intake consists of a cement channel surrounded by gabions, leading stream water to an open intake basin which contains two perforated pipes (Figures 63-65). There are no protection measures such as fences, screens or a superstructure to cover the intake. During strong rainfall, the stream carries a lot of soil into the intake basin and local nomads have to dig it out, as happened in the spring/summer of 2016 (Figure 63). The author also discovered garbage such as plastic bags and soda cans in the stream surrounding the intake.

Figure 61: On the way to Lo Manthang's public water supply intake (indicated by arrow; July 2016)
Figure 62: Water intake structure seen from above; intake basin indicated by arrow (April 2017)

Figure 63: Channel diverting stream water into the intake basin; mound of dug out soil to the right
Figure 64: Intake basin from above with two pipes leading to a nearby reservoir
Figure 65: Perforated pipes in intake basin

From the intake basin, water is led to a nearby reservoir, sized 1.9m*3.9m (Figure 66), and then through a conveyance pipe and smaller reservoirs (1.7m*1.8m) to 15 public taps in town. The pipe is mostly buried, but emerging in places and leaking (Figures 67-69). The same leaking spots were recognized in 2016 and 2017, indicating that maintenance had not been carried out. Furthermore, one of the smaller reservoirs halfway between the intake and Lo Manthang was cracked in April 2017 and lost a lot of water (Figure 70). Another hike to the intake at the end of May 2017 revealed that no repairs had taken place in the meantime.

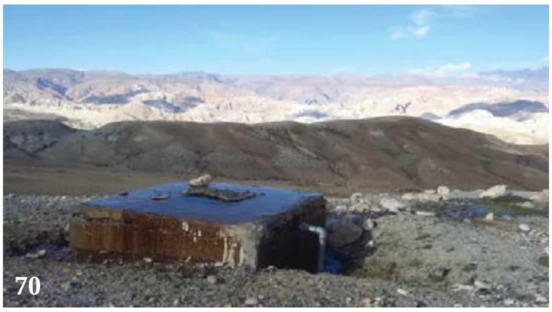


Figure 66: Reservoir near intake basin

Figure 67: Exposed water supply pipe

Figure 68 and Figure 69: Leakages in supply pipe

Figure 70: Cracked reservoir with substantial water loss above Lo Manthang

The lack of maintenance was not only observed by the author but also mentioned by several Lo Manthang residents and reported in an earlier study on Upper Mustang (Pokharel, 2009). While major repairs such as fixing cracks in reservoirs are the responsibility of the WSSDO in Jomsom, the local users' committee is in charge of minor repairs such as leaking pipes (B. Yadav, personal communication, May 27, 2017). Sujata Joshi from the Water Quality Section of the DWSS indicated that materials (pipes, fittings, etc.) are usually provided by the WSSDO whereas the local people contribute labor (personal communication, April 4, 2017). However, neither maintenance scheme seems to work smoothly and the current water supply is not reliable all year round. For instance, in the spring of 2017, the residual head at the tap stands was too low, possibly related to leakages in the conveyance system. The lack of pressure led to waiting times at the tap stands and made it impossible to fill rooftop tanks without a pump.

At present, permanent private connections from the public water supply are not allowed in Lo Manthang. Residents carry water in jerry cans from the public taps to their homes, and guesthouses attach hoses to fill up their storage tanks (Figure 71). There is currently no price on water and no regulation of or restriction on its use (guesthouse owner, personal communication, July 22, 2016). However, carrying water from the tap is strenuous and time-consuming so that households use it sparingly. Whereas water collection is mostly the women's chore (Sherpa, 2008; Verma & Khadka, 2016), at the Lo Kunphen School and in the *amchi* household young men were also seen carrying water on a daily basis.

Figure 71: Public tap in the center of Lo Manthang

During the winter, however, there is no running water at the common taps because the piped water supply freezes entirely. This was not only confirmed by all interview partners, but also mentioned by other reports on Upper Mustang (Sherpa, 2008; Verma & Khadka, 2016). Residents remaining in Lo Manthang have to carry water from the river, an arduous task which female respondents described as one of the greatest hardships. The owner of one of the three guesthouses that stay open in the winter said that only carrying water for her family would not be so difficult because they use little. She stated that foreign guests use more water, though, and providing enough for large tour groups requires many trips to the river each day. The water then has to be stored in a barrel inside the house as it would freeze outside. In 2017, water at the public taps only started running again at the beginning of April.

Besides the water supply at the 15 public taps, the author also noticed an above-ground black pipe with a single outlet carrying water from a bog about 20 minutes' walking distance southwest of town (Figure 72). This water is supposedly not used for drinking, but only for washing clothes and bathing as it warms up inside the pipe during the day. The intake of the pipe is in a small pool of water filled with algae and scum on the surface (Figure 73). No protection measures exist around the intake; animals were seen grazing in its vicinity, and there were visible hoof prints and dung all around the bog.

Figure 72: Bog southwest of Lo Manthang from where a pipe leads water to town

Figure 73: Intake pool of the pipe

According to most respondents there is currently enough drinking water, but several residents voiced concern that it might not be sufficient in the future due to increasing demand and less precipitation. Especially guesthouse owners seemed aware that water might become scarce at the tap stands. They mentioned the growing number of hotels and tourists who need more water for showers and laundry. While expanding tourism may create jobs and local income, it "may also contribute to the increasing stress on water resources, thus widening the gap between locals and visitors" (Fort, 2015, p. 811). Without any charges on the use of water, the resource is prone to overexploitation by the private sector (Lanza & Pigliaru, 1995). Besides, a respondent in his sixties as well as a nomad pointed out that snowfall had decreased, leading to less meltwater and poor vegetation growth – in line with reports that state limited water availability for human consumption (Banskota & Sharma, 1998), agriculture and rangelands (Bernet et al., 2012; Fort, 2015).

In order to cope with future water scarcity, guesthouse owners suggested that a new drinking water pipe should be built with government support, or that they might consider building a private pipe from another meltwater source in the mountains. Groundwater is not being tapped in Upper Mustang as interview partners and the literature confirmed, and to date the groundwater budget has not been assessed in detail (Bernet et al., 2012; Fort, 2015). Inferring from the topography and hydrological indicators, the groundwater table in Lo Manthang is dozens of meters below the surface, emerging at the rivers in the eroded valleys on each side of the plateau on which the town is located. According to Madhav Dhakal from ICIMOD who worked in conservation agriculture in Lower Mustang for three years, groundwater use is not feasible because it would be too difficult to extract (personal communication, April 13, 2017).

In terms of water supply monitoring and quality control, Lo Manthang has potential to improve. According to S. Joshi from the DWSS, the town is not among the four schemes in Mustang District which started implementing the WSP in the fiscal year 2016/17. In those schemes, the WSP team members are in charge of protecting the water source, fixing damages in the transmission line promptly and reporting damage beyond their capacity to the WSSDO in Jomsom (personal communication, April 4, 2017). K. Pandey from the main DWSS laboratory in Kathmandu further explained that the DWSS Water Quality Section and the WHO train water users' committee members and staff of the district office twice a year in water quality testing (personal communication, April 4, 2017). Pandey conceded that whether the distributed test kits were actually being used had not been evaluated, though.

It is also uncertain if and when the drinking water quality of the supply scheme Lo Manthang has last been assessed. The DWSS Water Quality Section has not done any testing in the Himalayan belt so far and S. Joshi assumes that no other section would have conducted tests, either (personal communication, April 4, 2017). The regional laboratory in charge of testing samples from Mustang is located in Pokhara. However, P. Subedi who has worked there as a chemist since 2012 said he had never analyzed any samples from Lo Manthang until 2017 (personal communication, April 25, 2017). No records could be obtained from the WSSDO, either, so that the tests done during this research project are the only available water quality data.

Test results from sampling at the public tap at the jeep stand in Lo Manthang (meltwater) as well as from the black pipe (bog water) indicate that the water quality is unobjectionable (see Appendix G for results of the complete analyses). Except for pH, all parameters were found to be within the thresholds of the National Drinking Water Quality Standards (GoN, 2005). The pH was slightly above the recommended range of 6.5-8.5 with pH 8.6 at the public tap and pH 8.7 in the water from the bog. This is not of great concern, though; the WHO has not even established a pH guideline value because the naturally occurring range in drinking water does not affect human health negatively (WHO, 2017a).

Neither of the sources showed any contamination with *E.coli* (Figure 74). This result was unexpected, not only because of the lack of source protection and non-existent chlorination, but also because in other districts microbiology is the parameter with the greatest deviation from the threshold (S. Joshi and K. Pandey, personal communication, April 4, 2017).

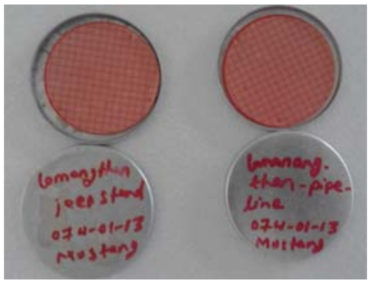


Figure 74: Petri dishes after incubation – no indication of *E.coli* CFUs which would appear as yellow spots

Even though the test results are reassuring, it must be noted that they only represent the samples that were taken at one particular time in the spring. During the summer months with more nomads herding their animals up in the mountains the water around the intake might be more prone to pollution. Furthermore, Pokharel (2009) points out that water-borne diseases are more common during the monsoon season. Based on the test results no statements can be made on the quality of the water in the drainage channels and streams in and around Lo Manthang, either. Since those are used for various purposes (see *4.1.3 Graywater Situation* below), contamination is highly probable and the risk of illnesses increases with lacking hygiene practices, as Sherpa (2008) and Verma and Khadka (2016) also noted. For instance, Ghana Shyam Gurung, director of the WWF Nepal, mentioned that his home village Dhee could no longer use stream water for drinking purposes as it used to because of pollution upstream. Instead, the villagers had to find a spring source for drinking water (personal communication, March 27, 2017).

In 2017 the author found out that the WSSDO was planning to build a new water supply scheme for Lo Manthang from a different intake in the mountains. According to Chief B. Yadav, the new system will consist of an intake at 4,420m a.s.l., reservoir tanks made of reinforced cement concrete, using a silica-cement admixture instead of the currently used sand-cement mixture, and high density polyethylene pipes (personal communication, May 27, 2017). The WSSDO intends to lay the pipes one meter underground to prevent freezing, and during construction of the new supply scheme the WSP will be implemented. Yadav mentioned two reasons for planning a new supply scheme: Firstly, an analysis in the regional laboratory in 2015 had apparently indicated excessive hardness in the current supply, which is why they decided to find a new intake where water quality would meet the national standards. This argument surprised as the regional laboratory could not recall any testing in Lo Manthang. Moreover samples from the current supply scheme showed $CaCO_3$ values well below the national threshold of 500mg/l (GoN, 2005), namely 152mg/l (see Appendix G). The second reason cited by Yadav seemed more convincing: Due to the predicted water shortage with the current scheme, a new source would be required to supply more. Whereas 45 liters/day per person had been calculated for the old (current) scheme, the new scheme is projected to supply 60 liters/day per person. Yadav also emphasized that each household in Lo Manthang would have a private connection, financed to 80% by the government and 20% by the local people. Users would be asked to pay a small amount to the users' committee for their connections, and the current public tap stands would no longer be needed.

While the project addresses some of the concerns expressed by residents, it seems ambitious, not least because of the timeline Yadav has in mind: He would like to complete the new scheme in 2017 so that households would have their private connections by 2018. In the spring of 2017, however, no construction or digging of trenches for the conveyance pipe had started yet, and the regional laboratory was just doing initial sampling of the new intake to check if the water quality in that location was even suitable (P. Subedi, personal communication, April 25, 2017). Interview partners also pointed out that having running water in their houses would be a challenge with the local architecture as buildings are currently made of unburned mud bricks. Waterproofing a room with cement and tiles would be an impossible financial burden for many ordinary residents. One respondent further criticized that the government was going to build yet another supply scheme instead of properly maintaining and repairing the old one.

4.1.2 Toilet Systems and Excreta Disposal

According to the DWSS (GoN, 2014), sanitation coverage in Mustang District increased substantially in the last decade: from 41% in 2009/10 it rose to 52% in 2012 and supposedly reached 100% in 2014, in keeping with the district-wise action plan outlined in the SHMP (GoN, 2010b). Mustang was then declared ODF (GoN, 2014) and ranked 11th among the ODF districts (MoWSS, 2016). However, "ODF" does not necessarily equal full coverage; the designation only means that at least 80% of households have a toilet (Neeru Thapa, ACAP, personal communication, July 29, 2016).

Sanitation coverage also varies considerably between villages in Upper Mustang. A survey by ACAP and the Upper Mustang Biodiversity Conservation Project in 2002 revealed that while 76% of households in Lo Manthang had toilet facilities, coverage in other VDCs in the area was much lower, with as few as 11% household toilets in Chhoser VDC (Tib. *mtsho shar*; Pokharel, 2009). Ten years later, Pant (2012) found that among 43 randomly selected households in villages across Upper Mustang, about one third (33%) had no toilet, while twice as many households (65%) had a traditional dry toilet and one household a pour-flush toilet (Pant, 2012). He pointed out that the large proportion of households without a toilet may be related to Upper Mustang's very low infrastructure development as well as significantly lower education and income levels compared to other administrative units of the ACA (Pant, 2012). Indicative is also that the district level Rural Water Supply and Sanitation Program in 2015/16 included five water supply projects in Upper Mustang but no interventions in sanitation.[8]

As for Lo Manthang in particular, the National Population and Housing Census by the CBS (2014) states that out of 172 households, 169 have an ordinary toilet (meaning a dry toilet), one a flush toilet, one no toilet, and two did not mention whether they had a toilet. Besides, guesthouses, hotels, schools and the monastery have built flush or pour-flush toilets. Both sanitation systems, the traditional dry toilet and the flush or pour-flush toilet, shall be described below, including the way excreta and blackwater are disposed of.

Dry toilets, used by almost all private households in Lo Manthang, are the traditional type of sanitation system. They are located on the second floor of the building and consist of a hole through which excreta drop into a storage chamber on the ground-floor below (Figures 75 - 78). Compared to a pit toilet, such above-ground collection of excreta reduces the risk of groundwater pollution (Schönning & Stenström, 2004). After use, an amendment or bulking material is added, either through the toilet chute or directly in the storage chamber. As per availability, various materials are used as amendments: first and foremost ash from dung fires, but also dry goat droppings, cow and yak dung, and saw dust from carpentry workshops. These amendments not only absorb the moisture and smell from urine, but they also reduce the density of the excreta mound, which helps aerobic decomposition (Depledge, 1997). Furthermore, they increase the carbon to nitrogen (C:N) ratio, therefore providing a C source for heterotrophic microorganisms that break down excreta. When ash is used it raises the pH, which improves pathogen die-off (Schönning & Stenström, 2004; Tilley, Ulrich, Lüthi, Reymond, & Zurbrügg, 2014; WaterAid, 2011). Based on observation, cleansing materials such as toilet paper are generally not thrown down the toilet but collected separately.

[8] File provided by the WSSDO in Jomsom in July 2016, relevant content translated by I. M. Amatya.

Figure 75: Traditional dry toilet on the second floor, just below the stairway to the roof

Figure 76: Traditional dry toilet with ash as an amendment and a box for non-degradable waste

Figure 77: Excreta storage on the ground-floor

Figure 78: Goat droppings used as an amendment for the dry toilet

In a household of four or five people, the storage chamber needs to be emptied about every two to three months, that is, about two to three times per summer season. In the winter when only one or two people per household stay in Lo Manthang the storage fills up less quickly. Since most toilets are single-vault, the excreta at the top of the pile are still fresh upon emptying and contain high levels of pathogens. Emptying is either done by household members or by people hired for that purpose, for instance if the household does not have time, does not own any fields or has given up farming. Excreta are then carried in baskets on people's backs to the corner of a field where they are left, uncovered, until the following spring. According to respondents, emptying the excreta storage is not only laborious but also unpleasant, especially if insufficient amendments have been added and the excreta are wet and smelly. G.S. Gurung (WWF) states that humanure has always been used in Mustang, but its current acceptability rises and falls with how smelly it is and whether it is properly mixed with other organic material (personal communication, March 27, 2017). Furthermore, handling of fresh feces also poses a serious health risk (Pickford & Shaw, 2005). After letting the excreta rest outside over the winter, they are incorporated into the soil together with animal manure (Figure 79) when plowing the field the following year (Figure 80). It is uncertain whether this practice allows for sufficient pathogen removal as recommended by the WHO guidelines for the safe use of excreta in agriculture (WHO, 2006; see section *5.2.2* below). Due to the arid and cold climate, the excreta do not break down as in a compost heap but rather desiccate. This deactivates but not necessarily eliminates pathogens; some may stay dormant and be reactivated upon addition of moisture (Schönning & Stenström, 2004; Tilley et al., 2014; WHO, 2006). While cold temperatures may delay hygienization – "[m]ost microorganisms survive well at low temperatures (<5°C)" – strong UV radiation on the other hand may speed up pathogen die-off (Schönning & Stenström, 2004, p. 13). Possible improvements for excreta sanitization will be outlined in section *5.2.2*.

Figure 79: Mound of manure to be incorporated into the soil on a field in Lo Manthang

Figure 80: Spring plowing in Lo Manthang

Overall, the traditional dry toilet has been perfectly suited to the local context. It does not waste or pollute the limited water resources; it works despite freezing temperatures and makes use of locally available amendments; it closes the nutrient loop by providing valuable fertilizer for agriculture that would otherwise be difficult to get in this remote location; and it is adapted to the traditional architecture. The latter point is important to remember: Houses in the old town of Lo Manthang are made of stones for the foundation, unburned mud bricks and rammed earth for the walls, floors and roof, and wooden beams for doors, window frames and ceilings (Bernet et al., 2012). The construction style and materials would have to change should water be introduced in the form of plumbing or sanitary technologies because the traditional masonry is not waterproof.

Despite this adapted technology, guesthouses, hotels, schools and monasteries in Lo Manthang have started replacing the traditional dry toilet with water toilets in the past decade. In local institutions, these water toilets generally have an interface to squat, whereas guesthouses and hotels build both squat toilets and toilet seats (Figures 81 and 82). The simpler versions are flushed by hand, by pouring a jug of water filled from a barrel or tap down the toilet ("pour-flush toilets"). The fancier versions have a toilet tank with a button to press ("flush toilets").

Figure 81: Pour-flush squat toilet in a guesthouse in Lo Manthang

Figure 82: Flush toilet with a toilet seat (pedestal) in the same guesthouse

Blackwater from these toilets flows through underground pipes into leaching cesspools which are mostly built within a few meters of the building. The leaching cesspools in Lo Manthang are a blend between a septic tank and a soak pit: cubic pits of about two meters' depth with an open bottom, cemented or stone-masoned walls and a cemented top (Figures 83-85).

Figure 83: Leaching cesspool under construction at a private school in Lo Manthang

Figure 84: Cementation of the top of a leaching cesspool along the road

Figure 85: Large leaching cesspool at a newly built hotel

The use of this technology is a recent development in Lo Manthang, copied from cities like Pokhara where trucks pump out septic tanks (which is what Mustangis call their cesspools). Such motorized desludging will not happen for a while in Lo Manthang, but the owners of these cesspools hope that the liquids will infiltrate into the soil, leaving only solids behind so that it will take many years before the cesspools will be full. However, the infiltration surface of the cesspools seems too small; they tend to clog and fill up within four to five years, depending on the size and usage.

Since the construction of such systems has only taken place over the last few years, few people have experience with the challenges of full cesspools. One guesthouse owner mentioned that their cesspool filled up within five years the first time, but the second time it only took two years. They then transferred the wet slurry (Figure 86) into a soak pit behind the house where it was covered a bit and gradually infiltrated. According to the respondent, emptying the cesspool could only be done at night because it was extremely smelly – probably because of anaerobic decomposition processes (WaterAid, 2008a) – and considered shameful. He struggled to find workers; only low-caste people from Jomsom or elsewhere in Nepal would do the job. In order to avoid such problems, other cesspool owners who have land available stated they would build a new cesspool once the first one is full. This was done by the monastery, for instance – instead of emptying and repairing the leakages of their cesspool (Figure 87), a second one was built a bit further downhill. Another guesthouse owner mentioned yet a different disposal method: Seemingly unaware of the involved health risks, he was planning to pump the slurry directly to the fields when the cesspool fills up.

Figure 86: Slurry inside a cesspool, seen through the top opening

Figure 87: Leakages from the monastery's full cesspool

Cesspools are not the only challenge with water toilets, though; further problems are encountered due to the flushing water and pipes. In the winter when there is no running water at the public taps it has to be carried from the river, and even then most flush toilets do not work because of frozen discharge pipes. The owner of one of the guesthouses that remain open during the winter recounted that even pouring hot water down the drain could not defrost the pipes in the winter, so that guests had to resort to open defecation in the fields for lack of an alternative. Besides, the wastewater pipes are sometimes installed too close to the surface where they get brittle because of repeated freezing and thawing and damaged by domestic animals trampling on them.

So why is it, then, that more and more water toilets and cesspools are being built? The majority of Lo Manthang residents who were interviewed said that (pour-)flush toilets were more convenient, more modern, more hygienic and more attractive than the traditional dry toilets, not least because the excreta just "disappear." Guesthouse and hotel owners as well as people from the general public thought that tourists needed water toilets and would not stay in a guesthouse with only traditional toilets. Without providing "Western" toilets, meaning one with a seat and toilet tank to flush, guesthouses would lose business as tourists would just go to a different place. Even guesthouse owners who know of and appreciate the benefits of the traditional toilets feel compelled to install water toilets to remain competitive. The perception that foreigners preferred flush toilets was also noted among lodge owners in other trekking areas during an assessment on EcoSan by WaterAid (2008a).

Some respondents, including the two privately run charity schools, mentioned that a lack of amendments for the dry toilets had made their use unfeasible. Unlike private households, these institutions neither have ash from cooking stoves nor animals whose dung they could use. Since dung is in short supply in Upper Mustang, buying it is difficult and expensive. As for agricultural byproducts such as straw and chaff, respondents said there was barely enough to feed domestic animals through the winter. Hey, dry leaves and tree bark are almost non-existent due to the limited vegetation. Some carpentry workshops generate saw dust from imported wood, which is said to produce an excellent fertilizer when added to dry toilets (carpenter, personal communication, July 24, 2016). However, most saw dust is currently used privately or delivered to a mill where it serves as a fuel to roast barley for the local staple food (Tib. *rtsam pa*). Soil as an amendment for dry toilets does not seem to be an option in Upper Mustang as damaging the sward and digging up the ground is against local beliefs anchored in Buddhism (DeGraff, 2013). This is also understandable from an ecological perspective, considering the slow soil-forming processes in such a harsh environment. Without amendments, however, the dry toilets turn wet and smelly, providing conditions for flies to breed and spread pathogens (Depledge, 1997). Besides, urine leaks into the mud walls and damages them.

Institutions and guesthouses also replace the traditional dry toilets due to the high number of users and large quantities of excreta they would produce. Since emptying the excreta storage is still done by hand, it is a strenuous job, and as mentioned above, not a respected one. Furthermore, unless the excreta can be used to fertilize one's own fields, putting up with such hard work has no direct benefit and seems unnecessary to many locals. As WaterAid (2008a) found, people's reluctance to empty the excreta storage themselves, difficulty in finding workers for the job and decreasing agriculture have made the traditional toilets seem cumbersome, irrespective of the influence of tourism.

All these reasons – most likely a combination of them – have led to the construction of water toilets and cesspools in Lo Manthang, even though there is no long-term strategy how do deal with the sewage. Unfortunately, no interventions in Upper Mustang have addressed sewage treatment so far. While ACAP has been promoting the construction of both dry and water toilets in the area, the organization's previous Unit Conservation Office Chief for Jomsom and Lo Manthang, N. Thapa, said that dealing with wastewater had so far been up to the owners (personal communication, July 27th, 2016). As elsewhere in Nepal, the focus has mostly been on toilet construction without incorporating the planning and management of onsite treatment (DWSS & MoWSS, 2016b).

Even though Mustang was declared ODF, there are still households without toilets in Lo Manthang: Among 15 interviewees, two said to have no toilet. While one of these families uses another household's facility, the other one lives on the edge of town and goes to the fields. A female respondent voiced embarrassment to defecate in the open because she might encounter other people. She would much prefer having a private toilet of any type rather than go outside.

Lacking toilet access is not just a problem for some Lo Manthang locals, but also for migrant workers. Many of them rent a room for a few months over the summer but do not necessarily have toilet facilities, so they defecate in the open. Evidence could be found on the fields and slopes around town. Several respondents indicated that the rules against open defecation were not enforced but handled leniently. Even though there are two public pour-flush toilets in Lo Manthang, one on each side of town with two cubicles each, they are not maintained: One of them has turned into a garbage dump (Figure 88) and the other one is overfilled with excreta as there is no flushing water (Figure 89).

Figure 88: Disused public toilet surrounded by garbage on the southern side of Lo Manthang

Figure 89: Visible lack of maintenance in the public toilets on the northern edge of town

The lack of maintenance of Lo Manthang's public toilets seems nothing new: Already in 2012, Pant noted that they were no longer used, and ACAP who built the toilets is also aware of the situation. According to N. Thapa (ACAP), the population is expected to manage the toilets (personal communication, July 29, 2016). In her opinion, however, the local people are unwilling to maintain public toilets voluntarily and pay little attention to sanitation. A similar judgment was passed by B. Yadav from the WSSDO Jomsom: His office apparently proposed public toilets to members of the water users' committee in Lo Manthang, but they showed no interest (personal communication, May 27, 2017). Nevertheless, Yadav also mentioned that in 2017 other WSSDO staff explored the possibility of public toilets near the jeep stand with Lo Manthang's Youth Club. This initiative was brought up by one of ACAP's local staff in Lo Manthang as well, though no further details on the project could be provided. ACAP's current Unit Conservation Office Chief for the area, Tulsi Prasad Dahal, confirmed that the local community had approached ACAP about public toilets, but ACAP had not allocated any budget for the project (personal communication, May 16, 2017). Interviews conducted by the author with townspeople indicated that many were undoubtedly in favor of public toilets, as will be further discussed in section *5.3.4*.

4.1.3 Graywater Situation

In terms of graywater, the situation in Lo Manthang – and Upper Mustang in general – is special because of very limited domestic water availability and use. The drinking water carried in jerry cans from the public taps is also used for washing hands and faces as well as vegetables and dirty dishes. The small quantities of graywater from these activities is then either scattered on the mud floor, mixed with organic kitchen waste and given to domestic animals, or poured out in the courtyard. Some houses have graywater pipes leading from the kitchen into partly open, partly covered ditches which run along alleyways through the old town (Figures 90 and 91). In some buildings the traditional dry toilets have a separate opening for urinating, and pipes from such "urinals" lead directly into the water channels, too. The channelized streams along the edges of town are also used for washing pots and pans, doing laundry, cleaning vehicles and agricultural products (Figure 92).

While households produce little graywater, guesthouses that have installed water tanks and bathrooms with running water generate substantially more. Graywater from guesthouse kitchens and showers is either infiltrated somewhere on their property or led through pipes to the common water channels. According to one guesthouse owner, they deliberately avoid disposing of graywater in the cesspool together with blackwater because they think that the soap in graywater would kill the beneficial microorganisms that "eat" feces (personal communication, July 21, 2016). The graywater from channels and streams ends up in the monastery's or the royal family's vegetable plots (Figure 93) and in irrigation channels feeding the agricultural fields southeast of Lo Manthang (Figures 94 and 95).

Figure 90: Channel that used to be Lo Manthang's drinking water source; a domestic graywater pipe leading directly into the channel

Figure 91: Partly open, partly covered drainage ditch running through town

Figure 92: Channelized stream with a woman washing rapeseeds and another one doing laundry

Figure 93: Vegetable plot fed by drainage water in the center of town

Figure 94: Graywater channel opening up near a public tap on the edge of town…

Figure 95: … and turning into irrigation water for the fields

As Pant (2012) observed, basic infrastructure for drainage and sewage as well as solid waste management is lacking. Only in 2006 did a project by the American Himalayan Foundation improve the drainage system in the old town and cover some of the ditches (John Sanday Associates, n.d.; Amchi Gyatso, personal communication, July 19, 2016). Based on observation and accounts by locals, the water quality in those ditches is deteriorating, though. While one of the water channels through town used to supply Lo Manthang's drinking water, it is now visibly polluted with plastic waste and algae growing on the channel walls (Figure 96). Most channels in and outside the city wall carry soapy water and garbage such as packaging and even batteries which end up on cultivated land (Figure 97). Furthermore, the increasing number of cesspools for blackwater in close proximity to water channels may cause fecal contamination (Figure 98).

Figure 96: Accumulated garbage and algae in a drainage ditch inside Lo Manthang town

Figure 97: Garbage carried to the fields by irrigation water

Figure 98: Water channel passing a hotel's cesspool (arrow) on the way to the fields

4.1.4 Wastewater Pipe Project

In the fall of 2016, increased awareness on wastewater led the Lo Manthang VDC to dedicate 2017's entire annual development funds, NRs 2,500,000 (US$ 2,500), towards building a wastewater pipe (S. Craig, personal communication, February 18, 2017). Such funds are provided by the central government to all VDCs which can then decide how they would like to use the money and submit an application to their respective DDC. In Lo Manthang, the 16 elected VDC members were particularly concerned about the large number of cesspools built all over town and graywater from guesthouses being disposed of in irrigation channels (Amchi Gyatso, personal communication, April 28, 2017).

Unfortunately, detailed information on the project was difficult to obtain as it was just starting to evolve during the author's fieldwork period in the spring of 2017, and the local government was in the midst of restructuring. The VDC's previous secretary, the only one who could get in touch with the DDC, had resigned at the beginning of the year without passing on information about the wastewater pipe plans to the new secretary. Moreover, after the elections in May 2017 the Lo Manthang VDC was going to be merged with two other VDCs and renamed *Gaunpalika*. Lo Manthang would be represented by five newly elected delegates in the *Gaunpalika* instead of the previous 16 VDC members (Amchi Gyatso, personal communication, April 28, 2017). These major shifts in local leadership seemed to delay the project and made it unclear who was in charge. According to B. Yadav from the WSSDO in Jomsom, the DWSS was not involved; the project fell under the DDC's responsibility (personal communication, May 27, 2017). The majority of respondents among Lo Manthang residents had never heard of the plan, and those who had knew little about it. Finally, Amchi Gyatso and Damar Bahadur Tamang, an engineer from Mustang's DDC, shared what they knew about the development (personal communication, April 28, May 23 and 27, 2017).

At that early stage, opinions regarding the type of wastewater the pipe would carry varied between local residents, Amchi Gyatso and engineer Tamang. All Lo Manthang residents who were interviewed assumed that it would be for both gray- and blackwater. One guesthouse owner emphasized that the pipe would only be useful if they could dispose of blackwater to empty their cesspools. Among the 15 respondents, ten thought the wastewater would then be discharged into the rivers on either side of Lo Manthang's plateau without prior treatment. Four suggested that it might be infiltrated through a large pit or cesspool, and one person said it might be led to the fields for irrigation. However, direct disposal into waterways or irrigation channels would not just be a serious health hazard but also against Nepali law (DWSS & MoWSS, 2016b).

According to Amchi Gyatso, the VDC intended to build two different pipes: one for graywater that would discharge into the river, and a separate one for blackwater that would lead to a communal cesspool in the valley near the river. The risks of such a cesspool polluting the groundwater if built too close to the river were unknown to most. In any case, the exact location had not been decided on, but depended on the DDC Engineer Tamang who would be in charge of the design. The idea was that the private cesspools built along the road in town would no longer need to be used if there was a centralized sewage system. Yet Nepal's regulations stipulate that domestic sewage must flow through a septic tank before reaching a sewer, so even a sewage collection system would not make the current cesspools redundant (DWSS & MoWSS, 2016b; K. Neupane and I. M. Amatya, personal communication, March 21 and 30, 2017, respectively).

The private cesspools or septic tanks will also still be required if the project is carried out according to engineer Tamang's mission: After the DDC approved of Lo Manthang VDC's application for a wastewater pipe, Tamang was sent for an onsite inspection in May 2017 based on which to design a pipe for graywater only. When asked how it could be ensured that no blackwater would be fed into the pipe, he pointed out that the *Gaunpalika* and a local committee would have to enforce it and also make rules according to the government's guidelines regarding pretreatment. Tamang was planning to design a high density polythene graywater pipe of 35cm diameter, running about one meter underground to avoid freezing in the winter. The pipe seems oversized, considering that only guesthouses have running water so far, and Tamang could not provide any household-wise graywater estimates for design purposes. In 2017 there was no plan for treatment facilities – Tamang explained that the project was just in the initial planning stage and with a budget too small to build a whole sewer let alone a treatment system. For the moment, only ten collection chambers and a sewer main along the edges of town (outside the city wall) could be afforded. As most interviewees expected, the wastewater seems likely to end up in the rivers north and south of Lo Manthang, though the engineer has not determined the distance between the pipe outlet and the river yet.

Dumping of sewage – possibly containing blackwater – near or even into the river will not just affect Lo Manthang, but also downstream communities. Lo Manthang is at the top of the Kali Gandaki catchment and pathogens may spread if blackwater is not properly managed. Although locals do have some awareness of the negative effects of indiscriminate excreta disposal and would like to avoid it (see *4.3.2 Awareness of Links Between WASH, Health and the Environment* below), they are not familiar with wastewater treatment options. Respondents as well as the engineer showed great interest when the author showed pictures and explained the purpose and functioning of natural treatment systems, though. If the initial pipe layout could be designed in a way allowing for subsequent construction of an infiltration or CW system, future environmental pollution and health hazards might be minimized. However, almost a third of the respondents pointed out that few people thought about potential negative consequences in advance or cared about the fate of others as long as their own situation was improved. Those respondents criticized that short-term thinking for one's own benefit had become common, even if it meant improving Lo Manthang's conditions at the expense of people living downstream. As Nawab et al. (2006) indicated, this could be explained by the "Tragedy of the Commons," a term coined by Hardin (1968, p. 1244) describing a situation where common resources are overexploited or misused by individuals for personal gains without considering their management for the long-term benefit of the whole community (p. 1244).

In the case of WASH in Lo Manthang, limited experience with and exposure to sustainable improvement options also poses the risk of a "quick fix" copied from elsewhere deteriorating the situation in the long run or transferring the problems to a new area. In their assessment of Mustangi villages living with water stress, Bernet et al. (2012) noted that

> (…) the fact that the villagers are practically not supported in finding and implementing solutions for their apparent and pressing problems, bears the risk that non-optimal solutions are found, mainly due to the lack of professional elaboration and assistance. For appropriate and sustainable solutions, access to trustable and complete information is crucial. Furthermore, the taken decisions often miss a time dimension, meaning to say the planning horizon is dangerously short. (p. 3)

Similar risks exist regarding the way Lo Manthang is and will be dealing with wastewater from the increasing number of water toilets and possibly household-level water connections in the future.

Local residents' attitudes towards the wastewater pipe – assuming that it would also carry blackwater – are generally positive, though. Guesthouse owners replied that it would make disposal of wastewater convenient, and local residents would appreciate the ease of pouring graywater into a pipe inside the home instead of having to carry it outside or wetting the floor with it. According to two interviewees, collecting wastewater centrally and leading it far away instead of all the cesspools inside town would be useful. Two more people thought the pipe was a good idea because it would make Lo Manthang cleaner, and if houses could be kept cleaner it would improve people's habits, hygiene and health. In view of the WSSDO's plan for private water connections, one respondent brought up that water supply and drainage had to be considered in combination – if there was going to be running water in each household, they also needed a good plan for drainage. However, another respondent also raised a valid concern: Currently, graywater from channels and streams is used for irrigating agricultural fields – if it was collected in pipes and diverted to the river, where else would they get irrigation water from? Engineer Tamang had not yet considered this challenge.

When asked whether a wastewater pipe would change anything regarding their own toilets and excreta disposal system, that is, whether they would consider installing a water toilet, all but one respondent declined. Some of them already use water toilets because they own guesthouses, so in those cases the question was not applicable. Those respondents who use traditional dry toilets mentioned their various benefits as well as some disadvantages of water toilets (compare *4.3.1 Used and Preferred Toilet Systems* below). The predominant reason ordinary households cited for retaining dry toilets was that they were satisfactory and their fertilizer needed for the fields. Furthermore, several respondents were aware that water toilets could not be used in the winter because of freezing, and were not feasible for most local residents because of the required plumbing for water supply, waterproof construction, and disposal infrastructure. Two guesthouse owners thought that those high expenses were actually the only reason why private households did not build flush toilets. Otherwise people would readily replace their traditional dry toilets with water toilets because they consider the latter more modern, they thought. Another guesthouse owner commented that for buildings not located along the main sewer line it would be difficult to connect, especially in the uphill direction, so for many nothing might change in the way they dispose of their wastewater anyway. Overall, there seems to be a range of practical constraints that prevent most locals from changing their sanitation system.

4.1.5 Hygiene Practices

Since the assessment of hygiene practices was not as thorough as on water supply and sanitation, this section can only provide a glimpse of the hygiene situation and related habits in Lo Manthang. Regarding daily practices, hand- and face-washing and tooth-brushing is generally done in the morning, either at home with water from a jerry can, at one of the public taps or near water channels and streams. Further hand-washing was observed to take place prior to preparing meals as well as before (and sometimes after) eating, especially when hands were used to knead roasted barley flour or to mix rice and lentils as is the custom in Nepal. No hand-washing after toilet visits was witnessed, though. In fact, when the author washed her hands in such situations, some bystanders thought she was going to cook or clean dishes – it did not seem to be a habit to "just" wash hands without actually needing to be clean for subsequent work.

Personal hygiene beyond face- and hand-washing seems to be limited. Some men wash their upper bodies at public taps and near streams; girls and women were seen washing their hair, but not their bodies. Few people seem to use the shower house run by the Youth Club, though no direct inquiries were made. From previous experience living in similar conditions on the Tibetan Plateau, the author knows that washing the whole body is rare in rural areas, especially among the older generation and women. This is likely to be the case in Upper Mustang, too, probably due to a combination of factors including the harsh climate (requiring a protective layer on the skin to prevent it from drying and cracking), lacking facilities and privacy, and concepts of modesty and shame preventing especially females from showing too much bare skin in public.

Hygiene habits are changing with time and exposure all the same. According to Lhundup Namgyal, ACAP's health worker in Lo Manthang, there did not use to be any soap or shampoo a few decades ago, and people washed their bodies and clothes only once a year (personal communication, July 25, 2016 and May 25, 2017). For his parents' generation, people currently in their 60s or 70s, even washing one's face was considered bad, and instead of washing their hands before eating, people would just wipe them on their clothes. When he was small, only few households had toilets, everyone else defecated in the open. People did not use to clean themselves at all when going to the toilet, neither with water nor with toilet paper – a fact that was also mentioned by one of the teachers at the Lo Kunphen School. However, Amchi Tenzin described how people's habits and perception have changed over time:

> In the past, until about the 1990s, it was common to go to the toilet anywhere outside, whenever there was no one around. People didn't have exposure to other places, didn't know how sanitation was handled elsewhere, and didn't feel very embarrassed to go to the toilet in the open. Then people started going to places like Pokhara and Kathmandu and became more aware of sanitation and private toilets. That's when hygiene started improving.
>
> (personal communication, April 29, 2017)

Likewise, Namgyal stated that the general understanding of health, hygiene and related practices had improved considerably since his childhood. For instance, he asserted that most people except those above 60 or 70 now knew about the importance of hand-washing before eating and after the toilet. This was also noted by Verma and Khadka (2016) during a focus group discussion with women in Lo Manthang VDC. As one of their study participants explained:

> We hardly used to wash our face. All our kitchen walls were black. We never used to wash dishes, but lick the dishes and reuse [them]. But, now, after an awareness raising program from the Annapurna Conservation Area Project, we know that hygiene is very important. Tourists do not like dirty areas. We maintain sanitation. (p. 61)

Awareness-raising events by ACAP and the American Himalayan Foundation have been conducted especially for women's groups who will then spread the knowledge to their families (T. P. Dahal., personal communication May 16, 2017). Besides, the WSSDO also has awareness programs for V-WASH-CC members in every VDC, covering various topics from safe drinking water to hygiene practices, advice on building household latrines, and community sanitation (B. Yadav, personal communication, May 27, 2017). More information on the local residents' awareness of links between WASH, health and the environment will be presented in section *4.3.2*.

Nevertheless, Upper Mustang is still considered to lag behind in terms of hygiene standards, which may also be a cause for water-related illnesses. N. Thapa from ACAP recognized that a lot of positive change had already taken place, such as the habit of cleaning dishes, but she thought that yet more awareness was required (personal communication, July 29, 2016). When asked for examples of areas that needed improvement, she stated that Lo Manthang town seemed unhygienic, with animals, water ditches and people all on the same road (Figure 99). Another example was given by Sherpa (2008) regarding water supply and hygiene: "Although there are community drinking water taps in villages, people still use river water flowing in open canals to cook, wash [their] face[s] and brush their teeth (p. 3)." While the author did not see local residents actually fill their drinking water vessels with stream water, one day she witnessed a middle-aged man coming to one of the open laundry places in town and using his hands to scoop a drink of water directly out of the channel, without seeming to bother about health risks.

Figure 99: Road in Lo Manthang with water channel and a herd of goats

Regarding WASH-related illnesses, different respondents provided diverging information. According to health worker Namgyal, diarrhea from dirty water and weather changes occurs twice a year, in the spring and autumn. From his experience, diarrhea cases are declining, though, because the people of Lo Manthang now use perfectly clean snowmelt water from the public taps whereas in the past they used to drink stream water. Furthermore, Namgyal thought that reducing open defecation and constructing water toilets with cesspools had helped overall sanitation and limited the spread of diseases, as had better hygiene and hand-washing practices. Nonetheless, he saw scope for improvement regarding cleanliness, personal hygiene, and the protection of the drinking water source.

On the contrary, ACAP's Unit Conservation Officer T. P. Dahal and Amchi Tenzin both stated that diarrhea cases were increasing, though for different reasons. Dahal said that water-related diseases in Upper Mustang had risen in recent years because of increased population movement, different habits, more tourists but limited sanitation facilities, workers from other parts of Nepal, and proliferation of pathogens due to global warming (personal communication, May 16, 2017). Amchi Tenzin on the other hand related the increase in diarrheal diseases to changed diets, especially eating too much sugar, fats, and old meat (personal communication, April 29, 2017). He was certain that diarrhea in Lo Manthang was not connected to the water they use: Like in the past, they drink snowmelt water which is apparently heavier, not the kind that causes diseases. Amchi Tenzin continued that in Pokhara, contamination might be a problem because wastewater was infiltrated and groundwater used for drinking, but in Lo Manthang no connection existed between toilets and drinking water. Unlike Namgyal, neither Dahal nor Amchi Tenzin brought up the influence of hygiene habits on the spread of illnesses. In Pant's (2012) study on sanitation in Upper Mustang, 42% of respondents answered that their community experienced frequent dysentery and diarrhea outbreaks. However, no further details about the causes of these illnesses were mentioned nor a comparison with baseline data presented to identify a decreasing or increasing trend over time.

4.2 WASH Situation at the Lo Kunphen School

4.2.1 Water Supply

Based on the WASH standards for schools in low-cost settings by the WHO (Adams et al., 2009), water supply at the Lo Kunphen School was assessed in terms of accessibility, quantity and quality. Regarding accessibility, the first and most consequential finding was that the school did not have any running water, which the headmasters and teachers identified as the greatest challenge and a hindrance to promoting health and hygiene. According to one of the teachers, the school used to have running water from a tap in front of the building. However, a few years ago the Lo Manthang Youth Club forbade private connections for schools, guesthouses and households because water for the community was not sufficient anymore. Even though the Lo Kunphen School has plumbing on the second floor for the kitchen (Figure 100) and an adjacent shower, it cannot be used because everyone now has to haul water from the public taps.

Figure 100: Out-of-use plumbing in kitchen; vegetables are now washed with water from jerrycans

The school uses mainly two public taps, one in the small alley directly behind their premises and another one about 150m away near the stream that enters the town from the southwest, depending on availability. Water for cooking and drinking is carried by the cook, amounting to about 125 liters daily (five large and five smaller jerrycans). The students take turns carrying flushing water for the recently built water toilet (see section *4.2.2* below). Before the water toilet was built, only two students had to help carry water, but since they require eight jerrycans of flushing water nowadays, five students are needed.

The water flow at the public taps is unreliable, though, and carrying water is hard work. Sometimes the closest supply point just behind the school dries up and water must be fetched from the more remote tap, as happened for instance in the spring of 2017. The school does not use water from the black pipe for consumption or flushing. Several teachers mentioned that the students were struggling with the heavy jerrycans (Figure 101). It apparently takes them between 30 minutes and an hour every morning to fill up a barrel with flushing water in the toilet. Especially the younger children splash water while carrying it – the jerrycans tend to be used without lids – so that their pants get wet, which makes them prone to getting sick in the cool climate.

Figure 101: Lo Kunphen students carrying water to the school

As for the daily water requirement per person, different values can be found in the literature. The Sphere Project (2011) prescribes 15 liters per person per day (l/p/d) for drinking, cooking and personal hygiene as the minimum in disaster situations, also stating that this amount can be increased if possible to comply with local standards. The Nepali standard is twice as high at 30 l/p/d (NCA, 2016). For schools such as Lo Kunphen, the most specific recommendations are given by the WHO (Adams et al., 2009): For boarding schools, the basic requirement is 20 l/p/d for all residential students and staff, to which another 3-6 l/p/d need to be added if pour-flush toilets are used. Calculating with these numbers, a school with almost 40 residents would require about 1000 liters ($1m^3$) of water daily. These standards are currently not met at the Lo Kunphen School where only water for consumption and toilets is available, but none for personal hygiene. In keeping with the WHO guidelines, though, there is definitely no water wastage at the school as water is not freely accessible except for drinking and flushing the toilet. Graywater is only produced in negligible quantities in the kitchen, for example from cleaning vegetables. A pipe from the kitchen drain leads graywater into the water channel behind the school which ends up in the monastery's vegetable plot.

As indicated, the lack of water at the school also affects personal hygiene, dish-washing and laundry routines. All washing activities are done at the public taps or streams, not on the school premises. Even though the WHO guidelines require hand-washing stations with soap inside the school, especially near the toilets and in the kitchen (Adams et al., 2009), at the Lo Kunphen School there is no water point for hand-washing or personal hygiene.[9] The guidelines also state that boarding schools should have one shower available for every 20 residents (students and staff), with separate facilities or user times for girls and boys (Adams et al., 2009). However, the Lo Kunphen School does not have a functioning shower or any other private place for bathing. The shower built on the second floor behind the kitchen a few years ago has fallen into disrepair and is now used as storage room since there is no running water (Figure 102). The students therefore have to wash their bodies at the stream (see section *4.2.3* below). Likewise, dish-washing and laundry are done at the public water points with the graywater flowing along the channels to the town's vegetable plots and agricultural fields (Figure 103). Contrary to the WHO guidelines which call for hot water and detergent to wash eating utensils and clothes (Adams et al., 2009), only cold water and soap are available for the Lo Kunphen residents. Concerning laundry, the students also face another challenge: Without running water at the school, they can only wash clothes on the weekend and not according to the weather. If there is no sunshine on the weekend, the clothes take longer to dry, so that some students have to wear ordinary clothes instead of their school uniforms at the beginning of the week.

Figure 102: Shower room on second floor, now used as storage space due to the lack of running water

Figure 103: Students washing dishes at the public tap behind the school

From observation and teachers' accounts, the water in the open channels and streams is often dirty. As long as it is only used for laundry this is of minor concern, but for dish-washing, hand-washing and bathing drinking water quality should be used (Adams et al., 2009). This requirement is not necessarily fulfilled, even with water from the public taps, though. While no contaminants of concern were found in the analyzed sample, the public supply could be polluted at other times, or dishes could be (re-) contaminated, for instance, between the tap stand and the school.

The headmasters', teachers' and students' opinions on the quality of the drinking water from the public supply diverged. Some believed it to be perfectly clean, but others were not so sure and potentially related the drinking water to health problems such as diarrhea and skin infections. When asked for possible sources of contamination, Amchi Tenzin mentioned animals grazing above the intake of the current water supply scheme and suggested that the intake should be built higher, at the actual snowmelt source, and protected well. One of the teachers thought graywater from people washing clothes upstream might enter the supply, which seems unlikely, though, as the supply pipe does not follow the stream. However, without regular monitoring – which has not happened so far – Lo Manthang's and therefore the school's drinking water quality cannot be assured.

Nevertheless, the water Lo Kunphen currently provides to the students for drinking meets the standards. According to the above-mentioned WHO guidelines, the water must not contain any fecal pathogens, should be of less than 5 NTU turbidity, free from chemical contaminants, and have acceptable smell, taste and appearance to the consumers. Furthermore, it should be protected from contamination during transport and storage and treated at the school if it comes from a surface water source (Adams et al., 2009). The school's drinking water fulfills most of these criteria: The analyzed parameters were within the thresholds, and the cook at Lo Kunphen boils the water before filling it into thermoses and putting it into the dining hall for consumption. The safety of water transport and storage could not be checked. The WHO guidelines also prescribe that drinking water must be available at all times and that a safe alternative supply should be used if the first one does not meet the needs (Adams et al., 2009). In the

[9] The students' hygiene practices will be explained in section *4.2.3*.

case of Lo Kunphen, the students can drink hot water whenever they feel thirsty, at mealtimes and during the breaks between classes, but they also said that they drank cold water directly from the public taps. The students involved in the focus group interviews reported having gotten sick from the cold tap water, and one girl said that even after boiling they sometimes got stomachaches from drinking it.

In summary, while the cooperation with Lo Kunphen started out as a sanitation project, the lack of running water at the school turned out to be of central importance: Inadequate water supply also compromises sanitation and hygiene, which affect the students' and staff's daily routines and well-being.

4.2.2 Toilet Systems and Excreta Disposal

The Lo Kunphen School currently has the infrastructure for two traditional dry toilets and two pour-flush toilets, but due to major operational problems only one of the pour-flush toilets can be used at present. The functioning of and difficulties with each system, including excreta disposal, shall be elaborated below.

The traditional dry toilets, one for boys and one for girls, are located on the inner-city side of the school, on the second floor behind the kitchen (Figure 104). The outer mud brick wall of the building makes up one side of the toilet, while the remaining sidewalls and doors are made of wooden frames with metal sheets. The floor around the toilet opening is cemented (Figure 105), and one of the cubicles is covered by a roof while the other one is open air. A drain in one corner of the toilet is meant for urinating, with a pipe leading the urine downstairs to the drainage channel that discharges into the monastery's vegetable plot. The toilet chute opens into a storage room on the ground-floor, which is adjacent to and accessible from the alley behind the school. The storage room has an open window in the mudbrick wall and a door opening without an actual door (Figures 106 and 107).

Figure 104: Courtyard inside city wall, arrow indicating entrance to the dry toilets

Figure 105: One of the dry toilets with main chute and urine drain in the corner

Figure 106: Alley behind the school with entrance to the excreta storage (indicated by arrow) and vertical urine pipe from second floor toilets to an underground drainage channel

Figure 107: Excreta storage from inside

In the past, users would add ash as an amendment, and during the summer the storage would fill up within two to three months.[10] When they emptied the storage, the uppermost excreta were still fresh, just covered by ash but not actually decomposed. The excreta would then be carried to the *amchi* family's fields as described above. Lo Kunphen students and teachers recounted how difficult and smelly that task was, with excreta soiling their heads and hands and sometimes dripping from the baskets on their backs. Amchi Tenzin mentioned that they used to hire local women to empty the toilets, paying them a salary and providing food. Even though field application of human manure has always been practiced in Upper Mustang, he confirmed that emptying the excreta storage was undeniably considered a dirty job. He continued that excreta had to be disposed of on their own fields, no one else's – contrary to another respondent who said that his family provided excreta to other farmers because they no longer cultivated fields themselves. In

[10] As mentioned in section *2.3.1*, no one remains at the school in the winter.

any case, before moving to Pokhara in the fall, the school would empty the storage chamber one last time and leave the excreta by the side of the field over the winter, without any mixing or covering with soil. In the spring they would then spread them as fertilizer over the vegetable fields.

For the Lo Kunphen School, these practices have changed, though. According to Amchi Gyatso's son Lhundup, the difficulties of emptying the excreta storage and the decreasing number of fields in Lo Manthang on which to apply fertilizer from the toilets has compelled them to consider alternatives. Amchi Gyatso and Amchi Tenzin further explained that the number of animals in Lo Manthang was decreasing, which resulted in a lack of dung and led people to uproot plants from the mountainside as a fuel. Because of these developments and in order to improve air quality and reduce respiratory diseases caused by smoke from dung fires, the headmasters thus decided to switch to cooking with gas at the school. However, this has meant that there is no more ash to add to the traditional toilets – a transition that has also been noted elsewhere in Nepal by WaterAid (2008a). The school does not have stoves for heating as it is only inhabited during the summer, and ash produced by other residents in the winter cannot be used, either, because only few people stay in Lo Manthang, generating little ash which they use themselves. Except for a bit of dust, the school could not find any alternative amendments, and the continuous use of the dry toilets has become impossible due to excess moisture, strong odors, and damage to the walls. Since the storage chamber is on the ground-floor facing north, direct solar radiation cannot be used to help dehydrate excreta, either. As of 2016, Lo Kunphen students were not supposed to use the dry toilets anymore. During stakeholder consultation it seemed like this decision and the reasons for it had not been clearly communicated or understood by some of the students, though. For instance, some mentioned the difficulties of emptying the excreta storage as the only reason why these toilets were not used anymore, without bringing up the lack of amendments that turned them too wet and smelly. Some other students said that they could and still did use the traditional toilets, seemingly unaware of the associated problems.

Instead of the dry toilets, the *amchis* decided to build two pour-flush toilets in 2015, using the leftover funds a sponsor had given them to rebuild a wall damaged by the earthquake. The toilets are located in the outer courtyard, one on the ground-floor between one of the classrooms and the staircase (Figure 108), and the other one on the second floor above. However, the toilet on the second floor cannot be used because of cracked cement and a leaking drainage pipe which caused urine to enter the mud brick wall. Therefore, the ground-floor pour-flush-toilet is currently the only functioning toilet, used by almost 40 boys, girls and staff. The insufficient number of toilets was the first thing the headmasters, all teachers and students mentioned when asked about problems with their sanitation system. It leads to waiting times, and the lack of separate lavatories is especially inconvenient for adult residents. The WHO guidelines stipulate that there need to be completely separate toilets with different entrances for male and female students as well as for staff; in total at least four gender-separated toilets for children and adults (Adams et al., 2009). Besides, the Nepali School Sector Reform Plan specifies that primary schools need a minimum of three toilets, at least one of them for girls, including water and cleaning facilities (MoWSS, 2016). At the moment, the Lo Kunphen School cannot fulfill either of these requirements.

Figure 108: Entrance to the Lo Kunphen School's only usable toilet, located in the outer courtyard below the staircase and next to a classroom

The pour-flush toilet on the ground-floor consists of a urinal ditch in the entrance area and a small lockable toilet cubicle behind (Figure 109). The floors, urinal ditch and walls up to about 60cm are made of cement; otherwise the walls of the building are made of mud. Inside the toilet cubicle there is a ceramic squat toilet pan with a water barrel and jug for flushing and a drain in the floor for cleaning water (Figure 110). This drain as well as the outlet of the urinal ditch (Figure 111) are connected to an underground pipe that leaves the school premises and empties into a narrow drainage channel running along the outside of the city wall (Figure 112). This channel passes a row of trees and houses and then discharges downhill into the open on the northwestern corner of town (Figure 113). The excreta mixed

with flushing water from the toilet pass through an underground pipe to a cesspool just outside the front entrance of the school, as shall be further elaborated below.

Figure 109: Pour-flush toilet with urinal ditch and toilet chamber behind

Figure 110: Toilet pan, water barrel and jug for flushing; water puddles due to malfunctioning drains

Figure 111: Cemented urinal ditch with clogged drain

Figure 112: Channel leading urine and graywater along the city wall to the northwestern corner of town

Figure 113: Outlet pipe of the channel; plant growth indicating nutrients

According to the WHO guidelines, toilets need to be suitably located, safe to use, and provide privacy and security (Adams et al., 2009). The location of Lo Kunphen's toilets seems well chosen, easily accessible from the classrooms and dormitories. Some of the girls stated that the younger ones did not dare go to the toilet on their own at night, even though there is light, but that might be the case with any location as the school is not that spacious. One teacher pointed out that bad odors entered the classrooms if the toilet door was left open, and if it was closed the smells inside the windowless toilet room got even worse. Unfortunately the school premises are of very limited size and the buildings are so close to each other that a more secluded toilet locality would be difficult to find. Inside the toilet, users can have privacy as there is a latch to lock the door. Based on teachers' accounts, students often go to the toilet in small groups at the same time, which does not seem to be a problem for children of the same sex, except that they apparently tend to forget to flush if they are together.

Regarding toilet practices, most users squat above the pan, but boys and men stand when using the urinal ditch. For anal cleansing, some use water while others use toilet paper which they purchase themselves for NRs 50-80 per roll (US$ 0.50-0.80). Amchi Gyatso estimated that the students use about half a jug (0.5-1.0 liter) of water for each passing of feces, the adults about one jug. Although the WHO states that cleansing material should be available continuously, this is not the case at Lo Kunphen: Teachers and students reported that the water from the barrel is often used up around noon and there is no more water until the next morning as they only fetch water once a day. This also affects toilet cleanliness because users cannot flush anymore as they are advised to. Moreover, one teacher explained that insufficient water in the toilets posed a challenge for the older girls and female teachers during their period: They mostly use reusable cloth pads but do not have a place to wash them in private. Washing them in public when everyone does laundry at the stream was described as embarrassing.

As stipulated by the WHO, there is a garbage bin for toilet paper and other waste inside the toilet cubicle (Adams et al., 2009), and students are told not to throw paper or other solid objects down the toilet. Both *amchis* are aware that not all students follow the rules, but see no possibility how to enforce them. Solid household waste is picked up every Saturday by a garbage collection tractor for all of Lo Manthang. The Lo Kunphen stakeholders are not sure where the garbage is then disposed of.

In terms of cleaning and maintenance, Lo Kunphen students take turns cleaning the toilets once a day, supervised by teachers. While the frequency is in accordance with the WHO minimum standards (Adams et al., 2009), the conditions and cleaning method fall short of the requirements. For instance, special cleaning products are used only once a week; on other days they clean with water only, without disinfecting exposed surfaces as recommended by the WHO. During the initial assessment, one respondent voiced concern that their toilet cleaner *Harpic* might harm the (beneficial) microbes in the cesspool. The students are specifically advised not to use soap with the cleansing and flushing water they pour down the toilet for the same reason. Another challenge stakeholders pointed out concerning cleanliness was the material the toilet is built of: The cemented floors and urinal ditch seem difficult to clean and keep the stench of urine even after cleaning. The headmasters considered tiles a better option thanks to their smooth, completely waterproof and easy-to-clean surface – but cement was the cheapest choice when they built the toilet. The most fundamental shortcoming, though, mentioned by all teachers, is the lack of water for cleaning. Without sufficient water, the toilet and urinal ditch cannot be thoroughly rinsed, which has made the toilet extremely smelly, especially the entrance area with the urinal ditch. Besides, the drains are sometimes blocked so that urine and water pool on the floor and in the ditch (see Figures 110 and 111 above). Teachers noticed that the children would accidentally step into these puddles and wet their pant rims. While the puddles jeopardize proper hygiene, further health risks are fortunately limited because tropical waterborne diseases like malaria do not exist in Upper Mustang.

A very real concern for the future, however, is what will happen with the infectious slurry from the cesspool once it is full. As many other cesspools in Lo Manthang, the Lo Kunphen School's was built adjacent to the road, with cemented side walls and an open bottom. Its size is approximately 3m by 3m and 3.65m depth, resulting in an infiltration surface of about $9m^2$ and a volume of about $33m^3$. The headmasters and teachers hoped that the flushing water would quickly infiltrate thanks to the sandy and stony underground, leaving only the feces behind that would be "eaten" by beneficial microorganisms. Since only little flushing water is used and only the bottom of the pit allows for infiltration, the solids in the blackwater are likely to clog the infiltration surface, though, so that the cesspool will gradually fill up as guesthouse owners have experienced. At the top of the cesspool there is apparently a square opening with a lid for inspection and emptying, but in 2016 and 2017 it was covered with a pile of sand from construction activities (Figure 114). The inside of the cesspool could therefore not be checked.

Figure 114: Sand mound covering the Lo Kunphen School's cesspool, just outside the building next to the road

At the time of research, the pour-flush toilet and cesspool had only been in operation for approximately one summer season; the school had started using them around July 2015. The stakeholders expected that it would take many years before their cesspool filled up, and they did not have any idea yet how and where to dispose of the slurry once it would need to be emptied. The (manual) desludging every few years poses a significant health risk which had not been considered when the cesspool was built. Further onsite treatment or disposal is impossible due to the location of the school within the old city, confined by other buildings and the road. There is no space to build another cesspool on the school's land, and the many cesspools along the road are already becoming of concern as they may affect the ground stability when heavy vehicles such as tractors and construction machinery pass (Figure 115).

Figure 115: Cesspools in front of houses may affect the road stability for trucks, tractors and construction machinery

The WHO guidelines state that if a school is not connected to a municipal sewer, soak pits or infiltration trenches should be used for wastewater, with installation of grease traps, requiring weekly monitoring and cleaning (Adams et al., 2009). While the Lo Kunphen School's blackwater system does neither have any grease traps nor monitoring routines in place, it does comply with the other specifications. As required, its location does not affect groundwater resources, being located far more than 1.5m above the groundwater table (compare section *4.4.1* below) and at least 30m from any groundwater source – groundwater not even being tapped in Lo Manthang. In accordance with the guidelines, the blackwater drainage is also completely underground so as to avoid direct exposure and vector breeding.

Overall, though, Amchi Gyatso concluded that the pour-flush toilet was a problematic issue (personal communication, July 25, 2016): The school is at a loss with how to manage the cesspool in the future, and since water resources are scarce, proper O&M of the toilet are already impeded. Besides, he recognized that hygiene is insufficient without water, as will be discussed in the next section.

4.2.3 Hygiene Practices

A lack of water makes it difficult for the Lo Kunphen School to promote hygiene systematically as prescribed by the WHO guidelines (Adams et al., 2009). Without hand-washing facilities inside the school the WHO considers a sanitation system incomplete because hand-washing after using the toilet should become a habit for students and staff. Several teachers mentioned the absence of running water for hand-washing as one of the main hygiene problems at the school. Even though there is a barrel of water inside the toilet cubicle, students explained that it was only used for flushing but not for hand-washing. The headmasters, teachers and students all confirmed that going to the public tap behind the school for hand-washing after using the toilet was rare, especially among the younger students. Nevertheless, students reported that they did wash their hands about two to four times a day: In the morning before class they clean their hands and faces at the stream, and before lunch they wash their hands again at one of the public taps. Further hand-washing may take place before dinner or when it is their turn to wash dishes. Each student has his or her own bar of soap, but it is unclear whether they actually bring it with them to the stream or public tap. According to the teachers, being good role models – deemed essential by the WHO – is difficult as there are no facilities inside the school to practice and demonstrate proper hygiene behavior. In addition, local habits seem to have also evolved around not having water for hand-washing available; even adults rarely seem to wash their hands if not for food handling.

Apart from hand-washing, personal hygiene is limited at the Lo Kunphen School, which interestingly only the girls and female teachers remarked. Every Wednesday all students must wash their hair, and every Saturday they are taken to a water channel or stream for bathing. While they are supposed to wash their entire bodies, the girls said they were embarrassed in public and just washed their hands, faces, and feet. One of the female teachers confirmed that the girls always kept their T-shirts and panties on, even though she advised them to clean their underwear frequently, especially when menstruating. Two 15-year old girls disclosed that they hardly ever got a chance to wash their bodies. Even in Pokhara where there is a room for bathing, only younger students apparently take weekly hot showers, whereas the older girls said they did not use it and sometimes went to a nearby river instead. The boys do not seem to face the same problems, saying that during the summer they wash about two to three times a month by the river in the valley north of Lo Manthang. When the weather and water are cold, they reported going to one of the guesthouses with solar water heaters where they would pay between NRs 50-60 (US$ 0.50-0.60) for taking a shower.

In order to prevent the spread of illnesses, the WHO recommends checking students regularly for lice and fleas and treating patients with vector-borne diseases rapidly at home (Adams et al., 2009). During the winter when all Lo Kunphen students are in Pokhara, they are inspected for lice whenever they shower – though the lice are said to often return within about two weeks. Since the school in Lo Manthang has no shower room, inspections are more difficult. Also, because the students are boarders with most of their families living in different villages, they are not immediately sent home when they are sick. One of the teachers explained that the children did not always notify the teachers when they were not feeling well. If they were really ill they would have to stay in bed or even in the *amchi* family's house for a few days. Fortunately, the headmasters and some of the teachers are experienced with common illnesses and can often treat the students themselves (Figure 116).

Figure 116: Amchi Gyatso's son Lhundup treating a student who had injured his shoulder

Hygiene also includes proper use, cleaning and maintenance of facilities, which is currently insufficient as described in the previous section. The teachers are aware that better toilet cleaning practices are needed to improve hygiene and remove smells, suggesting that more water and more frequent use of toilet cleaner would solve the problem. Despite the limitations of the current facilities, they are trying to keep them reasonably clean, and as recommended by the WHO (Adams et al., 2009), the students are actively involved in maintenance. Not only do they take turns carrying water and cleaning the toilet, but they also sweep the classrooms and school grounds. Since the floors are made of mud they tend to be dusty, but the school environment seems adequately tidy without garbage lying around. The headmasters are also intent on enhancing the general cleanliness and living conditions at the school through renovations. Some examples are the cementation of both courtyards, roof construction to prevent leakages, and repainting of walls in the spring of 2017.

Finally, an important component of hygiene in schools is the promotion of effective hygiene education (Adams et al., 2009). At the Lo Kunphen School, "Health" is a subject in the Nepali curriculum that is taught from the fourth grade upwards for about four periods per week. There does not seem to be special hygiene education for younger children, but the curriculum could not be discussed or checked in detail. Every Friday the teachers organize special activities for the students, taking turns between different subjects so that every few weeks the activity will be on a health-related topic. The author could not evaluate whether these activities and hygiene education from the textbook are effective methods – while hygiene practices seem insufficient, this might be related to a combination of scarce water and a lack of practical training in hygiene habits. The staff are not specifically trained in providing hygiene education as the WHO guidelines suggest, and when asked whether the children knew how to use the toilet and wash their hands correctly, one of the teachers replied that it might not be necessary to teach those things as the children naturally copied what the adults did. If this is the case, the teachers' function as role models becomes all the more significant. In some instances, though, such as inside the toilet cubicle, imitation will not be possible and proper use will need to be taught.

To summarize, the conditions at the Lo Kunphen School are greatly limiting to promote and practice positive hygiene behavior, but there is potential and great scope for improvement if facilities can be upgraded and hygiene education scaled up successfully.

4.2.4 Stakeholders' Preferences, Views and Ideas for Improvement

The preferences, improvement ideas and underlying views of Lo Kunphen's headmasters, teachers and students were essential to develop tailor-made solutions for the school's WASH challenges. Whereas opinions on water supply did not vary much among stakeholders, their notions of different toilet systems and stated reasons for their preferences diverged markedly.

Water supply

In terms of water supply, the headmasters, teachers and most students agreed that running water at the school would be vital to improve living standards and hygiene. Only the boys responded that even though it would be great to have running water, it would also be okay if the situation remained just as it was. Everyone else welcomed the idea that the students would no longer need to leave the school grounds all the time for hauling water and various washing activities. Besides, water at the school would greatly improve cleanliness and facilitate personal hygiene, food preparation, possibly dish-washing and laundry, and maintenance of the pour-flush toilet. The students are aware that hand-washing is necessary to remove dirt and bacteria from their skin and that they might get sick if they eat with dirty hands.

The stakeholders' specific ideas of the needed infrastructure, supply and use of water at the school are as follows: In 2016, both headmasters agreed that an underground water storage tank was required. It could be filled by hose from a public tap and the water could then be pumped to two or three large PVC storage drums on the roof. They knew from other Lo Manthang residents that this system worked well in the summer, and in the winter when freezing would be a problem the school would reside in Pokhara anyway. One teacher suggested that a filter could improve the drinking water quality, or that they could use an alternative spring source above Lo Manthang instead of water from the public tap which he thought was unsafe. In response to the question what made the water unsafe, he mentioned excessive minerals that caused digestive problems, but not potential microbial contamination. Regarding the number of facilities, teachers agreed that several taps would be necessary to make hand- and face-washing in the morning convenient, and they suggested a location close to the pour-flush toilet, in the outer courtyard. For graywater disposal they saw no alternative but to lead it to the existing water channels on both sides of the school. In view of water scarcity, Amchi Gyatso considered it fortunate that the water could be used for irrigation of the vegetable plots, despite being soapy from laundry and dish-washing.

Female teachers and students – both boys and girls – expressed their wish for a shower inside the school. The older girls said that they would not mind using either cold or hot water, as long as they could wash in privacy about once a month. Among the younger girls one said that she would wash with cold water while the other thought hot water was needed, but they agreed that bathing every day would be ideal. The boys and female teachers pointed out that there should be separate showers for boys and girls, and that they definitely needed hot water: Without it, the showers might not be used because bathing with cold water was very unpleasant in Lo Manthang's climate. One male teacher felt that bathing outside by the stream was alright because of limited space inside the school.

Limited space was also the reason why the same teacher proposed that dish-washing and laundry should continue to be done in the public water channels. Another teacher agreed, but argued differently: These activities would need a lot of water from the public tap, which would intensify water scarcity in the future. According to the students, washing dishes and clothes outside was no problem. However, four teachers would appreciate dish-washing and laundry on the school premises. It would make it easier to properly clean eating utensils, and they would have more flexibility for doing laundry – not only on the weekend, but on any sunny day so that the clothes would dry quickly. One of these teachers cautioned that they would need a proper drainage system for graywater, though; otherwise dish-washing and laundry should be continued outside.

Toilets and excreta disposal systems

When asked about their preferences concerning toilet systems during the initial assessment, five teachers said they favored pour-flush-toilets whereas for two teachers pour-flush or dry toilets would be equally okay. Only Amchi Tenzin clearly stated that he considered the traditional dry toilets one of the best options because they produced sanitized fertilizer and harmless graywater from hand-washing. On the one hand, three teachers agreed, independently from each other, that the obtained fertilizer was valuable and the dry toilets the perfect solution for individual household. One teacher added that dry toilets did not emit any bad odors except in the evening – indicating that this might be because of less ash added – and that those smells naturally disappeared again over night. On the other hand, the same number of teachers thought that dry toilets were not suitable for institutions with lots of people because of the large amounts of urine that would turn the excreta heap too moist and damage the foundation of buildings. They explained that the lack of dung and ash made it impossible to control the moisture level and that the school did not have any budget to buy amendments. Besides, the labor-intensive and cumbersome emptying of the excreta storage was one of the reasons why the school had decided to build a pour-flush toilet in 2015. The convenience of excreta disposal was also the first reason mentioned by those in favor of the pour-flush toilet. They thought it was an easy, clean and modern solution – as one of the teachers phrased it: "I prefer the water toilet because it is in keeping with modern times. The traditional toilet has no disadvantage and produces fertilizer for the fields, but in modern times the Western water toilet is better" (personal communication, July 19, 2016). However, one of the teachers who did not have a clear preference argued that the "Western toilet" was only suitable with enough water; otherwise and especially in the winter the traditional dry toilets were better. The other teacher who did not outright favor pour-flush toilets stated that if water for hand-washing could be provided and an alternative amendment found he would not mind continuing to use the traditional toilets.

When the author inquired about future problems that might arise with the cesspool and the slurry therein, the teachers' responses differed. Two of them thought it would not require any emptying because most of the water would infiltrate. Two others hoped that they would be able to hire a truck like in the cities to pump out the slurry once the cesspool was full, though they did not know where the truck would then dispose of it. According to two more teachers, the slurry could be brought to the town's garbage disposal site or directly to the fields; while they admitted that this would be smelly, the risk of pathogen transfer did not occur to them. Only one teacher mentioned that the pour-flush toilets were a health concern because they produced infectious blackwater, in contrast to the traditional toilets which produced useful fertilizer. She continued that emptying the cesspool would have serious implications due to the spread of fecal pathogens and the slurry needed to be brought to a faraway place where it could not harm people. The headmasters both acknowledged that the lack of a long-term solution was a major concern regarding the pour-flush system. Amchi Tenzin indicated his interest in biogas production but was uncertain whether it would be feasible in Lo Manthang's cold climate.

The students unanimously preferred the water toilet, citing the convenience of excreta simply being flushed away so that they would no longer need to empty the dry toilets' excreta storage. The older students were aware that the traditional toilets had the advantage of producing fertilizer which would be lost in the pour-flush toilet, but this fact could not make up for the aversion they felt towards having to carry excreta to the fields. They also knew that getting soiled with feces could cause illnesses. Some students explained that they preferred the pour-flush toilet because it was less smelly, which was surprising, considering the strong odors most other stakeholders had complained about.

The stakeholders' suggestions for toilet improvements could be grouped into three main categories: 1) the number of toilets, 2) cleaning and anal cleansing issues, and 3) construction materials, time and costs. All agreed that more toilets were necessary, at least separate ones for boys and girls, with the total number of cubicles ranging between two and seven. Three teachers and Amchi Tenzin also strongly supported the idea of a separate staff toilet. Two teachers requested that there should no longer be any cemented urinals but only toilets with ceramic pans because of the bad smells of the former, and hanging air fresheners could be used to dispel remaining odors. In terms of maintenance, all teachers agreed that the cleaning routine had to be improved. They suggested more frequent and thorough cleaning, using a brush, toilet cleaner, and especially more water. One teacher thought that all toilet-related problems could be solved if only there was more water. In alignment with this, another teacher felt that flushing after use should be consistently practiced and two more said a small tap with running water inside the toilet would be of great benefit, especially for the female users. While the older girls normally use toilet paper for anal cleansing and stated they did not need water inside the toilet, the younger ones said they used either water or toilet paper depending on the toilet type. The boys clearly preferred water for anal cleansing and would appreciate a tap inside the pour-flush toilet, but if dry toilets should be installed, it would be okay for them to wash in the shower room instead. While they mentioned that buying toilet paper was costly, Amchi Tenzin considered it a negligible expense: Each child would only need about two rolls per month (about NRs 100 or US$ 1 per child per month).

In terms of overall costs, Amchi Tenzin estimated that they could improve the water supply and sanitation infrastructure for about NRs 250,000-300,000 (US$ 2,500-3,000). At the beginning he had favored local materials over imported ones, not least because of the transportation time and cost (initial meeting with S. Joshi in Kathmandu, November 2015), but in 2017 he decided that in order to keep the toilet surroundings clean, cement and tiles were necessary – which would of course increase the cost. After purchasing the required materials from Pokhara over the winter, they would be able to start construction in April or May, a time where they could find labor locally because people were not too busy with agricultural work yet. He was hoping that local people would then also learn how to use, maintain and repair the system through which they might be inspired to replicate it in their own homes. This leads to the following section in which Lo Manthang residents' attitudes towards sanitation will be explored.

4.3 Local People's Attitudes Towards Sanitation

4.3.1 Used and Preferred Toilet Systems

The 15 interviewed people in Lo Manthang represent all types of toilet systems and preferences. Nine respondents use traditional dry toilets (at home or in someone else's home); three use pour-flush toilets (at the school where they work and live); two use flush toilets (one respondent at home, and one at the hotel which is also her home); and one defecates in the open because her family does not have a toilet. Two of the dry toilet owners also use flush toilets because they stay at their guesthouse or hotel during the day. The obtained distribution is not representative of Lo Manthang, though, where private households almost exclusively use dry toilets. In fact, the only respondent with a flush toilet at home said that apart from his family no-one had a flush toilet in their village (a neighboring village of Lo Manthang).

Overall, the respondents were satisfied with the respective toilet they use, except the one who does not have a toilet at all, one pour-flush toilet user where a lack of water is problematic, and one flush toilet user whose toilet freezes and becomes unusable in the winter. Nevertheless, all respondents also mentioned challenges they had encountered with their type of toilet, and advantages as well as disadvantages of both dry and wet sanitation systems based on their own experience or perception. These findings are summarized in Table 6 below.

Table 6: Advantages and disadvantages of different toilet systems as mentioned by Lo Manthang residents (number of respondents in brackets)

	Advantages	Disadvantages
Dry toilets	• produce valuable fertilizer (8) • suitable for local houses (3) • no smells (2) • containment of pathogens (1) • no need for water (1) • convenient (1) • can be repaired by themselves (1)	• hard work to empty excreta storage (5) • carrying excreta considered lowly labor, badly paid, workers looked down upon (1) • wet and unpleasant to carry excreta (1) • no fields → no use for fertilizer (1)
Water toi-lets[11]	• convenient, easy excreta disposal (9) • modern (6) • cleaner, more hygienic (4) • no need for amendments (4) • more attractive, no visible excreta (3) • less pollution (2) • no smells (1) • more comfortable (1)	• frozen in winter (7) • smelly when in use / when emptying cesspool (7) • water / environmental pollution (5) • loss of fertilizer (5) • pathogen transfer, illnesses (4) • water needs to be carried (4) • not suitable for local homes (leakages; water tanks and cesspools causing instability) (3) • using scarce water resources (3) • new cesspool will need to be built when old one is full (2) • difficult emptying of cesspool when full (2) • construction of cesspool and plumbing expensive (2) • blocked pipes (e.g. when solid object are thrown down the toilet), overflow (1) • elderly people do not want to use water toilets (1)

When asked for their personal preference, the number of respondents favoring traditional dry toilets (7) was the same as for water toilets (7), with one person specifying that flush toilets were better in the summer and dry toilets better in the winter. Another respondent who had initially said she preferred flush toilets – which she normally uses – later mentioned that she was planning to build a dry toilet again for the winter, recognizing that the water toilet did not work all year round.

Yet looking at the long list of disadvantages of water toilets, it surprises that half of the respondents still favor them. They must either attach more importance to the advantages of water toilets compared to their disadvantages, or consider the disadvantages of dry toilets to be even worse. A range of factors

[11] The category "water toilets" neither distinguishes between pour-flush and flush toilets, nor between toilets with a squat pan or pedestal.

may have shaped local people's perception or preference. As Pant (2012) describes in his study on changes in sanitation behavior among communities in the ACA, exposure to tourists, media, and information can influence local residents' views and aspirations for the future. If such exposure and direct interaction with outsiders is continuous, a process termed acculturation may take place where local people gradually adopt the others' behaviors, values and beliefs (Pant, 2012). Acculturation can have positive impacts on WASH, such as improved sanitation standards and greater awareness of pathogen transfer and hygiene practices, but it can also lead to questionable developments within the local community, as happened with the short-sighted construction of cesspools in Lo Manthang. Besides influence from tourists, local people's attitudes may also have changed due to their seasonal migration to cities in the lowlands where a different climate, cultural habits and attitudes towards WASH prevail. As Shackley (1996) points out, "[t]here is an extra psychological dimension in that people in a rapidly developing culture may be afraid of seeming backward. They equate traditional with unfashionable (…)" and try to cultivate an "impression of modernity," by adopting new technologies or materials, even if those are less suited to the local context as the local version (p. 453). Although there are many rational arguments in favor of dry toilets, people are also led by emotions and perception of what a "good" sanitation system is – often associating raised living standards with flush toilets (Langergraber & Muellegger, 2005). This might (partly) explain why many Mustangis prefer water toilets despite their numerous drawbacks.

Acculturation is not the only factor shaping people's choices, though: The local context, including sociocultural, occupational, and economic aspects as well as changing life conditions also play an important role. As can be seen from Table 6 above, the most frequently mentioned advantages and disadvantages are related to practical needs, operational issues, matters of convenience, and ideals of "progress." Environmental and hygiene concerns were mentioned by fewer respondents. Similar findings were reported by Nawab et al. (2006) who noted during a sanitation intervention in Pakistan that "people's primary criteria for choosing a sanitation model were prestige, privacy and comfort and had little motivation for health and environment" (p. 240). Yet the need for fertilizer and the incompatibility of water toilets with local architecture have so far prevented most households in Upper Mustang from changing their sanitation system. Moreover, financial constraints may have been a major factor why local residents retain their dry toilets despite opposing preferences, as indicated by some guesthouse owners and also mentioned by Pant (2012). WWF Nepal's director G. S. Gurung, though, predicted that traditional dry toilets would not be feasible in the long run due to changed habits and livelihoods (personal communication, March 27, 2017). He explained that people were increasingly using water for anal cleansing, and livestock had decreased to the extent that insufficient dung and a lack of ash impeded the continued use of dry toilets. He concluded that "indigenous systems have their own limitations; when so many other circumstances have changed, it is impossible to keep the traditional ways, even if they were sustainable." It remains to be seen in which direction local sanitation systems will develop.

4.3.2 Awareness of Links Between WASH, Health and the Environment

As mentioned above, hygiene awareness and habits in Lo Manthang are said to have improved over the last decades. The information gathered through interviews and casual conversations provides only a very limited picture of people's understanding and perceptions of WASH links, but it may indicate existing gaps which future awareness-raising should address. In addition to hygiene and health awareness discussed in previous sections, this part explores local residents' perceptions regarding the disposal of untreated wastewater (assuming it would be mixed gray- and blackwater) into the river.

When asked about their opinions related to such discharge, two thirds of the 15 respondents expressed concern about potential health impacts. Three of them specified that it was not Lo Manthang that would suffer, but downstream communities – for instance, people in the village below might get sick because they wash their bodies and dishes in the river. Two people relativized that they did not consider water pollution a problem unless people drank from the river, which was not the case in those villages. There seemed to be limited awareness of transmission pathways other than drinking water – and gastrointestinal diseases tend to be attributed to other causes such as weather changes and unhealthy eating habits. Nevertheless, when the author pointed out that pathogens could also spread through other routes, for instance when children played in contaminated environments, one respondent dismissed the objection by explaining that this was exactly why they needed to wash their hands. Local people are definitely aware that direct contact with feces can cause illnesses even without knowing microbiological details.

For example, one guesthouse owner conceded that pathogen transfer was a real problem when emptying cesspools and disposing of the slurry too close to the houses, and as stated above, the Lo Kunphen students emptying the school's excreta storage were equally aware of health risks. Besides negative impacts on humans, two respondents specifically mentioned the health of domestic and wild animals that should not be neglected, either; they should have the same rights and receive the same concern as people.

Slightly more than a third of respondents mentioned that disposal of untreated wastewater would cause water and environmental pollution. One of them demonstrated further insight, saying that Lo Manthang's future wastewater pipe should have its outlet far away from the groundwater, that is, not near the river but on the terrace. Such awareness seems to be rare, though, and two respondents urged that local people needed to be educated with real life examples about the implications of blackwater disposal. Another incident pointing in the same direction was when an otherwise very outspoken and respected community member chose not to answer the question about potential impacts of wastewater discharge, saying that he had little experience with its problems or benefits. He might have felt uncomfortable giving an answer when he was not sure what was "right" or "wrong." In fact, different conceptions seem to circulate among residents regarding the characteristics of wastewater. One respondent recounted that they had heard algae would purify blackwater and remove feces from it, but he was not sure if and how pathogens would be eliminated. Another one said she had heard vegetables grew better with soapy water. This might be the case if Nepali detergents still contain phosphates, but the author made no further investigations into the matter. Some guesthouse owners seem to be aware that pouring graywater directly into the public channels is not ideal, and their accounts of how they dispose of it more safely – such as through infiltration – may have been an attempt to whitewash their actual practices, as local observers noted. However, the author could not verify the accuracy of either statement. Finally, some locals do not distinguish between graywater and blackwater, and two respondents argued that water toilets reduced the risk of pathogen transfer compared to dry toilets. In general, knowledge on the proliferation and spread of pathogens through blackwater seems limited.

Another issue mentioned by six respondents was the bad smell that would emit from discharged wastewater. Based on answers obtained during interviews and further informal conversations, a number of people consider unpleasant odors the main nuisance of wastewater and excreta. Several mentioned that cleaning out the cesspools or excreta storage rooms was smelly – but did not also bring up the risk of disease transmission. Two respondents even pondered whether the whole town would start smelling like a sewer if more and more cesspools were being built without any plan for emptying them.

In the course of the research the author noticed that some respondents' attitudes changed as they reflected more on WASH. Some of them seemed to develop a more positive view towards traditional dry toilets, considering their benefits, and others appeared to think more about pathogen transfer from wastewater. For instance, one respondent complained in 2016 about the number of cesspools and suggested a common sewer. When the author inquired where the blackwater from the sewer would go, he mused that a large pit for the entire town would fill up too quickly, so maybe they should pour it down the Kali Gandaki. The conversation then continued shortly on the subject of water pollution and wastewater treatment. In 2017, when the same respondent was asked where the wastewater from Lo Manthang's planned pipe might end up, he was quick to reply that discharging it into the river would pollute the water. Talking about these issues seems to increase awareness – and may translate into action one day.

4.3.3 Openness to Sustainable Sanitation

In this section the local people's general interest in and openness to EcoSan toilets and DEWATS will be presented. During interviews, urine-diverting dry toilets and constructed wetlands were used as examples to find out about residents' motivation for or reasons against such technologies and potential challenges with social acceptance.

Urine-diverting dry toilets (UDDT)

After the functioning, benefits and requirements of UDDT had been explained, eight respondents replied they would use such a toilet at home, whereas six said they would not and one was undecided. The proponents consisted of an equal number of men and women, indicating that there was no gender gap in terms of acceptance, as an EcoSan assessment by WaterAid had also found (Rajbhandari, 2008). While five of the six objectors were male, two of them actually defended dry toilets most adamantly and were not against UDDT per se. They argued, however, that they had well-functioning traditional toilets and saw no need to change them. They further explained that private households still had enough ash to add as an amendment, and decomposed excreta were neither smelly nor wet – a fact also stated by Rajbhandari (2008) – and therefore no problem to transport to the fields.

Other respondents gave different reasons why they would not want to use a UDDT. The majority of those rejecting it said the toilet was a good idea but difficult or strange to use because of the split interface. They specified that urine and feces usually came out together, so a toilet pan with a single hole would be more convenient. This coincides with the WaterAid study which found that one of the main obstacles to EcoSan was that it required a change in people's behavior and perception (Rajbhandari, 2008). Nonetheless, two respondents more inclined towards UDDT toilets said it might be difficult at first to learn how to use it, especially for children, but with good training they would gradually get used to it. This initial discomfort and subsequent habituation has also been observed by WaterAid (2008a). Another aspect requiring adjustment is the use of liquid urine as a fertilizer, which one respondent said was strange as they had so far only used it mixed with feces and ash. Two guesthouse owners, one of which said he might use a UDDT at home, commented that the technology would not be suitable for their businesses: For one, the large amounts of urine produced by tourists would mean a lot of work to empty the urine storage tank, and in addition, the UDDT was a new and unusual concept that did not meet the guests' need for water toilets. Difficulties in transporting urine should not be neglected if UD systems are to be implemented in Lo Manthang – it was also the reason mentioned by Rajbhandari (2008) why "[t]he rate of direct application of urine in the field is comparatively low and is not impressive compared to the efforts made, despite disseminating the importance of urine and its nutrient value among the EcoSan users" (p. 74). Finally, one respondent said even though UDDT was a good concept, he already had a water toilet and preferred it. The same answer was given by the interviewee who was unsure whether she would change – mainly because she was used to anal cleansing with water. While this is not impossible in a UDDT, it would require a special drain for cleansing water and risks incorrect use if water is available in the toilet cubicle.

On the other hand, the respondents willing to use UDDT at home offered a range of reasons related to the advantages of the technology. The main attraction, stated by seven respondents, was the availability of good fertilizer which would benefit Lo Manthang's agriculture. As indicated in section *2.1.1*, fertilizer is also by far the dominant motivation for current UDDT users in Nepal of which over 80% are farmers (Rajbhandari, 2008; WaterAid, 2008a). Instead of regarding urine and feces as waste, those users' attitude has started to shift and they cherish excreta for their economic value and income-generating opportunities through agricultural production. The downside of this is that without fields, the perceived value of UD toilets evades the owner – though some people have installed such toilets all the same and let their farming neighbors use the excreta on their fields (Rajbhandari, 2008). Contrary to the WaterAid study where men were more interested in fertilizer and women in hygiene aspects of the toilet, in Lo Manthang more *women* mentioned the benefit of fertilizer even though 60% of the study participants were male. This could indicate that the interviewed women are more engaged in agriculture, or at least more involved in the task of fertilizing the fields.

The second reason in favor of UDDTs stated by almost a third of respondents was that it does not need water. One person specified that the precious resource would thus not be wasted, but the others did not elaborate on their answer. It can be assumed that water saving is considered an advantage because water is not easily available but needs to be carried from the public taps, as WaterAid (2008a) found among current UDDT users. Besides, one respondent pointed out that people in Lo Manthang are used to waterless toilets and would happily use them if they knew the benefits.

Further reasons cited had to do with hygienization and appearance of the excreta collected in UDDTs. Three respondents said they would consider using the technology at home because it controls germs and helps pathogen die-off, and one stated it was better than a water toilet with a cesspool, probably because of unresolved issues with the latter. Another two respondents said they would appreciate the absence of odors in UDDTs. While it is true that properly operated UD toilets do not smell (Winblad & Simpson-Hébert, 2004), WaterAid's (2008a) assessment revealed that about 11% of UD toilet owners still complain about odors when using the toilet. It turns out that smells are mostly related to poor maintenance and malfunctioning or absent ventilation pipes, though, and only 1% have experienced bad odors when emptying the feces storage. One respondent stated that UDDTs were of interest to him because of the dry feces that would be convenient to reuse. This has also been reported by the great majority of current Nepali UDDT users – only three out of 218 households complained about excessive moisture when emptying the feces storage (WaterAid, 2008a). However, WaterAid emphasizes that two conditions are compulsory for well-decomposed odorless feces: They must be kept absolutely dry – no accidental addition of urine and cleaning water – and an appropriate amount of amendments should still be used (see section *5.1.2* below).

Only one respondent brought up that UDDTs would cause less environmental pollution than (pour-) flush toilets – the same person who had also mentioned that they could save water resources. This is a low turnout among 15 respondents, but not surprising: WaterAid's studies have also found that environmental protection is perceived as less of a benefit than the obtained fertilizer which can directly improve people's livelihoods (Rajbhandari, 2008; WaterAid, 2008a).

Despite most interviewees' general interest, even those in favor of UDDTs were hesitant to fully embrace the technology without actually having experienced it. As it is an unfamiliar concept which requires commitment and corresponding practice on a daily basis (Rajbhandari, 2008), it will take time for people to get used to, as one respondent pointed out. Five others said it was a good idea but awareness-raising and educational campaigns were needed. Only if people could learn about UDDTs' benefits and functioning would they accept a change of habits and possibly use them. This is in line with findings by Rajbhandari (2008) and Bing (2014): Education and awareness on behavioral changes, not just the technical infrastructure, are prerequisites for communities to understand and agree to EcoSan, especially in rural areas. Four respondents suggested that it should be demonstrated with a model toilet, for example at a guesthouse, or through an exposure tour to a place where UD toilets are already in use. These methods have also been successfully used elsewhere in Nepal: states that in order to create broader acceptance, small-scale pilot projects are useful to show the wider community that the technology works. Local people are most likely to be convinced if they get a chance to visit a well-functioning EcoSan toilet in a neighbor's home (WaterAid, 2011). Current users' high satisfaction with UD toilets has spread a positive image of the toilet to 98% of their neighbors, and 65% of neighbors who did not have a latrine yet stated they would build an EcoSan toilet (Rajbhandari, 2008). Nevertheless, the willingness to actually invest in such toilets has been very low (WaterAid, 2008a). This might also be a challenge in Lo Manthang as one respondent indicated: "People here don't have much education and wouldn't use such a toilet without being able to see its usefulness and accept it. Unless there is a sponsored model toilet they wouldn't want one." Since EcoSan toilets' initial cost tends to be higher than for other sanitation systems, Rajbhandari (2008) describes and at the same time warns that local people

> normally expect and demand subsidy to adopt the technology. (…) [They] are interested to install the EcoSan toilets, but without investing their own money. (…) The use of subsidy policy in promoting any sanitation technology must be cautious. It will definitely help to achieve some short-term gains, but appears to militate against long-term affordable solutions. (p. 74)

Besides finances, the importance of outside looks of the toilet is an important factor to keep in mind. Two of the respondents who said they would not use a UD toilet at home showed great interest in a solar composting toilet developed in Norway of which the author had brought pictures (Figures 117 and 118). “It would be a good idea to have a model toilet like the Norwegian solar toilet to demonstrate that a toilet can look modern while using traditional dry methods. Tourists would also use it,” one of them explained. As it turns out, a toilet's appearance makes a big difference and influences people’s perception, possibly more than the type of sanitation system below. Even guesthouse owners who were unwavering advocates of water toilets suddenly became interested – probably because they had not seen "modern"-looking compost toilets before. On the contrary, pictures shown for UD toilets were from rural Nepal, constructed in local style without fancy finishing. A picture of a UD toilet built at a school in Humla District (Figure 119) reminded one of the respondents of a smelly roadside toilet block he had once seen; a cemented raised pit latrine with an open excreta storage area below, without water or UD. Since the UD toilet looked similar to that roadside toilet, he said he knew how smelly this type of toilet was. Even though the author explained that the storage system was different, the whole EcoSan idea was spoiled for him from the beginning because he henceforth associated UD with the smelly roadside toilet he remembered. On the other hand, the Norwegian solar toilet seemed attractive to the same respondent because of its exterior – even though it uses no water at all which he had said was absolutely necessary. Attractive looks were also one of the reasons why Lo Manthang residents showed interest in constructed wetland for wastewater treatment.

Figure 117: Compost toilet developed in Norway with solar ventilation and dehydration mechanism

Figure 118: Interior of the solar compost toilet

Figure 119: Urine-diverting dry toilet block at a school in Humla District cement and stone masonry, with urine storage drum and ventilation pipes from feces collection vaults (ENPHO, n.d.-d)

Constructed wetlands (CWs)[12]

When the author had explained the principle of CWs through diagrams and photos of existing systems in Nepal, two thirds of respondents agreed that Lo Manthang should invest in such a treatment system. Four of those respondents said it was absolutely necessary – especially if more and more guesthouses were being built, the townspeople needed to discuss options and spend funding on a good drainage and wastewater treatment system. The other six advocates had some doubts about the feasibility of a CW in Lo Manthang but still found it a good idea for several reasons. The main draw seemed to be the reduction of pollution, smells and harm, with one person specifically stressing that a treatment system had to be installed *before* creating pollution and spreading diseases. Besides, they admired the nice looks of the CW and its capacity to clean and recycle water at the same time. It must be said that the photos shown during the interviews were from CWs in the Kathmandu Valley with lush vegetation growing on top (Figure 120), and though the author pointed out that the plant species suitable for Lo Manthang might look quite different, the colorful flowers may have influenced respondents by giving an unrealistic impression.

Figure 120: The first community-based constructed wetland in Nepal at Sunga, Thimi (ENPHO, n.d.-b)

The main concern that even several of those in favor of investing in a CW brought up was that the local people did not have the necessary education and experience. At the moment, they said, no one knew about the possibility of a CW and its benefits and therefore they would not choose to build one. As one respondent put it:

> Most people don't pay much attention to it [a CW] because they don't know about it. If you have never tasted a type of food you don't know if it's sweet or sour – it's the same with such new ideas. If people knew of the benefits they might be interested and invest in it.
>
> (personal communication, May 25, 2017)

In terms of how local attitudes relate to knowledge and responsibility, the respondents voiced various opinions. One said that educated people would consider wastewater treatment an important issue where-

[12] More information on CWs will be provided in *5.3.5 Local Wastewater Treatment.*

as uneducated people would probably not. Two others reasoned that especially the town's representatives, the local government, needed to get to know DEWATSs and recognize their importance before becoming willing to invest in one, which might take a while. Yet another respondent argued, though, that it was not enough if only a few educated people understood and showed interest in such systems. He insisted that *all* people had to be aware of the options and realize that they as local residents ought to cooperate and invest in development projects to feel ownership and maintain them well in the future. Eventually, money would have to be collected from the community and a public land plot found to build a CW, which required everyone's cooperation.

The remaining third of respondents expressed reservations or said directly that Lo Manthang would not invest in such a system. The reasons they stated covered a range of issues. One respondent claimed that if government funds were used, everyone should benefit and not just some people – explaining that only few residents owned guesthouses with running water and flush toilets. For most people a wastewater treatment system would be irrelevant and it would be unfair to spend common money on something they did not even need. This was also reflected by another respondent's reply that wastewater treatment might not be a priority for most. If a treatment system is not considered important, gaining the necessary support in the community might be challenging, as another interviewee pointed out: A CW would have to be provided for free, otherwise it would be difficult to persuade people to construct one. What Rajbhandari (2008) mentioned in the context of UDDTs above also seems to apply to wastewater treatment: "People need to be convinced (…) about the future benefits that can be reaped from this technology from an agriculture and an environmental perspective" (p. 72), otherwise they might not adopt it, let alone invest in it. But whether a majority of townspeople perceive sufficient future benefits from wastewater treatment is uncertain. According to one of the respondents who did not give the CW a realistic chance, Lo Manthang had no water problem and people would not want to invest in a treatment system unless downstream communities complained. Besides, locals would not believe that a CW could actually decontaminate water, a view that is attributable to a lack of awareness which has also inhibited the more widespread use of CWs (ENPHO & WaterAid, 2008). The second disinclined respondent indicated disillusion about the government, saying that it would not deem wastewater treatment necessary, despite environmental benefits. While possible health improvements related to sustainable sanitation are more present in people's minds, ecological aspects seem to receive limited attention. Again, as Rajbhandari (2008) has described in the context of EcoSan:

> The main reason for this is due to a lack of proper rules and regulations for the prevention of pollution in natural water bodies. People are discharging the highly polluted blackwater directly into the natural water body. In this situation, it is very obvious that the value of environmental protection that can be derived from this […] technology will be insignificant. (p. 71)

Despite the comparably low cost of a CW, ENPHO and WaterAid (2008) consider it "difficult to convince people to invest in a treatment plant instead of just discharging effluent into the river" (p. 7). These quotes from EcoSan experts underline a statement by a Lo Manthang resident who pointed out that "everywhere else" wastewater was directly poured into rivers – why would they do it differently? Even though Banskota and Sharma (1998) noticed a strong interest among the population of Upper Mustang in protecting their natural environment, including watersheds, pastures and wildlife, other issues are likely to have greater priority in their daily lives. In the words of G. S. Gurung (WWF):

> Awareness is there, but people want to move fast, modernize – and then awareness doesn't count. Only when the effect, the suffering is tremendous, when it has reached the boiling point, will people consider not polluting water or any other part of the environment. That's what human tendency is.
> (personal communication, March 27, 2017)

4.3.4 Priorities Overriding Sustainable Water and Sanitation Concerns

In order to understand local people's motivation and attitudes towards sustainable technologies, knowing more about their living conditions and perceptions is essential. In communities with other urgent needs and low WASH awareness, new technologies may face difficulties with acceptance, and people may consider any investment a waste of money (Nawab et al., 2006; Rajbhandari, 2008). How do Lo Manthang residents see that? Is water and sanitation a priority for them? Or do other issues outweigh the importance of WASH?

60% of respondents *did* mentioned WASH-related problems as their main concerns. Three of them stated that clean water and sanitation *were* the most important issues, though offering different perspectives: For one respondent, not having a toilet was the most serious challenge, while the others said emptying their cesspools, especially finding labor for it, was the most difficult. One of them indicated that having a sewage pipe would be useful, but it would be crucial to treat the water well before discharging it. A third of all respondents considered water supply the greatest trouble, more important than household sanitation or wastewater treatment. The most frequently mentioned problem was the lack of running water at the public taps in the winter. One respondent explained that they would not need much: Since winters were too cold for bathing and washing clothes, they only needed water for drinking, cooking and to give to the animals. They would greatly appreciate even just a single tap in town, supplied by an underground pipe that would not freeze. The interest in a non-frozen water tap was also found by Verma and Khadka (2016) during research among pastoralist women in Upper Mustang; the latter reported that running water in their village might halve their workload because they would no longer have to carry water from streams and rivers. According to one respondent, running water would not increase the number of people overwintering in Lo Manthang, though. He described the locals as business-minded – as long as there was money to earn, such as through tourism, they would stay in Upper Mustang, but otherwise they would go elsewhere to do business. Water availability would not change that. Nevertheless, to improve water supply during the agricultural season and make life easier for future generations, two respondents suggested they should consider building a dam: Water could be collected in the winter in the form of ice and then gradually used for cultivation upon melting in the spring. Furthermore, they could regulate water flow for irrigation during the monsoon. Other concerns were the preservation of a clean drinking water source, the low residual pressure at the tap stand because of damage in the conveyance system, and the difficulty to maintain hygienic conditions at home without sufficient water. Finally, one respondent specifically identified the lack of personal hygiene and cleanliness as the most pressing issue in Lo Manthang.

The poor condition of health care, low living standards and difficult livelihoods are other major concerns mentioned by seven respondents. One respondent stated that health was the most important, and while it depended on WASH to some degree, there were other factors, too. Even though Lo Manthang now has the ACAP health post – the government health post was not even mentioned – not having a hospital is considered a serious shortcoming. Besides, the ability to heat their dwellings in the winter also affects people's health and is challenged by the shortage of firewood and dung. Another respondent described the large gap between the rich and poor and how financial difficulties affected the latter in so many ways: They have no money for treatment in case of illness, to build a house, or to send their children to good schools. While several respondents reported that making a living was challenging for most people in Upper Mustang, without fields or job opportunities it becomes an overwhelming challenge. Even nomads and farmers struggle at times. For example, if there are prolonged periods of snowfall in the winter, nomads lose their livelihood because they do not have fodder storage and their animals die of starvation. Another respondent said that for Lo Manthang to survive in the long run, farmers needed training and support to diversify, such as by cultivating more vegetables in greenhouses.

As mentioned before, lacking education and the shortage of educational opportunities in Upper Mustang is another significant issue which four respondents brought up again. One respondent argued that better education could solve all problems because it would increase awareness. Another one expressed that education was essential to know good from bad and that there were still too many illiterate people in Nepal. The same respondent continued that a definite shortcoming was the lack of schools beyond grade 8 in Lo Manthang. After that, children had to go at least to Jomsom for further education. A widowed mother of a young boy was also concerned about the quality of education and lack of commitment in government institutions: At the time of the interview in late April she said that the government school and day-care center had not opened yet, even though most people were back in Lo Manthang.

Another respondent linked poor education to a lack of solidarity she perceived in town, criticizing that people only thought of themselves and not so much about the benefit or harm their actions did to others. The issue of selfishness was also mentioned by another interviewee who illustrated it by recalling that toilets did not use to cause any problems. Not only did they not produce any blackwater, but people also used to help each other carry excreta to the fields. On the contrary, it has become difficult to find workers and neighborly help in recent years – not just for emptying cesspools, but also for other tasks such as removing snow from the roofs of Lo Manthang homes whose owners spend the winter in cities.

Lastly, a number of respondents mentioned bad infrastructure and politics as important challenges. Three of them complained about deplorable road conditions that make life difficult, as one of them described:

> Until a few years ago there didn't use to be a motorable road, and the current road is still too narrow and dangerous. Many accidents happen and people die. Upgrading the road and asphalting it is important. That would be a big improvement. We would have a much easier time transporting things; now trucks can't come in the summer because the water level in the river is too high and the mud road gets wet and slippery.
>
> (personal communication, April 29, 2017)

A guesthouse owner added that if the road was better, more food and drinks could be brought to Lo Manthang and travel from Pokhara would be faster, which would also improve his business. Furthermore, especially young respondents brought up the lack of internet access and bad phone signal as well as limited electricity. The public solar power plant only provides electricity at night, not during the day, and few people have the means to supplement the public supply with private solar panels. The slow development of infrastructure may be related to the political environment, as one respondent believed: Corruption and embezzlement of funds were widespread and persisted through local politics and alliances. When asked whether anything might change with the popular elections in May 2017, the same respondent replied resignedly that the different political parties made all sorts of promises to gain votes – but there was little hope that (m)any of those promises would come true.

4.3.5 Traditional Views on Water, Water Pollution and Sanitation

Besides worldly concerns, Buddhist and pre-Buddhist animistic beliefs have influenced people's perception, attitudes and behavior across the Tibetan Plateau. Awareness of such beliefs regarding water, water pollution and sanitation might facilitate communication with local people and foster acceptance of sustainable yet unfamiliar sanitation systems. When discussing the value of EcoSan or wastewater treatment, for instance, arguments that resonate with the local population and link to traditional explanations and behavioral norms might create more engaged interactions and more sustainable outcomes. Therefore, this section will describe some WASH-related advice, rules and views from Buddhist teachings, followed by other traditional beliefs, folk customs, and sayings concerning water pollution and its consequences. Furthermore, the interview partners' opinions on these traditional beliefs and how they are changing will be presented, as well as the importance of unpolluted water in Buddhism and traditional medicine.

The Buddhist beliefs in reincarnation and the interconnectedness of all phenomena require to treat other sentient beings and their living spaces with respect (Chimedsengee et al., 2009). One of the fundamental principles is the law of cause and effect (*karma*; Tib. *las rgyu 'bras*): Positive actions will bring benefits, and negative actions will have undesirable consequences to the person who committed them, in this or in the next life. Since humans can be reborn as any form of sentient beings, including animals, depending on their past actions, being kind to other creatures is important (Chimedsengee et al., 2009). Not only could one become a non-human being oneself in a future life, but current animals could also have been one's close relatives in a previous lifetime.

Hence, in order to limit the harm done to aquatic beings and avoid karmic repercussions, preventing water pollution is necessary (Chimedsengee et al., 2009; Kabilsingh in Gottlieb, 1996). The Vinaya Pitaka – the Buddhist monastic code originally written down in Pali around the second century BCE (DeGraff, 2013) – contains several rules pertaining to water, water pollution, sanitation and hygiene. For example, knowingly pouring any substance into water that could cause the death of living beings is considered an offense (DeGraff, 2013; Kabilsingh in Gottlieb, 1996). Another rule averting water pollution and promoting public hygiene demands that rinsing water from eating bowls should not be poured out if it contains rice grains, unless the grains have been squashed so that they will dissolve in water

(DeGraff, 2013). Monks are also advised to pour drinking water through a strainer before using it to remove particles and living beings so as to avoid killing them (DeGraff, 2013). Regarding toilet practices and water, the Vinaya Pitaka states that one should neither urinate nor defecate into drinking or bathing water or onto living crops. However, there are no restrictions if these activities affect salty or stagnant water, already contaminated water or flushing water in toilets. Also, it is not considered an offense if urine and feces contaminate water by spreading naturally after being deposited on the ground (DeGraff, 2013). These rules can thus not serve as a religious argument to promote dry toilets because the use of water for sanitary purposes is specifically exempted from the principle of avoiding pollution. On the positive side, the monastic code does not forbid the reuse of excreta – in fact, a passage states that it does not violate the rules if urine and feces end up in a place with plants as long as they have not directly been excreted there (DeGraff, 2013).

The monastic code also calls for a certain toilet etiquette and hygiene behaviors. For instance, monks are required to take off and hang up their robes before entering the toilet, probably to avoid soiling them (Dhammika, n.d.). Besides, the rules specify that one should not urinate or defecate while standing, and after relieving oneself, cleansing with water should be practiced (DeGraff, 2013). This reflects the origin of Buddhism on the southern side of the Himalayas where anal cleansing with water seems to have been common already back then, though Dhammika (n.d.) also mentions wiping with grass or a piece of wood. Out of respect for the next person, the water containers should be refilled and the toilet cleaned (DeGraff, 2013; Dhammika, n.d.). In terms of hygiene, regular cleaning and sweeping of monastic toilets is prescribed, and for hand-washing a water pot placed outside the toilet (Dhammika, n.d.). The Vinaya Pitaka also instructs that a water vessel should not be touched with dirty hands (DeGraff, 2013), illustrating that the importance of clean water was understood over two thousand years ago.

While all these rules were written down in the original monastic code, they are not necessarily known or adhered to by Buddhist laypeople. They may also have been adapted or loosened for ordained monks in Mustang and across the Tibetan Plateau due to changing times and different environmental circumstances. Nevertheless, traditional customs that protect natural resources including water are still widely known also among non-monastic common people. These practices are based on a blend of Buddhist and pre-Buddhist indigenous beliefs.

Traditionally, certain natural spaces such as springs, mountains and rivers were considered sacred because they were said to be inhabited by a deity or regarded as a deity themselves (Chimedsengee et al., 2009). People made offerings to placate these deities and avoided disturbing them by respecting rules such as no killing of wild animals, no digging up of soil, destroying plant roots, cutting trees or polluting rivers. These beliefs promoted and maintained ecological practices over centuries. They were later integrated with Buddhism and continue to be practiced even nowadays – at least to some extent. Sacred places still exist, and Buddhist *nagas* (Tib. *klu*) or nature spirits are now said to reside in them (Chimedsengee et al., 2009). Moreover, a multitude of local spirits and deities are still worshipped and care is taken not to irritate them. While some of them act as protectors of the land and people, others are wrathful demons with the power to bring suffering and destruction. According to Amchi Sherab Tenzin, a traditional doctor with a private clinic in Kathmandu, disobeying the rules and breaking taboos related to sacred places may have serious consequences for the offender (personal communication, March 31, 2017). If those spirits or deities get upset, their punishment may come in the form of physical diseases, such as skin infections or kidney problems for urinating near a spring. On a larger scale, transgressions may bring misfortune to the culprit's family or even the whole community (also mentioned by Chimedsengee et al., 2009), for example, disharmonious relationships, bad dreams, disease outbreaks, natural disasters, bad harvests and famines. Amchi Sherab Tenzin reminded that all of these diseases and problems stem from environmental pollution and upsetting the local spirits, so that conventional medicine cannot cure the patient – a belief also cited by Craig (2011) concerning moral offenses linked to place-based spirits. Instead, Amchi Sherab Tenzin explained, specific rituals are required for pacification: offering a special vase to the *nagas*, burning incense, cleaning up or purifying places where they reside. To prevent the spirits' anger, for instance in case of necessary construction activities, a ritual needs to be performed requesting the spirits to move and asking for their permission to use a piece of land. Amchi Sherab Tenzin advised that such rituals should also be conducted before building a toilet or excavating a cesspool pit. If the damage has already been done and local spirits have been disturbed, the law of *karma* makes it the producer's responsibility to mitigate negative environmental impacts and ensure that the surroundings can recover (Chimedsengee et al., 2009). Though these customs and beliefs have been observed for many generations, are they still a part of people's everyday lives nowadays?

When Lo Manthang residents were asked about their concerns regarding the disposal of untreated wastewater into the river, upsetting local spirits was mentioned by two thirds, the same number that had brought up health concerns. Judging from these interviews, traditional views still seem to be known by most. At the same time, though, more than half of the respondents conceded that in the 21st century, more and more people did not believe in or care about spirits and related practices. While the elderly and people with religious education still followed those traditional beliefs, the younger generation – children and young people educated at Nepali schools – did either not know about or did not pay attention to them. Another respondent bemoaned that even adults who claimed they still had faith in spirits no longer acted accordingly. He insisted that humans had to be considerate of spirits even though the latter were invisible. However, with changes happening in so many areas of life, one respondent indicated that such views were outdated. People nowadays would not believe in local spirits, related illnesses and rituals anymore but would rather go to the hospital if they were sick, he pointed out. The decline of traditional beliefs and of religion in general has not only been noted by Lo Manthang residents but also by G. S. Gurung from the WWF. In response to the author's question whether it might be easier to promote sustainable sanitation in Mustang thanks to the region's Buddhist heritage, he seemed pessimistic: Whereas people still believed in Buddhist tenets such as reincarnation, the influence of religion in daily life was diminishing (personal communication, March 27, 2017). As Craig et al. (2010) found, some people in Mustang even associate changing beliefs, habits and lifestyles with health issues:

> Some interviewees connected the decline of (Buddhist) morality and the increase in greed, the neglect of local deities, the increasing consumption of non-local foods, and the outmigration of young people as well as the neglect of community elders to particular health problems. Others noted connections between the increasingly monetized economy […] and a decline in respect for, or attention paid to, lamas or other religious' figures, to specific disorders or conditions. (p. 13)

A statement by Lhundup Namgyal from the ACAP health post went along the same lines:

> The present generation does not care very much about ancient wisdom and beliefs. In the past, people knew that they should not pollute water. But nowadays excreta and water are mixed and there are more diseases because people no longer care to protect the water.
> (personal communication, May 25, 2017)

With regard to WASH-related pollution, Amchi Sherab Tenzin stated that the Tibetan medical texts provided no rules or guidelines to prevent the spread of illnesses. However, the importance and value of clean water for life and health is described in Buddhist texts and recognized in traditional medical practice. For example, water is one of the "Six symbols of longevity," a popular Buddhist motif that can be found on the walls of monasteries and homes alike (Figure 122). In that picture, a perfectly pure stream emerging from a sacred rock epitomizes the significance of unpolluted water for life on earth (Chimedsengee et al., 2009). This water of longevity is said to possess eight precious qualities which were first mentioned in Tibetan by Chim Jampeyang (Tib. *mchims 'jam pa'i/dpal dbyangs*) in the 13th century CE: "being cool, delicious, light, soft, clear, odorless, soothing and healing" (Jampeyang, 1989, p. 284). These qualities were also enumerated by Amchi Sherab Tenzin and Chimedsengee et al. (2009, p. 20).

Figure 121: A pure stream as one of the "Six symbols of longevity," a traditional Buddhist motif (Bhutan Art and Craft, n.d.)

Thanks to its beneficial properties, water is also greatly valued in Tibetan medicine. Crushed herbal pills are usually taken with hot water, and as stated by Amchi Sherab Tenzin, boiled water on its own is supposed to help cure various illnesses such as digestive problems, hick-ups, bile diseases, and asthma. It also has the potency to prevent colds and influenza, and if left to cool after boiling, it benefits the stomach, liver, and gall bladder. Amchi Sherab Tenzin explained that while indigestion was the first illness, boiled water was the first medicine. Based on traditional understanding, though, not every type of water is of equally high quality. Seven different water qualities are distinguished according to their origin, the best three being 1) rain water, 2) snowmelt, and 3) river water – which are deemed better than spring water, for instance. If drinking water is taken from a source other than the top three qualities, traditional medicine advises that it be boiled or else stomach problems, indigestion, colds and influenza would commonly arise (Amchi Sherab Tenzin, personal communication, March 31, 2017).

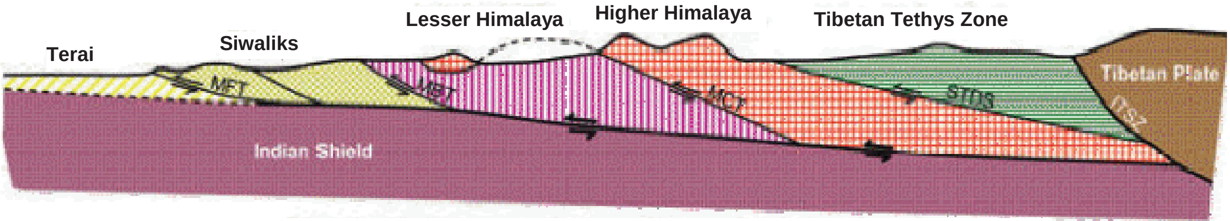
As for water pollution, two respondents mentioned an old Tibetan saying that water had self-purifying abilities and would be clean again after a distance of nine arm spans (about 15m). Even though contaminants might travel much further, this belief reflects a common conception in some Asian countries that flowing water is naturally clean (DeGraff, 2013). Nevertheless, the Tibetan saying also recognizes that letting water pass through soil cleans it even faster: It states that underground, the earth goddess only needs a distance of one arm span to purify polluted water. Amchi Sherab Tenzin predicted that for WASH interventions in Mustang, the greatest benefits and acceptance could be achieved by combining traditional approaches with scientific methods and arguments. Cleaning up polluted water would then not only be in accordance with ancient practices and religious beliefs, but also favorable from an environmental and public health perspective.

4.4 Soil Characteristics in Lo Manthang

4.4.1 (Hydro)geologic and Pedologic Context

The region's geologic history has been dominated by the formation of the Himalayas. This mountain range started to rise about 55 million years ago when the Indian continent collided with the Eurasian plate (Dahal, 2006; Upreti, 1999). Until today the Himalayas are considered an active mountain range, with ongoing tectonic movements and orogenetic processes: India continues to push northward about 5cm each year, and seismic activity in the area is not uncommon (Dahal, 2006), as the 2015 earthquake in Nepal sadly proved.

Mustang lies in the Tibetan Tethys Zone, north of the Great Himalaya Range and south of the Indus-Tsangpo Suture Zone belonging to the Eurasian – or Tibetan – Plate (Figure 121; Colchen, 1999; Dahal, 2006; Upreti, 1999). The Tibetan Tethys Zone is the northernmost tectonic zone of the Himalayas; a belt of 5-50km width that is exposed mainly in the Western Himalayas. It makes up some of the highest peaks, including the Annapurna I (8,091 m a.s.l.) and Dhaulagiri (8,167 m a.s.l.), and extends north beyond Mustang into southern Tibet (Figure 122; Dahal, 2006; Parsons, Law, Searle, Phillips, & Lloyd, 2014; Upreti, 1999). Mustang lies above the South-Tibetan Detachment, a fault system that forms the boundary between the crystalline rocks of the Higher Himalayas (gneisses, granites, schists and marbles) and the overlying Tibetan Tethyan sediments (Colchen, 1999; Dahal, 2006; Upreti, 1999). These sediments are an almost continuous succession of fossiliferous marine deposits of Cambrian to Cretaceous age (Paleozoic to Mesozoic, about 540-66 million years ago; Walker, Geissman, Bowring, & Babcock, 2012). Common rock types are shales, limestones and sandstones which are rarely metamorphized except near the fault zone (Colchen, 1999; Dahal, 2006; Parsons et al., 2014; Upreti, 1999).



MFT – Main Frontal Thrust, MBT – Main Boundary Thrust, MCT – Main Central Thrust,
STDS – South-Tibetan Detachment System, ITSZ – Indus-Tsangpo Suture Zone

Figure 122: General cross section of the Himalayas (adapted from Dahal, 2006)

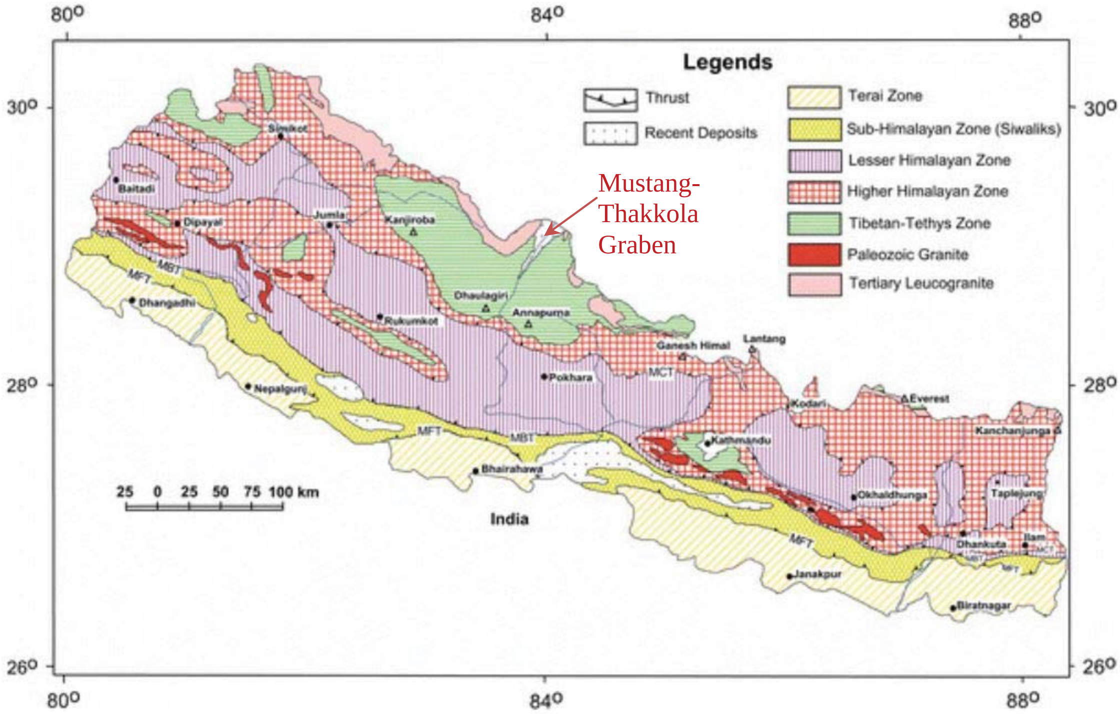


Figure 123: Geological map of Nepal (Dahal, 2006)

The landforms in Mustang have developed through tectonic uplift, faulting, and erosion (Dahal, 2006). The most prominent geological structure is the Mustang-Thakkola Graben which was formed through tectonic activity in the late Cenozoic (Adhikari & Wagreich, 2008; Colchen, 1999): After faulting in the Miocene (23-5 million years ago; Walker et al., 2012), extensional stress in the Pliocene and Pleistocene (5 million to 11,000 years ago; Walker et al., 2012) led to many grabens perpendicular to the main mountain range. Unlike other grabens in Asia, the Mustang-Thakkola Graben is not considered a proper rift, though, because the faulting did not evolve through volcanism or magmatism (Colchen, 1999). Nevertheless, it has led to the formation of one of the largest Himalayan valleys and one of the deepest gorges worldwide where the Kali Gandaki River flows south and cuts through the Great Himalayas (Hagen, 2004; Parsons et al., 2014; Upreti, 1999). The Mustang-Thakkola Graben itself is located north of the Annapurna and Dhaulagiri Ranges, oriented from north-northeast to south-southwest and extending about 90km in length and 20-30km in width (Colchen, 1999; see Figure 123 above). It thus forms a large basin that is now filled with about 850m of continental deposits. The altitude of the basin is between 3,000 and 4,000m altitude while the surrounding peaks reach over 6,000m a.s.l. These mountains and the base of the graben are made up of Tethyan sediments as described above, plus intrusive Tertiary leucogranites in the western and eastern direction (Colchen, 1999; International Geological Mapping Bureau, 1976). Such leucogranites also appear as pebbles in the conglomerates of the deposits that have filled up the basin (Colchen, 1999).

Filling of the Mustang-Thakkola Graben occurred both simultaneously and after its formation (Colchen, 1999; Parsons et al., 2014). Though the climate and environment at the time of deposition are unknown, the stratigraphy inside the basin has been studied extensively (Adhikari & Wagreich, 2008). It is made up of four different formations, one of them being the Thakkola Formation which crops out around Lo Manthang (Adhikari & Wagreich, 2008; Colchen, 1999). The Thakkola Formation is thickest in the west with over 700m of deposits and gradually thins out towards the east (Colchen, 1999). It mainly consists of braided fluvial deposits and some lacustrine (lake) sediments (Adhikari & Wagreich, 2008). The bottom 150m of the deposits are made up of conglomerates from metamorphosed Paleozoic rocks and leucogranite pebbles. Above follows a 200-300m thick intermediate zone of distinctive sedimentary units including sandstones, conglomerates, lacustrine limestones and clay. The uppermost deposits of at least 200m thickness comprise more weathered conglomerates overlapping with layers of sand (Colchen, 1999). Although the literature does not mention the role of glaciation on the Thakkola Formation, glacio-fluvial deposits, moraines and tills may have been formed, as in the other formations of the Mustang-Thakkola Graben (Adhikari & Wagreich, 2008; Dahal, 2006).

As for the geology in the immediate surroundings of Lo Manthang, only a rough assessment could be made. The town is located on a glacial outwash delta with a braided river system (Figure 124). Since the formation of the Mustang-Thakkola Graben, the rivers have not always been in the same location as today, but have meandered and taken different courses across the plain. The rocks and pebbles which the water transported are generally rounded as is typical for fluvial deposits. In periods with strong current, coarse material was carried further downstream of which large sub-rounded to rounded rocks and boulders on the slopes of Lo Manthang bear evidence (Figure 125). When the current was weaker, these large and heavy blocks were deposited higher up on the delta and more fine-grained materials such as gravel and sand were washed down to present-day Lo Manthang.

Figure 124 (left): Satellite image of Lo Manthang (Google Earth Pro, 2018)

Figure 125 (above): Large sub-rounded rocks on the northern slope of town

Over millions of years, these dynamics have filled up the basin in layers that are still visible today on bare slopes or when the ground is dug up (Figures 126-128). In an almost 2m deep construction pit in Lo Manthang, excavated for a cesspool, such layering was very distinct: The top 50cm were made up of sand, whereas the material below consisted of a mix of grain sizes with at least 40% unconsolidated rocks and pebbles >5cm (Figure 128).[13] As the location of the pit was in the center of the old town, it cannot be confirmed whether these layers have entirely been formed by the environment or partly influenced by anthropogenic activity, though. Where such sediments are exposed, they have weathered or disintegrated to varying extents based on their mother material, compaction and erodibility as well as external factors such as water, wind and temperature (Figure 129).

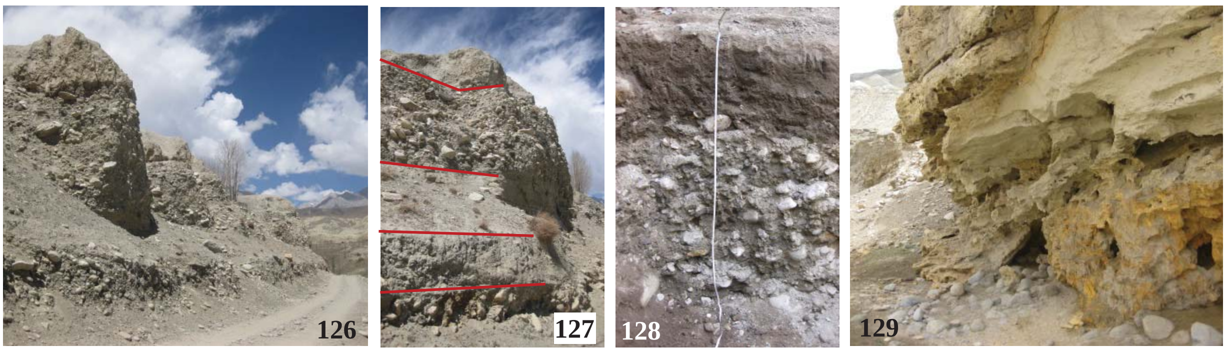


Figure 126 and Figure 127: Partially eroded layered sediments just outside Lo Manthang
Figure 128: Soil profile in construction pit in the center of Lo Manthang; 2m depth
Figure 129: Eroded rock, possibly limestone, near the river south of Lo Manthang

[13] This is also the pit where the sample for the GSD was taken from, at a depth of 1.9m.

Among the variety of rocks, two samples from the surface of the Lo Manthang terrace next to the agricultural fields were analyzed. The first one (Figure 130) represents a rock type that is ubiquitous around Lo Manthang, making up a large percentage of the pebbles, rocks and boulders that can be found along the rivers. It was identified as granite or grano-diorite (the latter containing less potassium feldspar), an igneous rock with clearly visible crystals. In the sample, mineral grains of quartz, feldspar, biotite and muscovite mica, and even a few tourmaline prisms were distinguished. Slight layering indicated some pressure that might eventually have transformed the rock into gneiss. Since this rock is clearly not of sedimentary origin, it cannot be from the Tethyan sediments but probably stems from the intrusive Tertiary leucogranites in the mountains east and west of the Mustang-Thakkola Graben. The second rock (Figure 131) was less typical for the surroundings but caught the author's attention because of its unique pattern and encrustation on the surface. Its identification was less straightforward, though: The black pattern pointed to amphibole whereas the outer coating on the edges and the opposite side of the rock (Figure 132) reacted strongly with HCl, indicating $CaCO_3$ such as in limestone. However, the coating dissolved with continued application of HCl and the host rock below did no longer react with the acid. It can thus be assumed that the $CaCO_3$ is not part of the rock's mineralogy but possibly a precipitate that has adhered to its surface, for instance from $CaCO_3$-containing water. The slightly rusty color of the coating could be owed to the presence of iron. The host rock below is likely amphibole gneiss, metamorphized from deposited sediments as no other mineral grains could be distinguished.

Figure 130: Rock sample 1, identified as granite, an igneous rock from the Tertiary

Figure 131: Rock sample 2, identified as gneiss with amphibole and $CaCO_3$ coating

Figure 132: Partly dissolved rust-colored $CaCO_3$ crust on rock 2 which strongly reacted with HCl

In terms of landforms, two rivers have eroded valleys into the sediments north and south of town; Lo Manthang and its agricultural areas lie on a plateau that drops steeply on its edges (Figures 133 and 134). The location of settlements on such terraces or alluvial fans is typical for Mustang (Fort, 2015).

Figure 133 and Figure 134: Steep slopes on the northern (left) and southern (right) edge of Lo Manthang's plateau; some bedrock outcrops near the valley floor (right)

While the river south of town has low current and little bedload at present, the northern river bed and its surroundings are filled with rounded rocks, partly consolidated fluvial deposits and conglomerates (Figure 135). In the southeast of town near the convergence of the two rivers, steep cliffs on both sides of the valley expose the bedrock (Figures 136 and 137). The rock types here appear to be sediments, including sandstones and limestones of different colors. The orange-red bedrock, for instance, is typical for weathered limestone found in Tibetan Tethys sediments (Upreti, 1999).

Figure 135: Conglomerates along the river north of Lo Manthang

Figure 136: Steep cliffs on the southeastern edge of the Lo Manthang plateau (looking south)

Figure 137: Convergence of the rivers southeast of town; colorful rock strata in the background

Concerning hydrogeology, the shape and appearance of the landscape indicate that the groundwater level is well below the terrace of Lo Manthang and emerges in the river beds on either side of town. The vertical distance between the plateau and the river is only 20-30m at the upstream (northwestern) end of town, but it increases markedly towards the southeastern edge of the plateau where the rivers lie about 100m below the agricultural fields (compare Figure 50 in section *3.4.1*). Drinking water extraction seems improbable because of the deep drilling that would have to be done and the lack of machinery. At the same time, the distance between the terrace and the groundwater level can also be an advantage: The risk of pollution from leaching cesspools is very small. Although bacteria can travel for almost 30m in gravelly soils (I.M. Amatya, personal communication, August 7, 2016), they are normally reduced below risk level within just a few decimeters in the unsaturated zone (Pandey & Jenssen, 2014). Pathogens are unlikely to pass through Lo Manthang's layered and heterogeneous underground all the way to the groundwater table. In order to avoid contamination, a potential DEWATS should thus be built on top of the plateau. In that case, wastewater would percolate through thick deposits and contaminants would be eliminated along the way. On the contrary, the flat areas along the rivers are unsuitable for a treatment system because they are too close to the groundwater table. In some places the groundwater even comes to the surface and forms small marshlands (Figure 138). Infiltration or discharge of wastewater in these places would pollute both the river and the groundwater.

Figure 138: Marshy area next to the river north of Lo Manthang

Regarding the investigated soils, they reflect the geologic surroundings, climatic conditions and lack of vegetation. The soil parameters pH and organic matter content shall be discussed in this section whereas soil texture will be part of the GSD analysis presented below. Predictably due to calcareous bedrock in the catchment, the soil pH at all three sites was found to be slightly alkaline (Table 7), in line with a study of rangeland soils in Upper Mustang by Maharjan (2010) and the rather high pH in Lo Manthang's drinking water. The pH variation between the three replicates for each location was minimal. $CaCO_3$ in soils can be a benefit if they are used for wastewater treatment: Along with iron and aluminum oxides, calcium (Ca) is an important sorbent for phosphorus (P) from wastewater, thereby reducing the nutrient load that will reach waterways (Siegrist, Tyler, & Jenssen, 2000). Since P is usually the limiting nutrient in freshwater bodies (Howarth, 2009), its removal may prevent eutrophication and algal blooms (Landon, 2006; WaterAid, 2008a) – although the latter would be less likely to happen in the fast-flowing mountain streams and rivers of Upper Mustang.

Table 7: Soil pH and organic matter content at three test sites

Location	Soil pH	Organic matter (% of dry matter, corrected for clay content)
Site 1	8.04 (±0.025)	3.76%
Site 2	8.01 (±0.017)	2.67%
Site 3	7.96 (±0.020)	2.83%

At site 1, organic matter content was within the 3-6% commonly found in agricultural soils (Fenton, Albers, & Ketterings, 2008), but slightly lower at the other two sites. Partly responsible for the relatively low organic matter content may be the depth at which the samples were taken (50cm); Maharjan (2010) found that at 40-60cm depth the soil organic C was already 25% less than within the top 20cm. Besides, sites 2 and 3 lie on the edge of the plateau and have probably not been cultivated for many years. This may have reduced the organic matter content because no new organic material was added and organic matter present in the soil may gradually have decomposed or been lost through topsoil erosion. Conversely, the soil at site 1 may contain more organic matter because it is surrounded by agricultural fields and may have been cultivated until recently: Roots from vegetation, crop residues, dung and regular irrigation may all have contributed to the addition and retention of organic matter, not least by stabilizing the soil. Greater aggregate stability and soil cohesion is only one of the many advantages of organic matter (Bot & Benites, 2005; Fenton et al., 2008). It also provides a C source for soil organisms such as earthworms which improve soil porosity, aeration and structure through their burrowing activity and gluey secretions (Bot & Benites, 2005). Thanks to more pores, rainwater infiltrates more easily and roots grow better. Moreover, organic matter content improves a soil's moisture holding capacity and fertility because nutrients are recycled and retained better (Bot & Benites, 2005; Fenton et al., 2008). Though the organic matter content in Lo Manthang's soils is on the low side, it may nevertheless be of some benefit when considering wastewater treatment: Organic matter helps remove nutrients and pathogens from the water, also thanks to the increased number and activity of soil organisms that break down pollutants (Bot & Benites, 2005).

4.4.2 Grain Size Distribution (GSD)

The grain size distribution revealed that the soils at 50cm depth were almost the same at sites 1 and 3, while site 2 had a higher percentage of coarse material (Figure 139). At 1.9m depth in the construction pit, the distribution was markedly different with hardly any fine material but about equal amounts of sand and gravel. The exact weight fractions can be found in Appendix H, Tables 12-14. It must be remembered that the GSD did not include any rocks larger than 5cm in diameter, which increases the actual difference between the four soils. In the construction pit, rocks made up an estimated 40% of the soil volume and at site 2 about 15%, whereas sites 1 and 3 contained hardly any rocks.

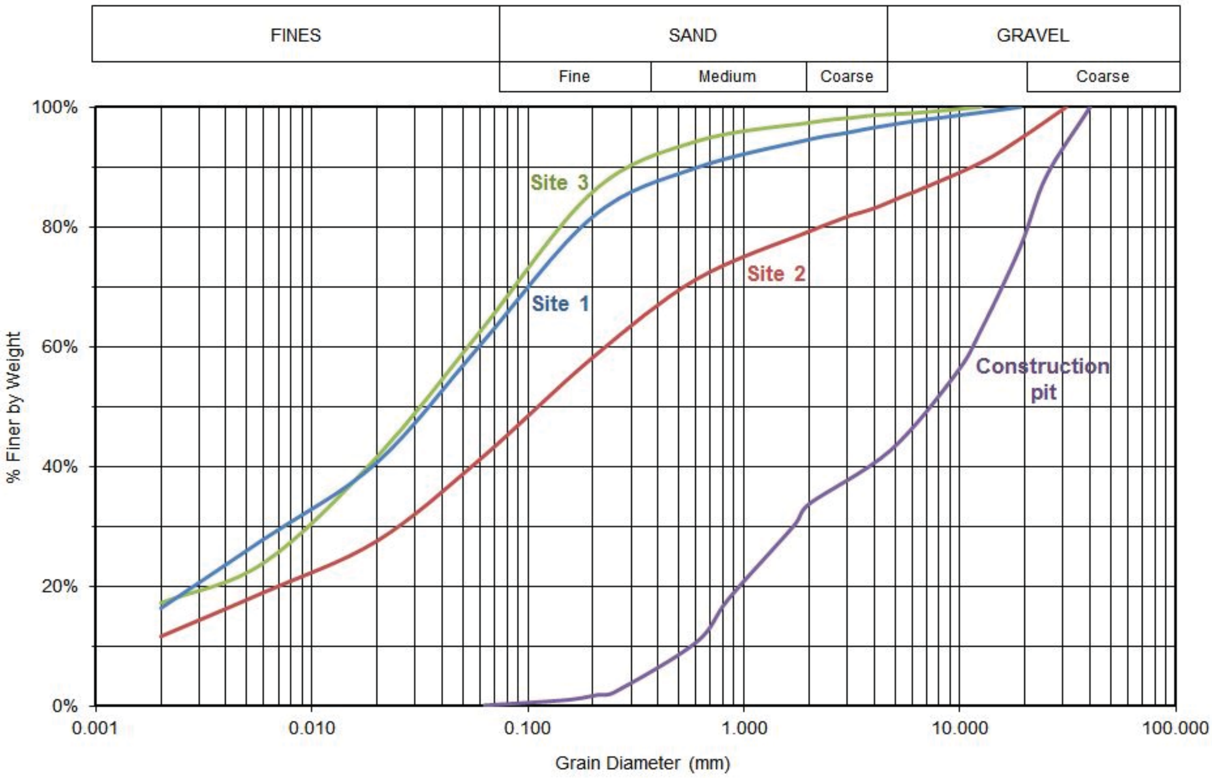


Figure 139: Cumulative grain size distribution curves for test sites 1, 2, and 3 (0.5m depth), and construction pit (1.9m depth)

The large spread of all four curves is a sign of the poor sorting of the soils. They all contain grains of various sizes, making it difficult to predict their effective porosity and thus hydraulic conductivity (see following section). Depending on how the grains are packed, there will be more or less interconnected pore space; in poorly sorted soils the smaller grains may fit between the larger ones and thereby reduce the porosity compared to well-sorted soils where all grains are of similar size (Schwartz & Zhang, 2003).

The GSD curves also show that the soils vary substantially between locations and depths, so that general statements for all of Lo Manthang are impossible. For a DEWATS, local assessments of potential sites will be necessary to determine in which place and at what depth the soil would be most suitable for a system.

The texture class of the fine earth fraction by GSD as well as feeling (field method) indicated loamy soils at the three infiltration test sites (50cm depth) and coarse sand for the soil in the construction pit (1.9m depth; Table 8). The results at the test sites correspond with Maharjan (2010) who found mostly sandy loams and loamy sands in Upper Mustang. Pokharel (2009), on the other hand, described agricultural soils as fragile, loose and sandy, which is also very plausible considering local variations.

Table 8: Texture classes of the fine earth fraction (<2mm) based on GSD and field assessment

Location	Clay %	Silt %	Sand %	Texture class based on GSD	Texture class based on field method (feeling)
Site 1	17.3	46.4	36.3	loam (tending towards silt loam)	clay loam
Site 2	14.7	37.3	48.0	loam (tending towards sandy loam)	Between sand and silt loam
Site 3	17.7	46.5	35.8	loam (tending towards silt loam)	clay loam
Construction pit	0.4		96.6	coarse sand	coarse sand

Comparing the results from the GSD-based texture class and the field test shows that greater clay content was assumed from feeling than what was actually found by the GSD. At sites 1 and 3 the plasticity and stickiness of the soil pointed towards clay loams (25-40% clay); for site 2 the limited cohesiveness and floury, grainy texture led to a classification between sand and silt loam (8-27% clay) (FAO, 2006). However, based on the more accurate GSD method, the actual clay percentages were below 20% in all samples.

Soils with many finely grained particles – especially clay – usually have a low K_{sat} (Schwartz & Zhang, 2003). Such soils are of limited suitability for wastewater infiltration because they risk clogging or even become impermeable. On the contrary, a high K_{sat}, often found in gravels and sands, is a desired property for wastewater infiltration, provided the distance to the groundwater table is long enough to prevent contamination. From the GSD alone it can be assumed that sites 1 and 3 would have the lowest K_{sat} because of their higher clay content. Due to the poor sorting, though, and without knowing the soil structure, only a combination of methods including infiltration tests can add clarity.

4.4.3 Hydraulic Conductivity and Suitability for Wastewater Infiltration

The averaged infiltration rates of three consecutive experiment runs at each test site are shown in Figure 140 below, based on the measurements in Appendix I, Table 15. As expected, sites 1 and 3 had very similar – though slow – infiltration rates, compared to site 2 where the water infiltrated three to four times faster. At all three sites, the infiltration rate decreased with each run, indicating that the soil was reaching more saturated conditions. Therefore, as mentioned in the methodology, only the infiltration rate of the last run at each site was used to calculate K_{sat}.

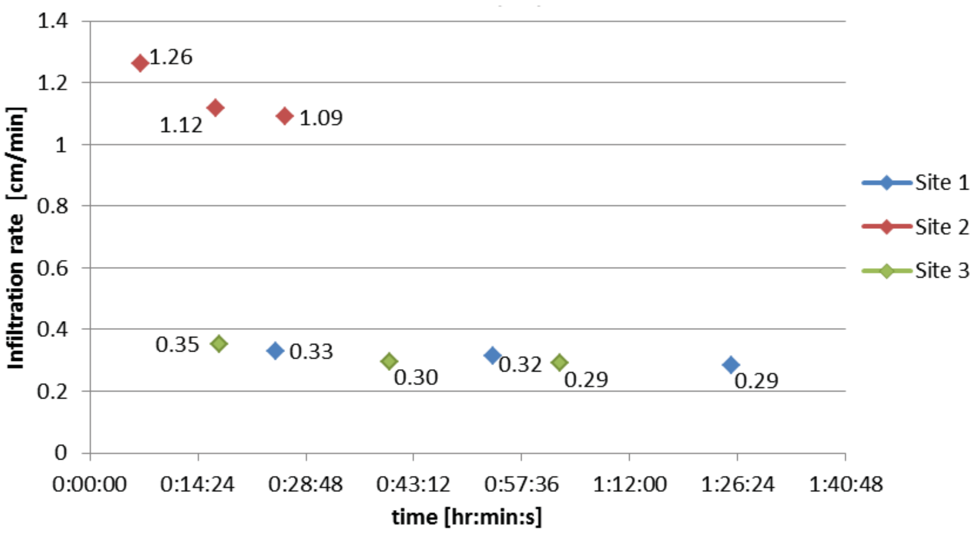


Figure 140: Infiltration rates at test sites 1, 2, and 3; three consecutive runs each

A comparison of K_{sat} results from different assessment methods is shown in Table 9. The construction pit is included here for the texture- and GSD-based estimates, but no infiltration test results exist because when those tests were conducted the following year, the cesspool had been built and the pit covered again. For the three infiltration test sites, the table shows the results based on the water level drop (assuming vertical infiltration through the pit bottom only) as well as the more realistic three-dimensional infiltration accounting for water leaving through the side walls as well. The results from the construction pit and infiltration tests are not only given in m/s but also in m/d which is a common unit used for wastewater infiltration systems, thus facilitating comparison with loading rate guidelines.

Table 9: K_{sat} values determined by texture class, pedotransfer function, and infiltration tests at four sampling locations

Location	Texture-based K_{sat} range [m/s] (USDA, n.d.)	K_{sat} calculated with Krumbein & Monk formula [m/s]	K_{sat} calculated from test results, assuming only vertical infiltration [m/s]	K_{sat} calculated from test results; 3-dimensional infiltration [m/s]
Site 1	$4.2*10^{-6} – 1.4*10^{-5}$ (silt loam, loam, very fine sandy loam)	$1.39*10^{-5}$ (at 5.9°C) $1.90*10^{-5}$ (at 15°C)	$4.76*10^{-5}$ (= 4.11 m/d)	$2.17*10^{-5}$ (= 1.87 m/d)
Site 2	$1.4*10^{-5} – 4.2*10^{-5}$ (fine sandy loam, sandy loam)	$2.28*10^{-5}$ (at 5.9°C) $3.10*10^{-5}$ (at 15°C)	$1.82*10^{-4}$ (= 15.71 m/d)	$8.28*10^{-5}$ (= 7.15m/d)
Site 3	$4.2*10^{-6} – 1.4*10^{-5}$ (silt loam, loam, very fine sandy loam)	$1.49*10^{-5}$ (at 5.9°C) $2.03*10^{-5}$ (at 15°C)	$4.85*10^{-5}$ (= 4.19 m/d)	$2.21*10^{-5}$ (= 1.91 m/d)
Construction pit	$>1.4*10^{-4}$ (coarse sand) (= 12.1 m/d)	$1.16*10^{-1}$ (at 5.9°C) $1.58*10^{-1}$ (at 15°C) (= 10-13,650 m/d)	-	-

For all methods, the order of the four locations according to their K_{sat} was the same: The construction pit had the highest K_{sat}, followed by site 2 on the southern edge of the terrace. Sites 1 and 3 in the center and on the northern edge of the terrace had the lowest K_{sat}. The methods yielded different results for each of the sites, though. The texture-based estimates gave the lowest K_{sat}, spanning across a range of texture classes. The results from the Krumbein and Monk formula indicated a faster K_{sat}, especially at 15°C because of the lower viscosity of water. The K_{sat} values calculated from infiltration test measurements were the highest, and faster for only vertical flow than when side wall infiltration was added.

Each of the used methods has inherent or potential shortcomings that may misrepresent the actual K_{sat}. One of the reasons for the lower K_{sat} based on texture class and Krumbein and Monk's formula is that these methods did not include the whole spectrum of grain sizes: The texture analysis only involved the fine earth fraction (<2mm) and the GSD used for the formula only rocks up to 5cm. Gravel, pebbles and (larger) rocks were therefore entirely or partially absent from those two methods, even though they greatly affect the K_{sat} of a soil. In addition, both methods can no more than approximate the actual K_{sat} because they neglect the soil structure. The packing of grains and interconnectedness of soil pores which determine the effective porosity are only accounted for in undisturbed soil samples or field tests. Empirical formulae are also prone to under- or overestimating the actual K_{sat} unless they are used exactly on the soil type they were developed for (Odong, 2007). Besides, Stibinger (2014) advises that the K_{sat} results from pedotransfer functions should not be taken as exact values but understood as order-of-magnitude estimates. In this light, the Krumbein and Monk formula produced results reasonably close to the K_{sat} from field tests.

Even field tests are not beyond any doubt, though. As Lee, Elrick, Reynolds, and Clothier (1985) and more recently Solheim (2017) have noted, different methods produce different K_{sat} values for the same soil. Lee et al. (1985) pointed out that there is no universal best method for infiltration tests, but that the choice depends on site conditions, soil type, investigative constraints and the desired accuracy of K_{sat}. For the field tests in Lo Manthang, the unavailability of sophisticated equipment was the main limiting factor determining the choice of method. Besides a lack of accuracy related to the chosen method, a source of error with field tests and subsequent K_{sat} calculations may stem from the use of formulas based on the assumption that soils are homogeneously structured. Most soils have different K_{sat} values for vertical and horizontal flow, and the K_{sat} may change even in the same flow direction due to layering (Schwartz & Zhang, 2003; Stibinger, 2014). However, the formula used here for calculating three-dimensional infiltration does not distinguish between vertical and horizontal flow rates through the bottom and side walls of the pit. In Lo Manthang where sediments are clearly layered, the infiltration rate and K_{sat} may also vary greatly depending on the depth of an infiltration pit and the dominant deposit at and below the infiltration surface.

Despite methodological shortcomings and uncertainties, what can be said about the suitability of the investigated soils for wastewater infiltration? The soils at the three test sites all fall into texture classes for which Jenssen (1986) recommends a loading rate of no more than 1 cm/d (= 10 liters/m^2/d). They are all located in sector 1 of the mean grain size/sorting diagram (Figure 141), which means that their K_{sat} cannot be predicted from the GSD. Site 2 plots outside the diagram because of its poor sorting and thus high sorting coefficient of about 153. According to Norwegian guidelines, the loading rate then depends on the soils' K_{sat} for clean water (Jenssen, 2016). For sites 1 and 3 with K_{sat} between 1-2 m/d, the recommended loading rate would be 0.6 cm/d (= 6 liters/m^2/d). Site 2, showing much more rapid infiltration during the field test (K_{sat} >5 m/d), falls into the category for which a loading rate of 2.5 cm/d (= 25 liter/m^2/d) is recommended.

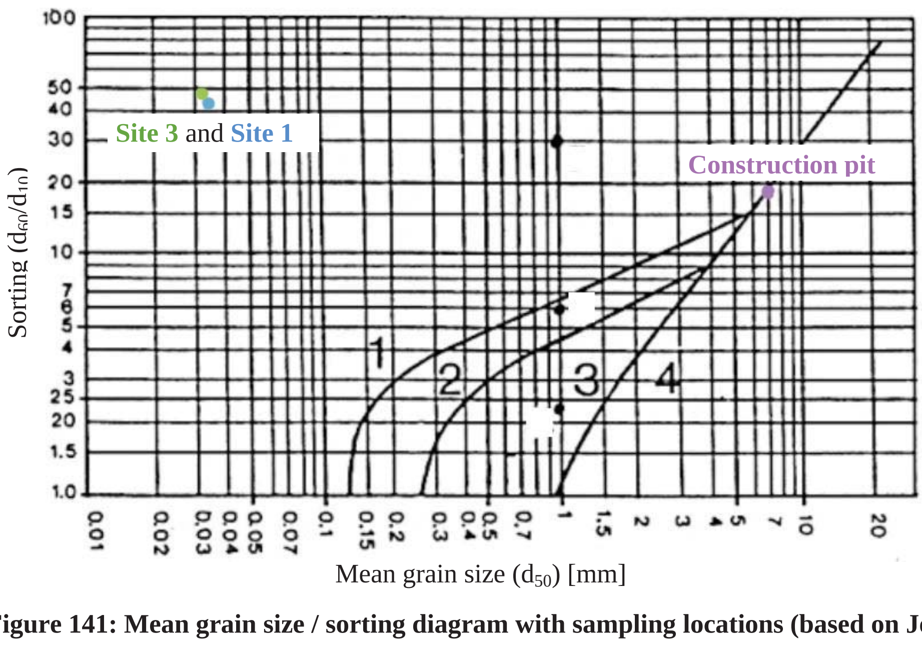


Figure 141: Mean grain size / sorting diagram with sampling locations (based on Jenssen, 2016)

Regarding the construction pit soil, the coarse material suggests that K_{sat} and infiltration rates here would be much higher than at the other three sites. The Krumbein and Monk results indicate a K_{sat} range for which Jenssen (1986) recommends long-term loading rates of 5 cm/d (= 50 liters/m^2/d). However, being poorly sorted, the soil is located just on the border of sectors 1 and 4 of the diagram in Figure 141 – between soils whose hydraulic conductivity can and those whose cannot be estimated from the GSD. Actual infiltration tests would need to confirm whether the soil's K_{sat} at that depth is higher and would thus be more suitable for wastewater infiltration.

To summarize, the loamy soils at a depth of 50cm at sites 1, 2 and 3 are of limited suitability for wastewater infiltration. Because of their finely grained texture they would be prone to clogging and could only sustain low loading rates. Nevertheless, even soils with low hydraulic capacity can be used for infiltration systems as long as large areas are available to compensate for the low loading rates. The soils at sites 1-3 may offer very good treatment thanks to their large percentage of fines and Ca content. The soil at 1.9m depth in the construction pit looks much more promising in terms of infiltration potential, but without field tests it cannot be ruled out that the poor sorting may cause a low K_{sat}. However, the existence of different soil types within close vertical and horizontal proximity can be an opportunity for an infiltration system: There might, for instance, be coarser deposits with greater permeability just below the loamy soils found on top of the terrace, so that an infiltration system located on a suitable plot southeast of town would be possible after all. More and deeper site investigations including infiltration tests should expand on the knowledge of soil conditions beyond the four locations presented here. Another option for natural wastewater treatment would be a constructed wetland which will be described along with further details on infiltration in section *5.3.5*.

5. SUSTAINABLE SANITATION OPTIONS

5.1 Improvement Options for the Lo Kunphen School

Based on the information gathered during background research and stakeholder consultation, the following improvement options were presented to the Lo Kunphen headmasters. For this thesis, the format of the two-page files provided to the school has been largely retained, but the different alternatives have been complemented with additional scientific evidence and explanations. Furthermore, the options the school ended up choosing have been elaborated in more detail, in particular sections *5.1.1* and *5.1.2*. These sections contain more technical information and more extensive descriptions regarding O&M as well as the benefits and challenges the school might encounter upon implementation and use.

5.1.1 Water Supply and Graywater Disposal

Brief explanation

Most stakeholders consider running water at the Lo Kunphen School as the number one priority. Without it, teaching and practicing proper hygiene behavior in daily life is a great challenge. The risk for hygiene-related illnesses increases, and such illnesses lead to discomfort, missed schooldays and higher expenses for medicine. Furthermore, carrying water from the public tap has been described as a heavy and cumbersome task for the children. According to WHO standards for schools in low-cost settings, a lack of water or hand-washing facilities should not compromise the students and staff's hygiene behavior (Adams et al., 2009). No matter how simple the hand-washing points are, their existence would be a great improvement over not having any facilities at all inside the school. Besides, showers could greatly improve the opportunity and privacy to maintain personal hygiene, especially for girls and female staff. Running water would also facilitate food preparation, cleanliness in the kitchen and allow for dish-washing on premises. To meet the WHO minimum standards of 25 liters/day per resident schoolchild and staff (Adams et al., 2009), the Lo Kunphen School would need about $1m^3$/day.

Suggested improvements include an underground storage tank which can be filled by hose connected to one of the public taps at night. Water from the storage tank can then be pumped to rooftop PVC drums using solar electricity during the day, and piping will lead it to all the points requiring water: a tap stand, shower(s), the kitchen, and possibly the pour-flush toilets if the school chooses to keep them. The plumbing can be designed by a local business according to Lo Kunphen's needs and preferences. For drinking water, biosand filter (BSF) technology could be used to ensure quality all year round. Since Lo Kunphen hardly generates any graywater on the school grounds so far, a future graywater disposal system will need to minimize negative impacts, for which an infiltration trench is recommended.

Required construction

- The underground storage tank needs to be cemented (10cm thick) and reinforced with iron bars on all sides. A plastic lining on the outer side can prevent contamination from surface infiltration and potential wastewater leakages (B. Nawab, personal communication, April 10, 2017).
- Water supply pipes must be installed *above* wastewater and urine pipes in case of leakage. Insulation of pipes or burying underground might be necessary to prevent bursting during the cold season.
- One 1000-liter or two to three 500-liter rooftop PVC drums would be sufficient for the school's basic daily water needs, depending on whether/how much water will be used for showers and dish-washing.
- The tap stand for hand-washing needs to be close to the toilets, for example in the outer courtyard along the wall across from the pour-flush toilet and classrooms (Figure 142). To save water, it should be equipped with faucets that only release water when pushed.

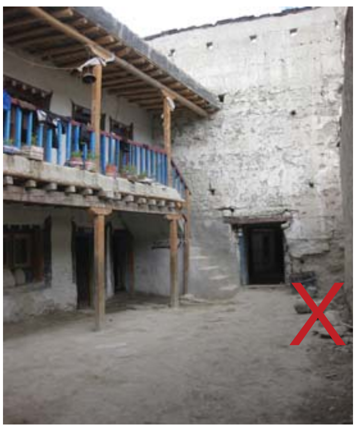


Figure 142: Outer courtyard, with proposed location of showers and tap stand on the right side, across from the gallery

Alternatively, buckets with taps (Figure 143) or tippy taps (Figure 144) can be installed (Adams et al., 2009). The latter is a simple technology only requiring a hanging device, some rope, jerry cans and a stick or plank that acts as a pedal to tip the jerry cans. The graywater would infiltrate through a gravel bed below.

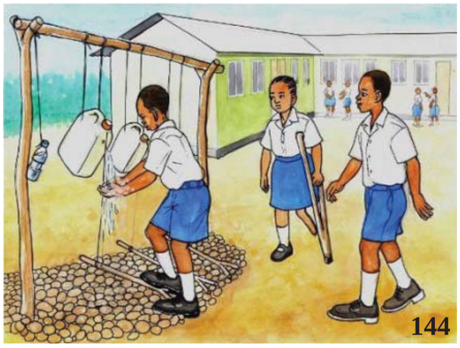


Figure 143: Hand-washing station with a bucket, tap and basin to catch graywater (Centers for Disease Control and Prevention, n.d.)

Figure 144: Tippy tap – a simple structure for hand-washing with limited water resources (Sustainable Sanitation Alliance, 2011)

- If a tap stand with basins and a proper drainage system is built (see graywater disposal below), it is recommended that dishes be washed inside the school. This would reduce the risk of contaminated dishes compared to carrying them to a public tap or washing them directly in the stream.
- Regarding showers, the existing one behind the kitchen should be repaired and taken into use once the school has water drums on the roof; the plumbing is already installed. It could be used by staff, while two additional showers (one for boys, one for girls) are suggested to be built in the outer courtyard next to the tap stand. Ideally, a solar water heater on the roof would provide hot water.
- In the kitchen, plumbing already exists and can be connected to a rooftop water storage drum. Based on the water quality tests, the water from the public taps is unobjectionable so that a different source does not seem required. To ensure consistent drinking water quality even for cold water and during the monsoon season and thereby prevent illnesses, water should be boiled and cooled so that students do not resort to drinking directly from the public taps. Otherwise, a BSF can be used as a simple, inexpensive method for drinking water treatment. This is one of the most promising point of use technologies to reduce waterborne illnesses (Sobsey, Stauber, Casanova, Brown, & Elliott, 2008). The BSF is an intermittently operated slow sand filter with a standing water layer of 5cm above the sand column (Figure 145; Jenkins, Tiwari, & Darby, 2011; Stauber et al., 2006). In the top 1-2cm of the sand, a biolayer with aerobic microorganisms develops which – according to the Center for Affordable Water and Sanitation Technology (CAWST, 2009) – remove about 99% of pathogens. These design features allow for pollutants in inflowing water to not only be trapped mechanically between the sand grains, but also removed through predation, adsorption, attachment, and natural death (Jenkins et al., 2011; Ngai, Shrestha, Dangol, Maharjan, & Murcott, 2007). BSFs have shown good removal rates for turbidity, organic matter, color, odor, iron and pathogens (Sobsey et al., 2008). They also have higher flow rates than other small treatment systems, that is, between 15 and 60 liters/hour (Ngai et al., 2007; Sobsey et al., 2008). Two BSFs should produce enough drinking water for the school.

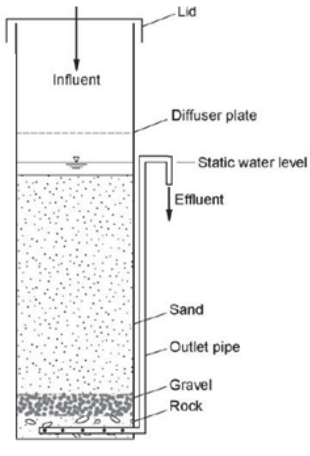


Figure 145: Design of a simple biosand filter for drinking water treatment (adapted from Jenkins et al., 2011)

- Graywater will be a new issue to deal with because "the closer the water point, the larger the quantity of water that is used for hygiene" (Adams et al., 2009, p. 20). From the kitchen and staff shower graywater is likely to be led by existing pipes to the water channel on the inner-city side of the school which goes to the monastery's vegetable field. However, to avoid the direct discharge of water mixed with soap and shampoo, a connecting pipe to the outer courtyard should be considered. For the tap stand and showers there, an infiltration trench is recommended (Figure 146), either below the courtyard or aligned with the current urine drainage channel along the city wall outside the school premises. Graywater from the kitchen and second floor shower could thus also be filtered. The trench should be filled with washed gravel, and for the underground version a geotextile membrane above the perforated, slightly sloped distribution pipe should prevent sand from washing into the gravel filter and clogging it (Jenssen, 2016). For a 20m long trench, the pipe should be 45cm above the trench bottom at the inlet and a minimum of 25cm at the back end (Jenssen, 2016). Graywater will then infiltrate from the bottom and side walls of the trench. In this way, not only will the soil retain and break down pollutants, but the water can also be recycled and nourish the trees growing alongside the drainage channel.

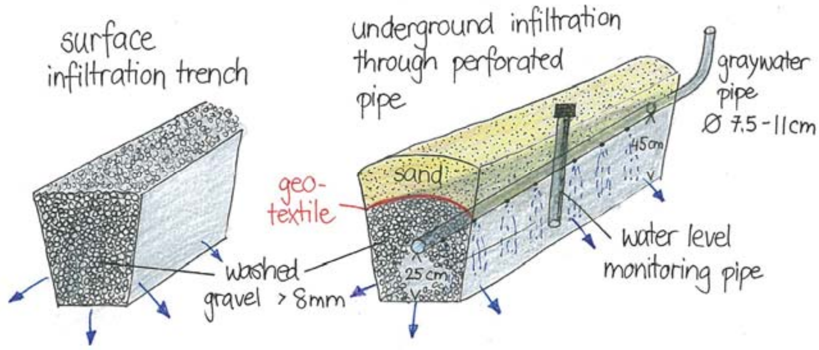


Figure 146: Cross-section of infiltration trenches for surface (left) and underground (right) infiltration (sketch based on Jenssen, 2016)

Required materials and expenses

- Cement, iron bars and plastic lining for underground storage tank
- Hose from public tap to storage tank
- Pump to lift water to the roof, connected to battery from existing solar system
- One 1000-liter (NRs 12,000) or two to three 500-liter (NRs 7,000) PVC drums
- Ideally: Solar water heater (costly – around NRs 75,000)
- Pipes from storage tank to rooftop drums and taps in different locations (kitchen, shower, tap stand, possibly toilets); and from drains to infiltration trench
- Taps (3 for tap stand; another 2 in toilets if the school decides do keep the pour-flush toilets); alternatively 3 buckets with taps or jerry cans with a tippy-tap structure for hand-washing
- BSF: 2 plastic containers of 70-100 l volume, minimum 60cm height with a lid; 13mm Ø PVC pipes and angle joints; diffuser plate, for example a large metal lid with holes; washed gravel of 6mm and 12mm for separation and drainage layers; sand of different grading (CAWST, 2009; Qi & Hu, 2016) – for best pathogen removal fine sand with a d_{10} value of around 0.15mm (Jenkins et al., 2011).
- Infiltration trench: distribution pipe (75-110mm Ø) with 6-8mm holes at 1m intervals, washed gravel (>8mm), geotextile, sand for backfill, water level control pipes (Jenssen, 2016)
- Transport fee for materials
- Labor for excavation and construction of storage tank

Operation and maintenance (O&M)

- The tap stand should be equipped with soap and kept clean to make its use a pleasant experience.
- A routine for shower use needs to be developed, encouraged and maintained. The WHO guidelines for schools suggest that "[i]f the age range of schoolchildren is more than three or four years, separate showers or showering times may need to be designated for younger and older children" (Adams et al., 2009, p. 20).
- Dish-washing should ideally be done with hot water – which could be provided by the solar water heater – and dishes should be air-dried as drying cloths can spread contaminants (Adams et al., 2009).
- Drinking water: Both hot and cold (boiled or filtered) water should be available at all times "and children encouraged to drink it, because even minor dehydration reduces [their] ability to concentrate, and may damage their health in the long term" (Adams et al., 2009, p. 19).
- BFS: The BFS must be used daily with charges of around 20 l and pause periods of at least one hour (ideally >15 hours) between batches to make sure incoming pathogens can be consumed by microorganisms in the filter (CAWST, 2009; Elliott, DiGiano, & Sobsey, 2011; Jenkins et al., 2011). Also, a standing water layer of 5cm above the sand must be maintained; if the water is too shallow it

risks evaporating quickly, if it is too deep, oxygen diffusion is reduced and aerobic microorganisms in the biolayer may die (CAWST, 2009; Ngai et al., 2007; Qi & Hu, 2016). Depending on the turbidity of the influent water, the flow rate of the filter will decrease within a few weeks to months because of clogging. The top one or two centimeters of the sand can then gently be stirred up by hand and the suspended sediments decanted, without removing any sand, though (CAWST, 2009; Elliott et al., 2011; Jenkins et al., 2011; Ngai et al., 2007).

- Graywater / infiltration trench: To prevent solids from clogging the distribution pipe, the drains need to be equipped with screens and cleaned frequently. Besides, the water level in the trench should be monitored regularly through vertical control pipes to check whether the distribution and infiltration function properly.
- Cleaning of water points: A daily cleaning routine of the tap stand and showers, including drains, should be established and monitored. The roof-top PVC tank should be cleaned periodically.
- Pipes and taps should be checked for leakages periodically. Before leaving Lo Manthang in the fall, all pipes should be emptied properly to avoid freezing and bursting in the winter.

Benefits

- In order to prevent diseases and improve well-being, sufficient and clean drinking water, safe sanitation that limits the spread of pathogens, and hygiene practices are essential. If children and staff are healthy they can learn and teach more effectively (Adams et al., 2009).
- If Lo Kunphen can provide water facilities at the school, the children will not have to carry water anymore and can use that time for studying or playing instead. Besides, running water at the school will greatly facilitate and encourage regular routines for hand-washing, brushing teeth, taking showers, and cleaning dishes without (re)contamination. Teachers will also be able to act as role models regarding WASH behavior (Adams et al., 2009).
- BSFs for drinking water treatment can reduce diarrhea incidence by 45-60% compared to untreated water, according to studies in other developing countries (Sobsey et al., 2008; Stauber, Kominek, Liang, Osman, & Sobsey, 2012; Stauber, Ortiz, Loomis, & Sobsey, 2009). In Nepal, 72% of households using BSFs reported better health after starting to drink filtered water (Ngai et al., 2007). BSFs can be constructed with easily available local materials, tools and skills; their O&M is simple and cost-free; they do not require spare parts, electricity or chemicals and have a long lifetime (Jenkins et al., 2011; Ngai et al., 2007; Sobsey et al., 2008). Thanks to these factors, satisfaction and long-term usage rates are clearly higher than for other point of use technologies (Ngai et al., 2007).
- By letting graywater infiltrate through a trench rather than directly disposing of it into water channels, the school can prevent water pollution and set an example for guesthouses and Lo Manthang residents. Onsite graywater treatment will particularly be of interest if residents receive water through household connections in the future. Lo Kunphen could continue its tradition of pioneering sustainable solutions by building and spreading knowledge about infiltration trenches.

Shortcomings and challenges

- Installing the water supply infrastructure will be a major financial investment. It might not be possible to implement everything at once. If the different components need to be prioritized, facilities for hand-washing should be one of the first concerns in order to improve hygiene.
- Developing proper hygiene behavior requires understanding, training and consistent practice by all staff and students; infrastructure alone will not be enough (see section *5.1.6* below).
- Potential BSFs will have to be properly used to provide the full benefit. Every spring it will take a few weeks before optimal treatment performance is reached because the biolayer first needs to develop. For heavily polluted water (which is currently not the case in Lo Manthang), even mature filters may not reach drinking water standards regarding bacteria and virus removal, so that a subsequent disinfection step would still be required (CAWST, 2009; Jenkins et al., 2011; Shrestha, 2004). Treatment efficiency may also be reduced for a few days after maintenance or if large water volumes are added (Ahammed & Davra, 2011; CAWST, 2009; Jenkins et al., 2011). Likewise, BSFs'

functioning may diminish if they are not used regularly and consistently. With prolonged pause periods (>48 hours), beneficial microorganisms in the filter may starve, or pathogens from a previous charge may incubate and increase contamination levels in the treated water once the filter is taken back into use (CAWST, 2009; Fiore, Minnings, & Fiore, 2010; Sobsey et al., 2008).

- Graywater infiltration and underground plumbing: The drainage channel along the city wall is on land that does not belong to the Lo Kunphen School. In order to build an infiltration trench there, the school will need to negotiate with the land owners. If use of that land is not possible, graywater infiltration directly below the outer courtyard is an option. Space will be limited, though, and depending on the amounts of graywater (assuming almost $1m^3$ per day) and the soil type below, infiltration might not be fast enough. Besides, for any underground pipes – including drains from the shower and tap stand – the recently cemented courtyard will have to be opened again, which will involve additional labor than if soil could just be dug up.

5.1.2 Dry Toilets With Urine Separation

Brief explanation

Urine in traditional dry toilets leads to excessive moisture if there is insufficient bulking material such as ash, saw dust, or dung. This produces bad odors, attracts flies, and may damage the foundation of the building. Such problems can be averted by collecting urine separately from feces, that is, by installing urine-diverting dry toilets (UDDT). These toilets use a pan with two holes (Figure 147); the front hole is for urine that is led by pipe to a storage drum, and the back hole is for feces which drop into a storage chamber or container. This separation not only makes sense to reduce moisture and smells, but also because of the different composition of urine and feces. Urine contains most of the nutrients in excreta – around 80% of the nitrogen (N), 55% of the phosphorus (P), and 60% of the potassium (K) – but hardly any pathogens of public health concern (Höglund, 2001; Schönning, 2001). It is thus safe to use as a fertilizer for food crops after a relatively short storage time (see *O&M* below). Since feces contain disease-causing pathogens, they must undergo a treatment process before they can be used as fertilizer, for example dehydration or vermicomposting. Conventional composting is difficult due to the cool and dry climate coupled with a lack of C-rich bulking material. The latter is required to reach an optimal C:N ratio (between 15:1 and 30:1) and sufficient aeration for microbial decomposition (Anand & Apul, 2014; Winblad & Simpson-Hébert, 2004).

Figure 147: EcoSan toilet with separate collection of urine (front) and feces (back) (WaterAid, 2008a)

When feces dehydrate, evaporation and a small amount of amendments lower their moisture content from a median of 75% upon excretion (Rose, Parker, Jefferson, & Cartmell, 2015) to less than 25% (WaterAid, 2011). With so little moisture, most pathogens cannot proliferate but die off, and there are hardly any smells or flies (see *Benefits* below). The volume of the feces remains about the same, though, because organic matter hardly decomposes under such dry conditions and added bulking material makes up for the reduction. The feces do not turn into compost, but into a nutrient-, C- and fiber-rich mulch that can improve the soil's water-holding capacity (Tilley et al., 2014; WaterAid, 2011). Dehydration is suitable for Upper Mustang's semi-arid climate with little rainfall and high evaporation rates, while composting would be more effective in warm, humid areas (WaterAid, 2011).

Another option is vermicomposting where earthworms are used to degrade source-separated feces (Gårdefors & Mahmoudi, 2015; Hill & Baldwin, 2012). Unlike dehydration or composting in toilets without urine diversion, vermicomposting substantially reduces the dry mass of the fecal matter by almost 60% and no bulking material is needed (Hill & Baldwin, 2012). It leads to a stable, pH neutral end-product containing concentrated, plant-available nutrients from the worm castings, especially nitrates but also micronutrients (Dickerson, 2001; Hill & Baldwin, 2012; Hill, Baldwin, & Lalander, 2013). Several studies indicate that vermicomposting reduces pathogens significantly and more reliably than conventional composting (Gårdefors & Mahmoudi, 2015; Hill & Baldwin, 2012); the earthworms may lower the *E.coli* count by a factor of 100 compared to treatment without worms (Hill et al., 2013).

Required construction and materials

Urine-diverting toilet pans with lids for the feces hole can be retrofitted into the existing dry toilets. Lightweight fiberglass pans (Figure 148) are available for about NRs 1000/piece (US$ 10) from a company in Butwal, southern Nepal (R. Shrestha, personal communication, May 9, 2017). Those pans are much lighter than ceramic ones, therefore easier to transport and apparently also to clean (K. Neupane, personal communication, March 21, 2017). While the urine-diverting pans work well for both men and women when squatting, the urine drain is not suitable for urinating in a standing position so that separate urinals (Figure 149) might be necessary for men to optimize urine collection (Tilley et al., 2014; WaterAid, 2011).

Figure 148: Fiberglass urine-diverting pan (ENPHO, n.d.-c)

Figure 149: Ceramic urinal bowl, available in Pokhara

- Pipes of at least 50mm diameter should lead urine from the UD pans and urinals to storage containers (WaterAid, 2011).
- The storage containers should be airtight to prevent volatilization of ammonia (NH_3) which would lead to odors and the loss of plant-available N (Schönning, 2001; Schönning & Stenström, 2004). Black PVC barrels with an outlet tap for emptying have been successfully used elsewhere in Nepal (Figure 150); otherwise a container on wheels could facilitate transport. The container should be dimensioned for annual holding capacity in order to comply with the six-month storage guideline for Mustang's cool climate to eliminate fecal pathogens that may accidentally have contaminated the urine (Höglund, 2001). Urine collected over the summer months could thus be stored until the following spring. Based on quantities stated by Gantenbein and Khadka (2009, p. 20), fulltime use by 32 primary school children and 8 adults during six months would require a urine storage of 4.3m^3. Smaller PVC drums that require more frequent emptying have been installed in other Nepali UDDTs, but the storage time then falls short of the recommended period to reduce risks from fertilizing crops with potentially cross-contaminated urine (Schönning & Stenström, 2004).

Figure 150: Urine storage barrel with outlet tap (ENPHO, n.d.-e)

- For feces, large roller carts (Figure 151) or garbage bins (Figure 152) can be placed under each toilet to prevent moisture damage to the mud walls and make emptying of the storage more convenient and hygienic. Alternatively, if additional amendments (such as sawdust) can be used and ventilation improved (compare section *5.1.3* below) for better dehydration of the feces, no special collection container is needed. Wheelbarrows could replace baskets for transporting feces to the fields (Figure 153). If feces will undergo vermicomposting, roller carts or plastic boxes on wheels (Figure 154) can be used. For vermicomposting over the winter, tarps should cover the feces containers to keep the moisture in (G. Hill, personal communication, February 19, 2017).

  To reduce the required emptying frequency, the combined volume of the feces containers should be large enough to hold a few months' feces from all residents. According to different sources, the feces volume excreted by 40 adults over six months corresponds to about 1.6-2.3m^3, based on a more fibrous diet in low-income countries and assuming a density of 1.1g/cm^3 (Rose et al., 2015; WaterAid, 2008a). Considering that most residents at the Lo Kunphen School are children, this volume may be overestimated. However, amendments and/or bedding for the vermicompost will increase the volume. WaterAid (2011) suggests that for design purposes, about 100 liter per person should be calculated for six months, adding up to 4m^3 for 40 people. Depending on the number and size of storage containers, they might have to be emptied more than once over the summer.




Figure 151: Feces storage cart (Hill, n.d.)

Figure 152: Large garbage bin, made by Hilltake Company in Nepal (Hilltake, n.d.)

Figure 153: Wheelbarrow (Power Porter, n.d.)

Figure 154: Plastic box on wheels for vermicomposting (Gårdefors & Mahmoudi, 2015)

- EcoSan toilets often rely on ventilation pipes to remove odors and help dehydrate feces (or supply oxygen for degradation in composting toilets). WaterAid (2011) states that vent pipes are not always necessary, depending on the climate and moisture content of the feces as well as the expected standards. If used, ventilation pipes should have a diameter of ≥15cm, protrude 50-90cm above the roof, and be screened and capped to prevent flies and rain from entering (WaterAid, 2011). To improve air circulation, pipes can also be fitted with wind turbines as illustrated in section *5.1.3*.
- Materials that need to be imported from Pokhara or elsewhere in Nepal will incur a transport fee.
- Recurring costs: If the residents do not empty the feces storage themselves, labor fees will be necessary to transport feces to the fields. Urine is such a valuable fertilizer that farmers should be happy to pick it up for free, but until they are convinced of its benefit, they might also claim compensation for emptying Lo Kunphen's urine drums.

Operation and maintenance (O&M)

Use: For the system to function properly, no feces should end up in the urine section or vice versa. Such improper use would contaminate urine with pathogens and potentially clog the urine pipe, or lead to excessive moisture in the feces compartment and hamper the dehydration process. The toilets would then likely turn smelly, reducing social acceptance (WaterAid, 2011). UDDTs therefore require conscientious use, especially at the beginning when the concept is unfamiliar. To avoid accidental urination into the wrong section and to prevent odors and insects – which could spread fecal pathogens to food (Depledge, 1997) –, the feces hole of the pan should always be covered with a lid unless in use (WaterAid, 2011). Likewise, the door to the excreta storage room should be closed.

Since water cannot be used for anal cleansing in the proposed UDDT model, the school may consider providing toilet paper for the students. If the students have to purchase it themselves the expense might be too high, which then bears the risk of deteriorating hygiene or the "secret" use of water, which will damage the functioning of the system.

Dehydration: As indicated above, a small amount of amendments (for example ash or saw dust) still needs to be used after each defecation to control moisture in the feces chamber and speed up desiccation (WaterAid, 2011). Without any addition of urine and water, smells will be minimal and the feces will turn into largely inert, easy-to-handle material within about six months (WaterAid, 2008a). Toilet paper and female hygiene products should be collected in a separate garbage bin as they will not decompose in a dehydration toilet, irrespective of storage time (Tilley et al., 2014; WaterAid, 2011; Winblad & Simpson-Hébert, 2004).

Vermicomposting: If instead of dehydration, feces undergo vermicomposting, the requirements are somewhat different. Vermicompost consists of bedding material, organic material in the process of decomposing, worm castings, worms at different development stages, and other microorganisms (Dickerson, 2001). For the worms to successfully feed on feces and enable pathogens reduction, they require appropriate environmental conditions, including a suitable temperature and pH range, low NH_3 concentration and high moisture levels between 60 and 75% (Gårdefors & Mahmoudi, 2015; Hill & Baldwin, 2012). The most common earthworms used for vermicomposting are *Eisenia foetida* (brandling worms), a species native to Europe and Asia which can tolerate temperatures between 5 and 43°C and prefer compost and manure environments to plain soil (Dickerson, 2001; Gårdefors & Mahmoudi, 2015). Whereas their ideal temperature is around 25°C, they can survive in temperatures close to freezing and cocoons even below zero (Hill & Baldwin, 2012). According to Madhav Dhakal from ICIMOD, this earthworms species, imported from Pokhara, survived and multiplied during vermicomposting trials in Lower Mustang when kept inside or in a sheltered area, at least over the 3-year period he worked there (personal communication, April 13, 2017). Regarding pH, levels between 6.0 and 7.0 are ideal; if the pH is too alkaline due to urine entering the compost, the worms risk dying (Dickerson, 2001). To avert that, a well-buffering bedding material should be chosen (Gårdefors & Mahmoudi, 2015).

As for vermicomposting containers, plastic boxes seem to be the best choice: They do not give off any harmful chemicals and retain the moisture – an advantage in a dry climate like Mustang's. Thanks to their smooth surface they are also easy to clean and prevent worms from crawling out (Dickerson, 2001; Gårdefors & Mahmoudi, 2015). On the contrary, metal boxes may poison the worms, and while wooden boxes are better insulating and absorbent than plastic, worms might escape through cracks. The containers should be a maximum of 30cm deep to avoid that the weight from feces presses down too much, making the compost turn anaerobic which may kill the worms and lead to foul smells (Dickerson, 2001). In fresh feces, NH_3 concentrations may be unfavorably high for the worms and they will need a safety zone made up of bedding material into which they can retreat (Gårdefors & Mahmoudi, 2015; G. Hill, personal communication, March 1, 2017). Bedding ideally consists of cellulose-rich material that helps maintain aerobic conditions in the box, such as a mix of torn or rolled-up newspaper, cardboard, shredded dry plant material, sawdust, or topsoil (Dickerson, 2001; Gårdefors & Mahmoudi, 2015). Provided there is enough moisture, the worms can also decompose toilet paper (Gårdefors & Mahmoudi, 2015; Hill & Baldwin, 2012). The bedding should fill the containers up to about a third (Gårdefors & Mahmoudi, 2015) and needs to be moistened to the degree of a wet sponge before the worms are added (Dickerson, 2001). Since worms dislike light (Dickerson, 2001), the location of the boxes in dark storage rooms below the toilets would be ideal.

Toilet cleaning: The use of water for cleaning should be minimized as it dilutes the urine, which may prolong the time needed to inactivate fecal pathogens accidentally deposited in the urine section (Richert, Gensch, Jönsson, Stenström, & Dagerskog, 2010; Schönning, 2001; WHO, 2006). Only the floor around the pan should be cleaned with water; for the pan itself a damp cloth should be used (Figure 155). To prevent calcium and magnesium deposits in the urine pipes, a mild acid such as vinegar and/or hot water can be used, but only in the front section; the feces must remain dry (Tilley et al., 2014). Blockages in the urine pipes can be removed with a stronger acid or a solution made from two parts of water and one part of caustic soda (NaOH; Tilley et al., 2014).

Figure 155: Cleaning of a UDDT (ENPHO, n.d.-a)

Maintenance: The upkeep of UDDTs is inexpensive but more time-consuming than sewer-based sanitation systems, and lacking maintenance impacts not only the functioning of the toilets but also their appearance (WaterAid, 2011). Urine pipes should regularly be checked for blockages from precipitates, and the feces compartment for unwanted urine or water addition (WaterAid, 2011). If the latter happens, further awareness-raising must be initiated and more amendments added to absorb the moisture. Collection carts or bins must be located exactly below the chute – especially at the beginning it will be important to check that feces do not drop outside. If the container opening is too small, a funnel-like structure may have to be created around it to ensure collection of feces *inside* the container. From time to time the dehydrating feces pile needs to be evened out to allow for better drying (WaterAid, 2011). On the contrary, if vermicomposting is practiced, the content of the boxes must be kept sufficiently moist for the worms, if necessary by adding water (Gårdefors & Mahmoudi, 2015; G. Hill, personal communication, March 1, 2017). Otherwise there is little maintenance because the worms themselves aerate, mix and hygienize the feces (Hill & Baldwin, 2012). In the winter, the boxes should be covered with straw and a tarp for insulation, moisture retention and darkness, but sufficient air must still enter to keep the worms alive (Dickerson, 2001).

Emptying: The guidelines for urine storage before field application are intended to increase the safety of handling urine and eating urine-fertilized crops (Schönning & Stenström, 2004). The risk of pathogen transfer does not come from urine itself but from cross-contamination with fecal matter. After the recommended six months' storage at 4°C[14], though, only viruses might still survive (Höglund, 2001). Although health risks could be minimized if these guidelines were followed, R. Shrestha from ENPHO states that such long storage times are hardly adhered to in Nepal because they would require extremely large urine drums (personal communication, May 18, 2017). To make UDDTs more practical, Shrestha has advised users of shared facilities (such as schools) to store urine for a minimum of seven days and not touch it during collection and application by wearing gloves, aprons and face masks. He also suggests that fertilization guidelines be followed (further specifications in section *5.2.2*) and reminds that urine is not an enormous health hazard even if fecal cross-contamination *does* occur. In fact, the high NH_3 content and elevated pH (~9) of urine inactivate many pathogenic microorganisms because the latter are used to a neutral pH around 7 (Höglund, 2001; Schönning & Stenström, 2004). As advised above, urine for fertilization should thus be as concentrated as possible to achieve maximal pathogen reduction.

With dehydration, emptying of the feces compartment should be done before the storage containers are too full to push or would cause the content to spill. If no special containers are used but more amendments added instead, the excreta mound should be removed as long as it is still manageably low; the higher it piles up, the more difficult emptying becomes (Lo Kunphen teacher, personal communication, July 21, 2016). Dehydrating feces should fill up the container or storage room less quickly than in the past when they were collected together with urine and more amendments.

With vermicomposting, less frequent emptying will be necessary because the feces volume will be reduced thanks to the break-down of organic matter (Gårdefors & Mahmoudi, 2015). The finished compost should be separated from the worms once the bedding disappears (Dickerson, 2001). This can be done by moving the digest-

[14] It should be noted that these guidelines apply to UD toilets used by various people such as in schools or public places. In families, pathogen transmission is more likely to happen from person to person rather than via urine. Therefore, one week's storage time before urine application on edible crops is considered enough, as long as the produce is used for home consumption (Schönning & Stenström, 2004; WaterAid, 2008a; WHO, 2006).

ed excreta to one side of the box and adding new bedding and fresh feces to the other side; the worms should then naturally crawl into the area with the new bedding so that the composted feces can be taken out. Alternatively, the entire content of the bin can be spread out in small mounds on a tarp in the open. The worms will move to the bottom because they dislike light. After about ten minutes the top of the mounds can be removed down to where the worms are, and this process needs to be repeated until one has a ball of worms (Figure 156) and a pile of compost (Dickerson, 2001). The worms can then be added to the vermicomposting box again once it has been prepared with new bedding.

Figure 156: Earthworms (*Eisenia foetida*) used for vermicomposting (Gårdefors & Mahmoudi, 2015)

Regarding disposal, fresh feces on top of a dehydration pile are highly pathogenic and a health risk when being handled and applied to the fields (Rajbhandari, 2008; Schönning & Stenström, 2004; WaterAid, 2011). While vermicomposting is better at removing *E.coli*, it cannot eliminate *Ascaris* ova, either, and further hygienization is required (Hill et al., 2013). To ensure safe reuse, it is therefore important to handle feces and compost carefully once they are transported to the fields and allow for sufficient decomposition time before applying them to crops. Related recommendations shall be further discussed in section *5.2.2* below.

Benefits

- Separating urine from feces solves the moisture problem and at the same time provides an excellent, readily usable and practically sterile fertilizer. Urine reduces the need for artificial fertilizer which is not only costly but also energy-intensive in production (N), a non-renewable resource (P from rock phosphate), and needs to be transported from far away (Langergraber & Muellegger, 2005; WaterAid, 2008a). Since chemical fertilizer is currently not used in Lo Manthang, urine is much needed to replenish agricultural soils. WaterAid (2011) suggests that urine and digested feces from UD toilets can create income-generating opportunities if they are marketed. The Lo Kunphen School could provide urine to farmers (for free or at a low cost), but even using it on the *amchi* family's field to produce vegetables for the school might save money: Urine application may increase yields and has been reported to work as a natural pesticide to control plant diseases (Bing, 2014; WaterAid, 2008a). As mentioned in section *2.1.1*, current UD toilet users have also noted that the quality and taste of vegetables improves when using urine, which has helped convince them of its economic and nutritional value (Bing, 2014).
- UDDTs may increase vegetable production and provide an opportunity for school children to learn about the nutrient cycle and benefits of closing-the-loop technologies (Adams et al., 2009). Students' involvement in maintaining the toilets as well as gardening can serve to practically demonstrate the usefulness of human waste – the nutrients excreted by each person are almost sufficient to produce his or her food (WaterAid, 2011) – and daily tasks can be linked to various scientific and hygiene-related topics they might learn about in class.
- Collecting urine and feces separately can reduce health risks and simultaneously increase convenience and comfort. Thanks to drier feces and no mixing with water, disease transmission is lowered, as is the risk for leaching, surface and groundwater pollution. Pathogens are not only contained but also more easily reduced, which makes the handling of dry feces safer compared to conventional pit latrines, let alone cesspools (Schönning & Stenström, 2004; WaterAid, 2011). Furthermore, UD reduces the volume of pathogenic material as the feces dehydrate, so that the collection system fills up less quickly and transport to the fields will be less burdensome (Schönning & Stenström, 2004; WaterAid, 2011). Feces alone also do not require much bulking material, which helps minimize the volume (Depledge, 1997). Compared to composting toilets, the moisture content in the feces compartment of UD toilets is reduced by half (WaterAid, 2011), which is particularly advantageous for the Lo Kunphen School as amendments are in short supply. According to Schönning and Stenström (2004), adding one or two cups of bulking material after defecation are sufficient for dehydration; for vermicomposting, amendments are not needed at all (G. Hill, personal communication, March 1, 2017). UDDTs will also increase comforts as there will be hardly any problems with odors or flies

as long as the toilet is properly used and maintained (Schönning & Stenström, 2004; Tilley et al., 2014; WaterAid, 2011; Winblad & Simpson-Hébert, 2004).

- A definite advantage of UDDTs is that they continue the tradition of dry toilets which save precious water resources from being poured down the toilet and polluted with nutrients and pathogens (WaterAid, 2008a). The technology is therefore especially appropriate in areas such as Upper Mustang where water scarcity is an issue (WaterAid, 2011).
- Finally, UDDTs are also gainful from a financial perspective: They "require much less investment as they need no water for flushing, no pipelines for the transport of sewage, and no treatment plants and arrangements for the disposal of toxic sludge" (WaterAid, 2011, p. 38). On the other hand, in order to be successful, they do entail higher expenses than other sanitation systems for awareness-raising, continued training and monitoring (WaterAid, 2011).

Shortcomings and challenges

- Besides requiring a paradigm shift among stakeholders who prefer or aspire to use flush toilets (WaterAid, 2011), the double-hole pan will also require new user practices. Developing new habits will necessitate instructions and may take a while to achieve. According to R. Shrestha, UDDTs are difficult to manage beyond household scale because every user needs to be trained to use them properly (personal communication, March 29, 2017). He cautions that this might be especially challenging with lots of students. Besides, WaterAid (2008a, 2011) also reports that small children sometimes urinate into the feces compartment because the pan is too large for them. Nevertheless, Shrestha was involved in a project in 2011 where ENPHO *did* build UDDTs at a school in Humla District, but unfortunately the author had no possibility to learn from that experience because there has been no follow-up and ENPHO lost the school's contact details.
- All consulted reports and WASH practitioners familiar with UDDT projects agree that training of users is absolutely key to the success of the technology, especially to increase knowledge and prevent O&M problems (Bing, 2014; Rajbhandari, 2008; WaterAid, 2008a; 2011; R. Shrestha, K. Pudasaini, S. Pokharel, personal communication, March 29, April 13, May 11, 2017, respectively). Training needs to be comprehensive and continuous, addressing a range of issues, including awareness-raising, correct use of the toilet, maintenance, and the safe reuse of urine and feces. In order to avoid cross-contamination, users should be aware of the different composition and pathogen distribution between urine and feces so they will understand why it makes sense to separate the two. Furthermore, anyone taking care of UDDT maintenance should know the importance and functioning of the different components of the physical infrastructure and receive training on how to solve technical problems. A survey among 36 UD toilet owners in Darechowk revealed that those who had attended six days of training were better equipped to handle maintenance and repair issues and had a better understanding of urine sanitization and pathogen transfer than those who had shorter training or none at all (Bing, 2014). Training made the users more capable, confident and responsible to deal with challenges related to the technology. Besides, proper storage and field application of both urine and feces must be taught to UDDT users and farmers so they will be able to reap the full benefits, ensure pathogen die-off and human health. Even in Darechowk, a VDC with over 50% EcoSan toilets that have been in use for a few years, Bing (2014) found that

> (…) further knowledge and continual training regarding [the] spread of disease[s] and proper handling of urine [are] needed for the population to fully accept the sanitation system. (…) The overall recommendation is to provide more comprehensive training in operation and maintenance and handling of urine in order to achieve optimal use and adaption of the sanitation system. (p. II)

Based on experience in other parts of Nepal, follow-up, monitoring and regular visits from UDDT professionals will be necessary even after implementation to ensure that users cope well with the technology (Bing, 2014; Rajbhandari, 2008). Without proper training and users' commitment to follow the instructions, many things can go wrong. Lacking care, knowledge and capacity for adequate use and management may affect the user friendliness of the toilets and lead to people's dissatisfaction with the system overall (Bing, 2014; WaterAid, 2008a).

- As mentioned above, incorrect use of UDDTs can cause system failure and bad odors due to insufficient aeration or dehydration. At the Lo Kunphen School, this might happen if no ventilation pipes can be installed and/or if the collection of feces in PVC garbage bins leads to anaerobic conditions. Unlike in a well-aerated compost heap where decomposition is rapid and odor-free, the feces might be too densely packed and undergo slower anaerobic degradation with foul-smelling emissions (WaterAid, 2011). To counteract that, the users will still need to add small amounts of bulking material after defecation. Since a lack of amendments has been at the core of the school's problems with the traditional dry toilets, only the purchase of external materials may be able to provide a solution. For instance, saw dust could be bought from Sonam Drugyal's (Tib. *bsod nams 'drug rgyal*) carpentry workshop in town for NRs 250 (US$ 2.5) per bag; about one bag per week should be sufficient. Otherwise a truckload of (fresh) dung could be bought for NRs 7,500 (US$ 75); it would need to be dried before use, but might last for a whole summer if only used as amendment in the toilets (guesthouse owner, personal communication, April 20, 2017).
- UDDTs require specific maintenance and repair skills which users might struggle with. One of the main problems encountered by UD users in Darechowk was blockage of the urine pipe, which almost two thirds of the households that Bing (2014) interviewed had experienced. Blockage occurred mostly due to organic matter on shoes and insects that accumulated in the urine drain and eventually blocked the pipe. Functionality and appearance of the toilets were then compromised by the small diameter of holes in the urine drain, pipes below 50mm diameter and users' limited know-how to unblock the pipes, so that 14% of households discontinued urine collection altogether. Bing's study participants also complained about the quality of the fiberglass pans which scratched, cracked or even broke frequently. One UD toilet owner mentioned subsequent difficulties with cleaning because feces and urine got stuck in the cracks of the pan and produced unpleasant smells (Bing, 2014). Bing thus suggests that abrasion tests should help identify the best pan material to avoid such problems in the future. In a study by WaterAid, only 12% of UD users reported challenges with cleaning, though pouring cleaning water in to the feces hole was a risk for people used to water toilets (WaterAid, 2008a). At the Lo Kunphen School, this could be prevented with clear instructions and supervised cleaning until appropriate habits have been developed.
- Urine and feces will still need to be removed manually (WaterAid, 2011) – which is one of the reasons that had prompted the school to change to a pour-flush system. Not only does such handling increase exposure to pathogens, but it also involves considerable physical labor. If the feces carts are used up and until emptying, health risks will be higher than if feces were stored for six months before transport. Even with dehydration, protozoa, helminth ova, and viruses may survive (Hill & Baldwin, 2012). However, exposure to solar radiation and dry air by the side of a field over the winter might inactivate pathogens more effectively than further storage in collection containers. Risks during transport can be minimized through protective clothing and personal hygiene afterwards, which is also advised by WaterAid (2011) and the WHO (2006) (compare section *5.2.2* below). As for vermicomposting, separating worms from the compost could be a lengthy procedure, though the compost would be safer to handle than desiccated feces. Despite the benefits of vermicomposting, practicing it would be an experiment in Upper Mustang as it is uncertain whether (imported) worms would actually be able to withstand the harsh climate or die from freezing – which they should be protected against (Dickerson, 2001). Furthermore, preparing vermicomposting boxes and ensuring adequate moisture levels might be more time-consuming than what the school is able or willing to invest.
- As for urine, unless the school applies it on the *amchi* family's fields, cooperation with farmers who come to collect it from the school will need to be established. This may be challenging because using liquid urine is new in Lo Manthang and may not be well-accepted initially. Moreover, its transportation and field application is more difficult than dry fertilizer, and odors may be unpleasant (Etter, 2009; WaterAid, 2008a). In Bing's (2014) study in Darechowk, about one fifth of interviewed UD toilet users reported that especially carrying heavy urine containers to far-away fields was tough; some said they spilled urine on themselves and 15% felt dirty after handling it. A similar number complained about bad smells when applying urine, but others eliminated this hassle by simply wearing a mask and gloves. One solution to avoid spillage and apply urine more precisely is

the use of watering cans, and for dealing with transportation challenges a mechanized system may be considered in the long run (Bing, 2014), though this would be a major undertaking and only of interest if UDDTs became more widespread in Lo Manthang.

Replication potential

The replication potential of UDDTs currently seems limited in Lo Manthang. For local households, urine separation may not be necessary as long as they have enough ash for traditional dry toilets to function well. Besides, the cold climate might cause urine pipes to freeze in the winter, even indoors as normally only one central room is heated (Lo Kunphen teacher, personal communication, April 29, 2017). Thus, the UDDT system may only work in the summer, which is suitable for the school but not for households that remain in Lo Manthang year-round. Furthermore, the cost of building a UDDT is a bit higher than for ordinary dry toilets, which may present an obstacle for poor families (WaterAid, 2008a).

5.1.3 Dry Toilets Without Urine Separation

Brief explanation

To counter moisture problems in the traditional dry toilets, the best option is to collect urine separately (see section *5.1.2* above). If that is not possible or desired, other measures are necessary, ideally in combination, to ensure hygienic conditions and sanitization of excreta. The toilets should still be located on the second floor with the excreta storage below, but the following adaptations are suggested:

1) Clean, attractive, odorless urinals (for example ceramic bowls, Figure 157) can encourage male students and staff to urinate separately and only use the dry toilet for defecation, which considerably reduces moisture, smells and flies (Depledge, 1997). The WHO guidelines for WASH in schools point out that urinals are also easy for children to use and "quicker and cheaper to build than toilets" (Adams et al., 2009, p. 22). If urinal bowls are too expensive or too bulky and heavy to transport, a simple "home-made" version can be created by putting a large funnel on top of a jerrycan (Figure 158). A ping-pong ball inside the funnel can help block smells and ammonia volatilization (S. Pokharel, personal communication, May 11, 2017).

Figure 157: Urinals at Thiksey Monastery, Ladakh (Neild, 2016)

Figure 158: Simple urinal made from a funnel above a jerry can

2) An alternative amendment should be used to absorb moisture. Based on interviews and investigations in Lo Manthang, the only available substitute to ash is to buy saw dust (Figure 159) from one of the carpentry workshops in Lo Manthang (see previous section) or dung which comes fresh in truck loads and needs to be spread out and dried first. These materials support dehydration, contrary to sand – which is abundant in Upper Mustang but cannot be used as an amendment as it does not absorb moisture (R. Shrestha, personal communication, March 29, 2017).

3) Ventilation of the storage chamber is another way to dehydrate feces and minimize smells (WaterAid, 2008a). Black pipes with roof-top wind turbines (Figure 160) can improve air circulation and evaporation of liquids. The pipes should protrude at least 50cm above the roof so that they receive solar radiation, which causes the air inside to heat up and increases natural convection (Depledge, 1997; WaterAid, 2011). Besides, wind blowing across the top of the pipe improves ventilation even more than convection (Depledge, 1997). However, for ventilation to work properly, the storage chamber needs to be as airtight as possible (Arve Heistad, personal communication, December 21, 2016).

Figure 159: Sawdust, an alternative amendment for dry toilets

Figure 160: Roof-top wind turbine ventilator

4) To reduce moisture- and smell-related problems, avoid leakage into walls, and facilitate emptying of the excreta storage, a movable container such as a cart, garbage bin on wheels or a large wheelbarrow can be used as described in the previous section (Figures 151-153).

Required construction and materials

- Ceramic urinal bowls for boys and male teachers
- Tiles for the surfaces surrounding the urinals to improve hygiene (WaterAid, 2011)
- Connecting pipes and urine storage drum
- Depending on the amount of urine entering the storage chamber – that is, whether the school invests in separate urinals or not – around two large bags of saw dust would be required per week. This would add up to running costs of about NRs 500 (US$ 5) per week or around NRs 13,000 (US$ 130) for the whole summer season.
- For increased air circulation and proper functioning of the roof-top ventilator, the storage chamber needs to be made as airtight as possible. Windows and gaps should be sealed, the door/opening of the storage chamber likewise.
- Removable lids should be placed on the toilet holes; this will also help reduce odors and flies.
- Ventilation pipes of smooth, matt black PVC or polyethylene (Ø ≥15cm) should be installed, long enough to reach from the excreta storage to at least 50cm above the roof and covered with fly screens (Depledge, 1997; WaterAid, 2011)
- Roof-top wind turbine ventilators can then be attached to the top of the pipes. In case there is no Nepali manufacturer, such ventilators can be bought from India for the equivalent of NRs 4,800 (US$ 48) per piece (Dura Plast, n.d.).
- For excreta storage, carts, drums on wheels or large wheelbarrows can be used, made of zinc, polyethylene, fiberglass, or PVC (Depledge, 1997). Ideally, there would be twice as many excreta storage containers as toilets (double vault principle) so that the feces can decompose for at least a few months before being handled to reduce the risk of pathogen transfer.

Operation and maintenance (O&M)

- Using and cleaning the urinals: As little water as possible should be used so as not to dilute the urine and ensure pathogen die-off (Schönning, 2001). For cleaning, the urinals should be wiped with a wet cloth (Tilley et al., 2014).
- Using the dry toilets: No water should enter the storage chamber; toilet paper and female hygiene products must be collected separately as they will not decompose under dehydrating conditions. The toilet hole should be covered with a lid after use.
- The ventilation pipe and wind turbine should be checked periodically to make sure that the protruding part on the roof is not shaded by any other structures and that the turbine is not obstructed from turning (Depledge, 1997).
- The excreta storage carts should be replaced whenever they are full, or before they get too heavy to push. Excreta should undergo further decomposition/co-composting for at least six months before being used as fertilizer (Tilley et al., 2014). This can be next to agricultural fields, but without contact to irrigation channels or waterways to avoid the spread of pathogens (for details see section *5.2.2*).

Benefits

- Dry toilets prevent wastage and pollution of precious and scarce water resources (Langergraber & Muellegger, 2005). Adapting the traditional toilets to present circumstances by integrating innovative features could be ground-breaking for their continued use, in Upper Mustang and beyond. Waterless toilets are the solution for the future (Winblad & Simpson-Hébert, 2004), and Lo Kunphen can lead the way by setting an example.

- Nutrients from excreta and separately collected urine can be recovered and safely used as valuable fertilizers in agriculture after minimal treatment. Such practices close the nutrient cycle between food and field and maintain soil fertility without the need to import expensive chemical fertilizers (Langergraber & Muellegger, 2005).
- The traditional dry toilets require no water, no plumbing, no septic tank, no sewage pipe and wastewater treatment system. Pathogens are contained rather than diluted or spread via water, which greatly benefits public health. Overall, such toilets will be cheaper and more sustainable (Langergraber & Muellegger, 2005; Winblad & Simpson-Hébert, 2004).
- Using hygienic urinals and well-maintained dry toilets will considerably reduce bad odors compared to the current pour-flush toilet and urinal ditch.

Shortcomings and challenges

- The toilets will remain smelly unless the use of urinals is strongly encouraged, the amount of urine entering the storage chamber reduced and saw dust added to the feces. A wet storage chamber combined with uncovered toilet holes and open windows and doors could become a breeding site for flies (Depledge, 1997).
- In view of the local mud masonry with lots of openings, making the excreta storage airtight will be challenging and ventilation might not substantially improve.
- Solar heating of the excreta storage would speed up the dehydration of feces and pathogen die-off (Schönning & Stenström, 2004; Winblad & Simpson-Hébert, 2004; R. Shrestha, personal communication, March 29, 2017). Unfortunately, the location and layout of the Lo Kunphen School inhibit the use of direct solar radiation, except on the roof which is already used for the school's solar power plant.[15]
- While moist conditions would be suitable for vermicomposting as described in the previous section, urine is likely to make the pH of the excreta pile too alkaline for the worms' tolerance range (Dickerson, 2001; Gårdefors & Mahmoudi, 2015). Thus, vermicomposting has to be ruled out as an option.
- The initial investment for the suggested improvements may appear high, especially for the urinals. The roof-top wind turbine may have to be imported from India if not available in Nepal. Furthermore, buying saw dust will be a continuous running cost.
- Emptying the storage carts might be strenuous and still be perceived as unpleasant, lower caste labor. If the school does not empty the carts themselves, extra costs will arise for hired workers.

Replication potential

Local households could easily upgrade their traditional dry toilets by integrating one or several of the suggested improvements such as simple urinals and wheelbarrows for facilitating excreta transport. However, the availability of amendments might be a limiting factor, especially if families also increasingly use gas instead of dung for cooking and produce less ash. Saw dust as a substitute is in short supply, therefore only an individual solution for the Lo Kunphen School and not a possibility for the whole town. Without alternative amendments, urine diversion seems to be the only option to keep the dry toilets functioning.

5.1.4 Pour-Flush Toilets

Brief explanation

If the Lo Kunphen School decides to continue using pour-flush toilets, it is important to repair and complete construction of the second toilet on the upper floor which is currently not being used due to urine leakage into the wall. The only functioning toilet on the ground-floor is not enough for the almost 40

[15] Building toilets or storing excreta on the roof, above people's living and working spaces and thus their heads, would be against cultural norms – besides problems with leakage and the impracticality of transporting dehydrated excreta two floors down upon emptying.

resident students and staff. According to Nepali WASH standards for schools, one toilet is expected to serve no more than 20 people and there must be separate facilities for boys and girls (GoN, 2010a, 2016b), which is also required by the WHO guidelines for schools (Adams et al., 2009). The author recommends that the ground-floor toilet with urinals be used for boys and the upper floor toilet for girls. If desired, a UD pan can be installed in the girls' toilet and urine for reuse led to a storage drum on the ground-floor. Further addition of urine to the pipe from the ground-floor urinal should be avoided as it goes to the drainage ditch along the city wall and discharges into the open without treatment.

Besides making the second pour-flush toilet functional, the ground-floor toilet and urinal area will need to be improved for better hygiene and comfort. Malfunctioning drainage, the cemented urinal ditch in front of the toilet cubicle and insufficient maintenance are causing puddles and extremely unpleasant odors. The toilet could be substantially upgraded by replacing the urinal ditch with easily cleanable ceramic urinal bowls (Figure 157 in section *5.1.3* above), tiling the surfaces around the toilet pan and urinals, and unclogging the drains. Furthermore, odors can be minimized by installing an S-bend with a water seal below the toilet pan (Narain, 2002). Finally, consistent user habits (flushing) as well as cleaning routines and practices will contribute to a clean and odorless toilet environment.

In order to provide a separate staff toilet, an amendment such as saw dust or dung should be bought so that adults can keep using the traditional dry toilets behind the kitchen. Since there are only eight staff members, the quantities of urine and thus the requirement for amendments will be much smaller than if all students used those toilets.

Required construction and materials

- On the upper floor: All cracks in the cement must be properly sealed, pipes checked for leakage and fixed or replaced if necessary. If a UD pan is installed, connecting pipes to a urine storage barrel on the ground-floor will be required.
- On the ground-floor: To improve the urinal area, ceramic bowls should be fitted, ideally surrounded by grouted tiles to facilitate cleaning, prevent urine leakage and bad odors. Likewise, toilet walls should be tiled up to a height of 60cm to facilitate cleaning (WaterAid, 2011). If urinal bowls are too expensive or difficult to transport, the homemade "jerrycan-funnel urinals" (Figure 158 in section *5.1.3* above) would still be more hygienic – if used precisely – than the current cement ditch. Instead of disposing of urine into the narrow channel along the row of trees, it could be collected and used as a valuable fertilizer. If either version is not feasible or desired, it would be wise to discontinue using the urinal area altogether, or install taps and use it for hand-washing instead.
- A storage drum on top of the toilets should provide enough water for at least one day's flushing and anal cleansing needs, amounting to about 300 liters based on an estimate of 7.5 l/p/d. It can be filled by hose and pump from one of the public taps.
- Pipes from the water drum should lead to a small tap in each toilet. Jugs or small buckets of appropriate size should encourage flushing and anal cleansing without promoting excessive water use.
- To prevent puddle formation of water and urine, the floor needs to be sufficiently inclined so that spilled water naturally flows towards the drains. If this is not the case, the slope of the floor might have to be increased by adding cement – or tiles which additionally simplify cleaning and improve hygiene.
- The drains need to be unclogged. The use of harsh chemicals can be circumvented by first trying household cleaners to open the drains. For example, a quarter of a cup of baking soda (sodium bicarbonate; $NaHCO_3$) and half a cup of white vinegar can be poured down the drain, left to act for a while, and then flushed with boiling water (Monterey One Water, 2017). More persistent blockages can be dissolved with a stronger acid or a caustic soda solution as described in section *5.1.2* above. If the drainage pipes keep getting blocked, it might be due to too narrow pipes or unsuitable conduit layout (for example, right angles), which needs to be corrected.

Operation and maintenance (O&M)

At present, it seems difficult to keep the toilets adequately clean due to a lack of water and inconsistent user practices, for instance, forgetting to flush after use. Infrastructural improvements such as a water storage system and taps with running water in each toilet should enable consistent cleaning habits, but those of course also depend on training and commitment. Dry materials (toilet paper, menstrual hygiene products, etc.) should not be thrown down the toilet but collected separately in a garbage bin to avoid clogging (Tilley et al., 2014). Clear instructions and repeated training may be necessary to ensure that all students and staff keep the toilet clean and odorless – without wasting water.

A daily cleaning routine should be maintained and monitored by teachers, in accordance with guidelines by the WHO (Adams et al., 2009). Student involvement is desired to raise awareness and promote the development of cleaning habits, as long as there is a fair, gender-neutral rotational schedule and cleaning is never used as a punishment. In terms of products used for cleaning, some teachers and the headmasters advocated more frequent use of commercial toilet cleaners to improve cleanliness and reduce smells. However, alternative household products such as baking soda ($NaHCO_3$, see Figure 161) may be preferable for environmental and budgetary reasons. Baking soda can be sprinkled on the toilet pan, scrubbed with a toilet brush and flushed with plain water (Monterey One Water, 2017).

Figure 161: Baking soda, available in a supermarket in Pokhara

Regarding the concern that the toilet cleaner *Harpic* might destroy the beneficial microbes in the cesspool, users can be reassured that the risk is minimal: Studies have shown that when used in the recommended quantities, commercial cleaning agents should not have any significant nor long-term negative effect on microbial communities in the cesspool (Edwards, 1996; Gross, 1987). Nevertheless, if commercial toilet cleaners are used, it is best to stick to the same product instead of switching between products or brands because the beneficial microbes in the cesspool learn to tolerate it (British Water, 2008).

Benefits

- Increasing the number of toilets to at least two for students and one for staff will greatly improve convenience. There will be shorter waiting times and more privacy, especially thanks to gender separation of the toilets. Adolescent girls will have the opportunity to wash reusable sanitary pads and maintain personal hygiene in private. This is particularly important as the lack of such facilities otherwise leads to high school drop-out rates among girls (GoN, 2016b).
- User comforts and hygiene will increase substantially if bad odors can be controlled and surfaces kept clean thanks to the above-mentioned improvement measures (tiling, ceramic urinals, well-functioning drains and an odor-seal below the toilet pan).
- Consistently following a daily cleaning routine will improve sanitary hygiene, thereby curbing pathogen transmission and potentially reducing the number of gastrointestinal infections such as diarrhea. At the same time, students become aware of the value of clean toilets and develop hygiene habits for the future (Adams et al., 2009).

Shortcomings and challenges

- Using precious and scarce clean water to flush a toilet is not sustainable, particularly in a region with limited water resources such as Upper Mustang. It will be the users' responsibility to avoid wasting water, which will be difficult to control and enforce.
- Since micro-organisms need moisture and nutrients to survive (Schönning & Stenström, 2004), pathogens may proliferate in wastewater and make it a health risk. Contrary to EcoSan systems, flush toilets do not sanitize excreta. The more the feces are diluted, the larger the volume of pathogenic slurry that will need to be treated or safely disposed of – which is one of the reasons why Narain (2002) has called flush toilets "ecologically mindless" (p. 1). While the toilet interface may be in line with users' expectations, such toilets just transfer the pollution problem in space and time. Lo Kunphen does not have a solution yet to the question what will happen once the school's cesspool is full (see section *5.1.5* below).
- If the nutrients from excreta end up buried in a pit – or washed down the river – they will become unavailable for reuse in agriculture, even though Lo Manthang's fields and production would benefit from this natural fertilizer and the organic matter contained in excreta.

- As for the functioning of pour-flush toilets, Tilley et al. (2014) note that they are more prone to clogging due to the small amounts of flushing water, which might complicate maintenance in the long run. Besides, they will most likely freeze in the winter as has been observed by local guesthouse owners as well as inhabitants of the climatically similar region of Ladakh in Northern India (Gondhalekar et al., 2015).
- Since water toilets are incompatible with the traditional architecture, further investments will be needed to prevent leakages.
- Repairs and problems with the piping might be beyond the school staff's capacity and would probably require a professional plumber.

Replication potential

Based on the inherent problems with pour-flush systems, the author does not consider their replication advisable for Lo Manthang. The construction of an ever greater number of water toilets would disregard the region's natural and climatic conditions while also aggravating the above-mentioned environmental and public health risks. Besides, the required infrastructure would be too costly for most residents living in traditional buildings, and there is hardly any space for the construction of cesspools, especially in the historic part of town surrounded by the city wall. By opting for pour-flush toilets, Lo Kunphen might give up its role model function because the system as currently operated is not sustainable.

5.1.5 Blackwater Disposal for Pour-Flush Toilets

Brief explanation

The pour-flush toilet at the Lo Kunphen School has been discharging wastewater into the cesspool in front of the school since summer 2015. It is unknown to what level the latter is currently filled, but based on the experience of the monastery and guesthouses which have used the same type of cesspools for several years, it is likely to fill up within four to five years. Especially the cemented sidewalls and clogging of the infiltration surface at the pit bottom will inhibit infiltration, and with continued use desludging will become necessary after shorter intervals. While pollution of groundwater seems to be a minimal risk in Lo Manthang, removing the slurry will be a serious health hazard for workers as well as anyone getting in touch with it at or around the secondary disposal site (Pickford & Shaw, 2005). Depending on current infections, the residents' excreta may contain a high pathogen load including giardia, helminths, hookworms, viruses and bacteria (WaterAid, 2008a). WaterAid (2008a) also cautions that disease-causing organisms are likely to spread further into the environment and pollute waterways unless the sludge is stabilized before disposal. Stabilization could for instance be improved with planted drying beds (Tilley et al., 2014), but the Lo Kunphen School does not have any space in the immediate surroundings for such treatment.

The lack of space in the vicinity of the school is also a prohibiting constraint on the implementation of any other alternative wastewater treatment system such as a CW or infiltration trenches for the effluent of the cesspool. Despite the headmasters' initial interest, the production of biogas seems unrealistic in Upper Mustang's climate: G. S. Gurung from the WWF stated that experiments had shown very little production, even in underground digesters, which was supported by R. Shrestha from ENPHO (personal communication, March 27 and 29, respectively) and Tilley et al. (2014) who pointed out that below 15°C biogas production would be very limited. In fact, anaerobic fermentation is most suitable for subtropical and tropical climates as it works best at mesophilic or thermophilic temperatures between 30-40°C or 50-60°C, respectively (Khatavkar & Matthews, 2013; Tilley et al., 2014). In cool climates, the construction and cost necessary to insulate or heat digesters make biogas production unreasonably expensive (Bates, 2012). Besides, human waste from the pour-flush toilet would have to be mixed with animal dung or other organic waste and an equal amount of water in order to reach the required consistency and a C:N ratio of 20-30:1 (Mang & Li, 2009; WaterAid, 2008a). Very low C:N ratios would lead to a high pH and may kill the bacteria necessary to produce methane (Mang & Li, 2009). Since there is already a shortage of dung and no organic waste in Lo Manthang – one of the reasons why the Lo Kunphen School is lacking amendments for the dry toilets – a biogas digester is hardly the right solution. WaterAid (2008a) also considers biogas digesters unsuitable for areas facing water scarcity because of the need to dilute excreta.

In the end, improving the functioning and longevity of the current wastewater disposal system seems to be the only viable – though not ideal – option if pour-flush toilets continue to be used at the Lo Kunphen School. For this purpose, the following measures are suggested:

Required construction and materials

- A second cesspool should be built next to the first one so that use can be alternated. Once the first cesspool is full, it can be left to rest – for further infiltration and decomposition – until the second one has filled up. By that time, the volume of slurry to remove from the first pit as well as the pathogen load will have been reduced significantly (Tilley et al., 2014). There needs to be at least 1m distance between the cesspools to avoid cross-contamination between the one in use and the resting one. The pipes connecting the toilet to the cesspools must have a junction that can be blocked so that only one cesspool is used at a time (Tilley et al., 2014; see Figure 162).

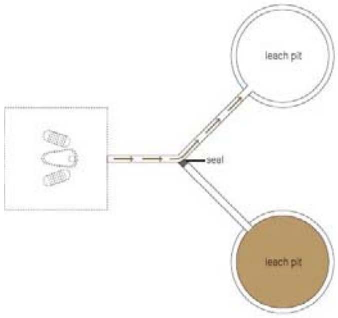
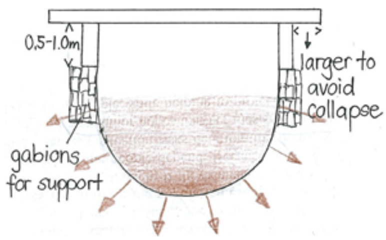


Figure 162: Twin pits for pour-flush toilet; idle pipe sealed at the junction (Tilley et al., 2014)

- The walls of the second cesspool should be U-shaped and not cemented all the way down but only for the top 0.5-1.0m (Figure 163). This will increase the infiltration surface and prevent the pit from filling up too rapidly due to clogging (A. Heistad, personal communication, December 21, 2016). To avoid collapse, the cemented slab at the top should be larger than the pit opening and the sides can be supported with rocks. Depending on the size of the cesspool, a support pillar might be necessary. All cemented structures should be reinforced with iron bars. If possible, the existing cesspool should also be made more permeable after it has been emptied the first time: The lower part of the cemented side walls should be removed or at least replaced with stone masonry or gabions (cages of galvanized steel wire filled with rocks) so as to allow infiltration through the gaps of the rocks (Figure 164).



163 infiltration on all sides

Figure 163: Sketch of cesspool shape for improved infiltration

Figure 164: Gabions to support the side walls of the cesspool (Contours Landscapes, n.d.)

- Connecting pipes and a plug for the junction will be necessary in order to switch blackwater flow to the second cesspool once the first one is full (Tilley et al., 2014).
- I. M. Amatya from Tribhuvan University recommends that the cesspool should be tightly covered and insulated to keep the temperature in an optimal range for bacteria even in the winter (personal communication, August 7, 2016). An ideal cover would be 15cm of soil on top of the cement lid, then a plastic layer, and another 15cm of soil. The soil should not be wet, and there needs to be drainage around the cement structure. Gutters should not pour water onto the cesspool cover.
- To avoid clogging of the infiltration surface, both cesspools can be inoculated with about 1 kg of cow or horse dung to promote the development of a varied community of beneficial microorganisms that will break down the organic matter (I. M. Amatya, personal communication, August 7, 2016). Furthermore, strips of carpet or other fabrics can be hung from the side walls and/or the cover of the cesspool to enlarge the surfaces for attached growth of microbes.
- Labor for excavating a second pit, cementing the side walls, emptying the cesspool every few years (interval difficult to predict) and transferring the fecal sludge to a composting site / disposal pit (which will also have to be dug)

Operation and maintenance (O&M)

- Only one cesspool should be used at a time and then left to rest for at least two years while the other one is filling up (Tilley et al., 2014). Periodical checking of the cesspool will be necessary to determine when it is time to switch, that is, when the slurry reaches 0.5m below the top (Pickford &

Shaw, 2005). The connection pipe to the cesspool that is not in use needs to be sealed properly at the junction (Tilley et al., 2014).

- The fecal sludge needs to be disposed of safely, out of reach of people, and without direct contact to crops and waterways. It should not indiscriminately be dumped, but preferably mixed with soil and composted within a designated area. A lining at the bottom can prevent leakage and a cover unnecessary exposure and spread of pathogens (B. Nawab, personal communication, April 10, 2017). After such post-treatment, the resulting humus can be used as soil conditioner and fertilizer on agricultural fields (Pickford & Shaw, 2005). Alternatively, the sludge can be disposed of in another pit, but it must be covered with soil or sand to reduce health and environmental risks.
- Even though pathogens should be significantly reduced upon emptying of alternately operated pits (Tilley et al., 2014), workers should wear protective clothing when digging out the sludge and transporting it to its disposal place for further hygienization.

Benefits

- Two alternately used cesspools can be used almost indefinitely (Tilley et al., 2014), provided that the organic matter breaks down well and infiltration is sufficient.
- The volume of sludge to be removed from the cesspools after a few years' resting time will be smaller than if a single cesspool had to be emptied immediately after filling up. Furthermore, removing the thickened sludge will be easier and safer than liquid slurry because pathogens will have been reduced (Pickford & Shaw, 2005; Tilley et al., 2014).
- With safe post-treatment the fecal sludge including nutrients and organic matter is not wasted but can be reused.

Shortcomings and challenges

- Cesspools do not treat the wastewater; the sludge still contains high amounts of organic matter (chemical oxygen demand (COD) of >20,000mg/l), ammoniacal N (NH_4-N; >2000mg/l), and up to 60,000 helminth eggs/liter (Pickford & Shaw, 2005). Its handling might thus still be a health risk for workers as well as the environment where the excreta are deposited.
- Emptying cesspools is said to be a laborious and excruciatingly unpleasant job for which it is difficult to find workers – and the sludge may have to be transported to a distant disposal site. This procedure will have to be repeated every few years, which leads to high recurring costs for labor.
- Regarding the required infrastructure, excavating another pit and constructing a second cesspool will also be costly. Besides, removing the cemented side walls of the existing cesspool to increase its permeability might require machinery.
- If increasing the infiltration surface of the current cesspool is not possible, the slurry might not infiltrate sufficiently through the clogged bottom. Furthermore, the exact infiltration capacity of the soil is unknown at present and can only be estimated based on infiltration tests. If the soil's hydraulic conductivity is low, infiltration may not be as fast as desired and the sludge will not dewater sufficiently, making emptying much more difficult.
- The location of the cesspools right in front of the school entrance and adjacent to the road is not ideal. Unfortunately, there does not seem to be an alternative site for a second cesspool on the school premises.

Replication potential

For the same reasons as in the previous section, the construction of further water toilets and cesspools for blackwater treatment is not recommended. However, if local guesthouses and institutions continue to consider them necessary, using twin cesspools and letting each of them rest for at least two years before emptying will be much safer than connecting individual cesspool to Lo Manthang's future wastewater pipe. The latter would most likely discharge into the river without treatment, leading to water pollution that would affect numerous communities downstream.

5.1.6 Hygiene Promotion

Physical infrastructure, clean drinking water and safe excreta disposal alone are not enough to effectively improve hygiene and health. Fecal pathogens spread through different transmission routes which must be known in order to take measures to reduce the risk of ingesting them. The so-called "F-diagram" (Figure 165) is often used to illustrate the main transmission pathways and possible barriers that prevent pathogens from reaching our digestive system.

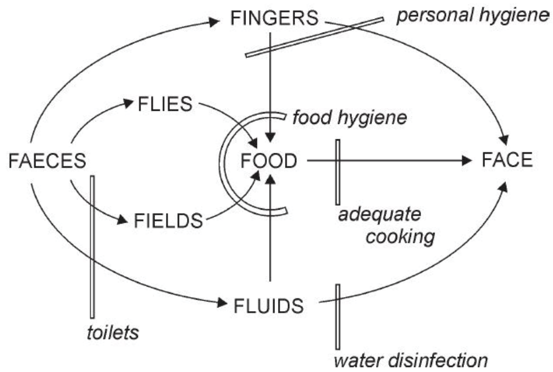


Figure 165: F-diagram showing the main transmission routes of fecal pathogens (Schönning & Stenström, 2004)

Contact with fecal pathogens might happen during defecation, when cleaning toilets, or when handling and reusing excreta that are not completely sanitized (Schönning & Stenström, 2004). Primary barriers prevent pathogens from spreading to fields and water, for instance through safe storage and containment of the infectious material as happens in EcoSan toilets (Langergraber & Muellegger, 2005). Contamination of food may happen if these primary barriers are insufficient, or if flies or humans carry pathogens from toilets to the kitchen or table. To curb the infection risk, secondary barriers include personal hygiene, food hygiene and adequate cooking to eliminate fecal pathogens before they reach our mouths (Langergraber & Muellegger, 2005). For contaminated water, disinfection through various means can remove pathogens, for example by using BSFs as described above. As the diagram shows, the consumption of polluted drinking water is only *one* way fecal pathogens may end up in human bodies, though. Domestic hygiene practices, including proper hand-washing, cleanliness (of toilets but also eating utensils) and hygienic food preparation are just as important (Schönning & Stenström, 2004; WHO, 2017a).

To prevent diseases caused by fecal pathogens, it is important to understand their origin and how our behavior influences the risk of getting infected. Such awareness-raising should be part of every water supply and sanitation program (GoN, 2010b; Pokhrel & Viraraghavan, 2004), including the one at the Lo Kunphen School, not just to ensure that the necessary facilities are provided but also to encourage users to develop and integrate "barrier" habits in daily life.

Hand-washing with soap has been identified as one of the most important hygiene practices (Adams et al., 2009). It is expected to reduce the risk of diarrheal diseases by 23% (WHO, 2004) and therefore also lowers associated morbidity rates (Pokhrel & Viraraghavan, 2004). The availability of running water at the school might not automatically lead to more hygienic behavior, though – hand-washing must be promoted through practical hygiene education integrated in the curriculum as well as in daily life. Teachers should not only rely on textbooks and wait until related units come up. Instead, they should seize the opportunity during and after construction of water supply and sanitation facilities to explain and discuss the purpose of different improvement measures and how students can and should adapt their habits. It might be necessary for staff (teachers and cook) to receive some training themselves to fully understand health and hygiene links and use effective teaching methods to impart that knowledge to the students. One of the many NGOs or individuals working in the WASH sector in Nepal should be approached for such training, as indicated in section *5.2.2* below.

It is crucial that the headmasters and teachers are aware of the school's responsibility to instill positive hygiene habits. As the students spend little time with their families and might not have the same facilities at home, the school might be the only place where they get the chance to learn about and practice hygiene behaviors. With appropriate WASH facilities as well as hygiene education, children will have the opportunity to develop hygiene routines they are likely to keep for life (Adams et al., 2009).

Since teachers are extremely important role models (Adams et al., 2009), they should recognize this function and set a good example by consistently demonstrating hygienic behavior, even if it means that they need to examine and adjust their own habits. For example, hand-washing at least after every toilet visit and before meal times, taking regular showers, and maintaining clean toilet and shower facilities should become natural and integral practices of teachers' and students' life, benefitting their health and reducing the spread of pathogens.

5.2 Stakeholders' Choice for Upgrading

When the different options were presented to the Lo Kunphen School, the local stakeholders' availability for cooperation was very limited (compare *6.2.2 Reflection on Methodologies* below). Only Amchi Tenzin could spare about two hours to learn about and consider the different alternatives, so that there was hardly enough time to outline their benefits and challenges. Specific components such as vermicomposting could not be explained to the stakeholders. At this stage, no one except Amchi Tenzin and the author was involved in the consultation process. Amchi Tenzin then took a decision on the preferred improvements and requested some adjustments to the proposed changes.

As outlined in the methodology (*3.6*), the designs presented below were sketched and a cost estimate drawn up with a number of choices depending on the budget Lo Kunphen would be able to allocate. For example, the school could specify the number of toilets, taps and showers, select between different qualities and sizes of water drums, storage containers and sanitary appliances, and choose whether they wanted ceramic urinal bowls, solar water heaters, and tiled surfaces. In most cases Amchi Tenzin preferred the more expensive option which would ensure greater comfort and cleanliness. The final cost estimate is shown in Appendix J (Table 16), amounting to slightly over NRs 600,000 (US$ 6,000) for all WASH infrastructure including transport fees for materials and labor costs. Potential compensation of experts conducting UDDT and hygiene training will be additional, as will recurring expenses for O&M. The latter could neither be discussed nor a maintenance plan elaborated in cooperation with the Lo Kunphen School. The two sections on water supply and toilets below thus do not specify responsibilities or routines concerning the practicalities of using and maintaining the facilities. It will be up to the school to implement the recommendations in the O&M section of *5.1.1* and *5.1.2* and pay attention to the mentioned shortcomings and challenges. Likewise, improvements on hygiene education could only be addressed in general (as outlined in section *5.1.6* above); the particular content and methods used will depend on Lo Kunphen.

5.2.1 Water Supply and Hygiene Infrastructure

Amchi Tenzin readily welcomed the author's suggestions for water supply infrastructure and made a few changes and specifications as follows:

- An underground storage tank might be a risk with earthquakes. Cracks in the water tank might lead to cross-contamination from the existing underground sewage pipe – water should thus preferably be stored above ground.
- 500-liter PVC drums manufactured by the Nepali Hilltake Company are the storage drum of choice, the drums of other brands being considered of lower quality. Regarding size, larger drums are apparently not possible to be placed on top of traditional mud brick or rammed earth walls for stability reasons. Amchi Tenzin confirmed that the drums would be filled by pump (powered by a generator) or solar electricity.
- Three taps were considered sufficient for the tap stand in the outer courtyard across from the current pour-flush toilet. Water at the school would only be provided for consumption and personal hygiene whereas laundry and dishes should continue to be done outside. The two main reasons for this decision were the increased need for water supply and greater quantities of graywater that the school would have to drain and possibly dispose of if dishes and clothes were washed on premises.
- Three showers would be necessary: The existing one behind the kitchen should be repaired for teachers to use, and two more constructed in the outer courtyard, as suggested, next to the tap stand. Amchi Tenzin considered a large solar water heater to be necessary so that students and staff would actually use the showers.
- Neither BSFs for water quality improvements nor the disposal of graywater through infiltration could be further discussed. They should be managed as recommended in section *5.1.1*.

Based on the above specifications by Amchi Tenzin, the following design was created and provided to Lo Kunphen (Figure 166). For detailed piping and fixtures the school will have to consult a professional plumber.

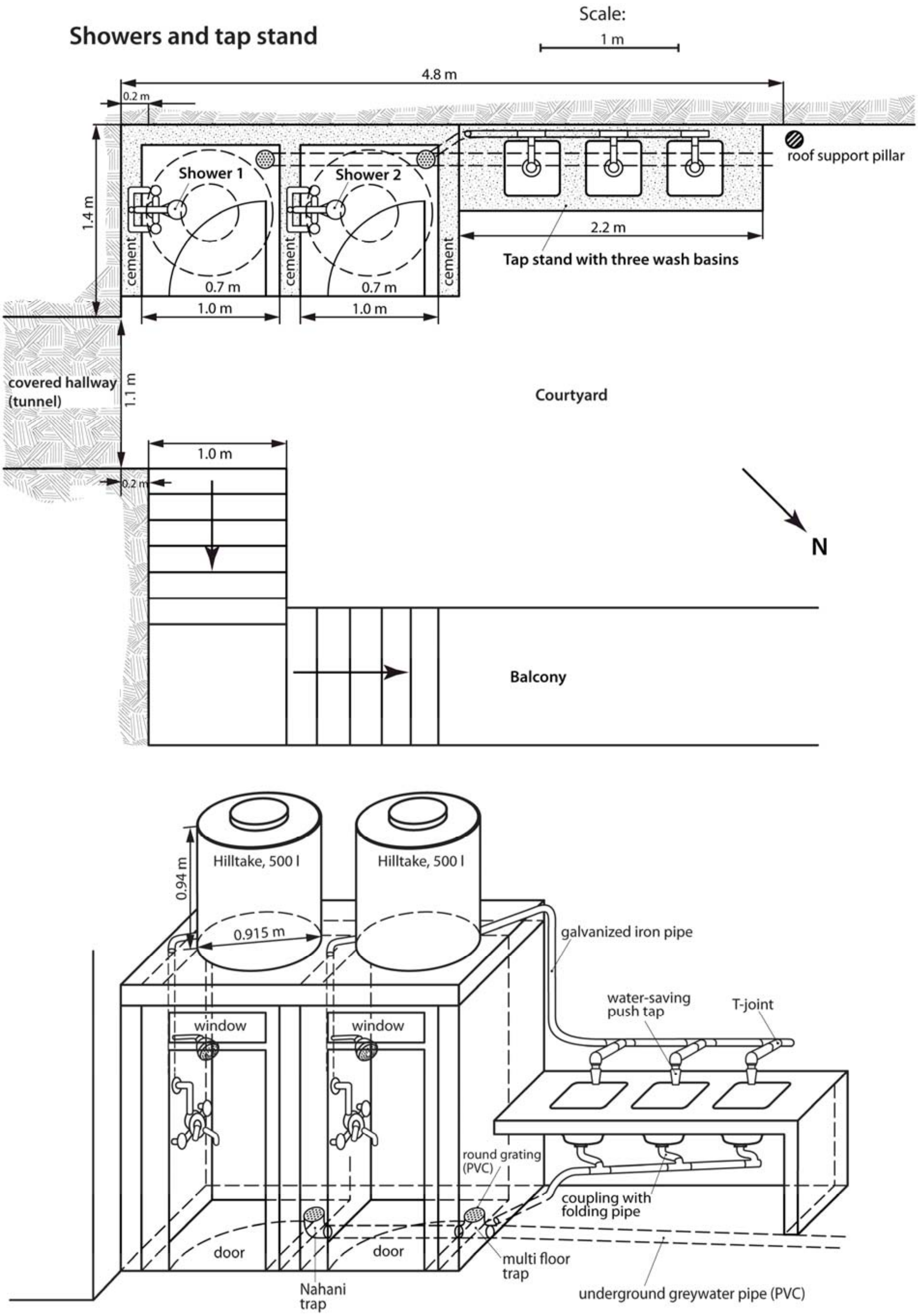


Figure 166: Design for showers and tap stand; floor plan (top) and three-dimensional view (bottom)

5.2.2 Sanitation Infrastructure and Reuse of Excreta

Due to the objective of making improvements at the Lo Kunphen School as sustainable as possible, the promotion of dry toilets over pour-flush toilets may have seemed natural. However, EcoSan systems are said to be more successful if the users choose them of their own accord from among different possibilities, rather than being persuaded that such toilets are the only solution (Rajbhandari, 2008). As WaterAid (2011) stresses, sanitation systems should be based on the users' needs and wishes, not on what an engineer thinks would be best for them. Therefore, the author intended to present the different options objectively, including their benefits and shortcomings. Following are the local stakeholders' – that is, mostly Amchi Tenzin's – reactions to the different sanitation options.

Regarding UDDTs, Amchi Tenzin explained that from the perspective of traditional medicine, he fully understood that urine contains most of the nutrients and is sterile while feces are made up of waste products. He thus considered it a good idea, but also had some concerns. For one, other people in Lo Manthang might not regard urine as a valuable fertilizer but as a smelly waste. So far, local farmers have always used partly dehydrated human excreta mixed with amendments such as ash, goat droppings, and dust, but never urine on its own. The use of liquid urine might be perceived as strange and disgusting. At their school, a urine storage barrel like the one in Humla (Figure 119 in section *4.3.3* above) would fill up quickly and would have to be emptied frequently. Local residents might then start gossiping about the *amchis* making the children carry urine to the fields. Instead, it would be more convenient to flush the urine into the water channel behind the school which ends up in the monastery's vegetable field. However, this is not advisable because with 40-60 liters of urine per day, several problems would arise from such a practice:

1) There would be a considerable loss of NH_3 and thus valuable nutrients. NH_3 volatilization would also cause unpleasant smells along the water channel which is not tightly covered for the entire distance.
2) The urine could ruin the soil of the vegetable field; its salt content may lead to crusting and blocked soil pores and impede capillary rise. Besides, due to continuous blanket supply, it would not be possible to control and adjust either the ratio of urine to water or the quantity according to crop requirements (R. Shrestha and S. Pokharel, personal communication, May 9 and 11, 2017, respectively).
3) Without any storage time, fecal pathogens from cross-contamination would enter the water channel and then the vegetable field directly, posing a health hazard. For that reason, Schönning and Stenström (2004) warn that excreta should not be disposed of in surface drainage gutters.

Amchi Tenzin's second worry was that it might be difficult to teach the children to use the split toilet pan correctly. One of the female teachers had the same concern and emphasized that the students would need to be trained well. At the same time, she and another teacher were in favor of UDDTs thanks to the excellent fertilizer they would provide. Besides, the option to use large wheelbarrows instead of baskets to transport excreta to the fields appealed to them. One of the male teachers clearly opposed the idea of UDDTs, though, as he felt water for anal cleansing was a necessity. The students were generally open to the idea of UD toilets and said they would adjust their anal cleansing habits if needed. Since the UD pan requires users to squat, the boys said they would appreciate separate urinals; peeing in a squatting position would be unusual for them. This was not surprising as several studies on EcoSan toilets mention that urinal bowls for men might be requested because of inconvenience and possible splashing when urinating into UD pans from a standing position (Rajbhandari, 2008; WaterAid, 2008a, 2011).

The other sanitation options were only briefly considered by Amchi Tenzin. The extra components that would be required to make the dry toilets functional again without urine diversion seemed too complicated and the option was discarded. While Amchi Tenzin showed interest in the Norwegian solar toilet (Figures 117 and 118 in section *4.3.3* above), he ruled it out for the school as they do not have any open space with sunshine. Nevertheless, he considered it a good demonstration object for an open, freestanding spot in town, to show people that toilets do not require water and can be clean. However, he mentioned that the design would have to be adapted to locally available materials because components such as the wind turbine or wood for construction would be difficult to obtain in Upper Mustang. The need for flexibility in the particular design or materials used for a toilet system has also been recognized by EcoSan experts such as Rajbhandari (2008) who states that "[o]ver designed, expensive or imported components make replication difficult without subsidies" (p. 72).

Amchi Tenzin also dismissed upgrading the pour-flush toilets as an option, mainly because of their large water requirement and unsolved problems with blackwater disposal. The suggested improvements for the cesspool therefore became redundant.

As a result, despite his initial concerns and most stakeholders' preference for water toilets, Amchi Tenzin decided to install UDDTs at the Lo Kunphen School. He specified that they would like to have six cubicles, two or three of them fitted with standing urinals for the boys, despite the cost for ceramic bowls and their transport. In terms of location, Amchi Tenzin decided to build the toilets in the same place as the existing pour-flush and traditional dry toilets. When the designs were made, only five toilets fit into the proposed space, though. Two of them – one for boys, one for girls – shall be built in the outer courtyard, on the second floor above the operating pour-flush toilet, transforming the current toilet below into an excreta storage room (Figure 167). Three more – one for staff and separate ones for boys and girls – shall be inside the city wall, on the second floor behind the kitchen, using the old excreta storage room below (Figure 168). To ensure sufficiently long storage and convenient transport of urine and feces, respectively, 500-liter PVC drums for urine and 260-liter garbage bins on wheels for feces were chosen, manufactured by the Nepali Hilltake Company. Large wheelbarrows as shown in Figure 153 above are unfortunately not available in Pokhara.

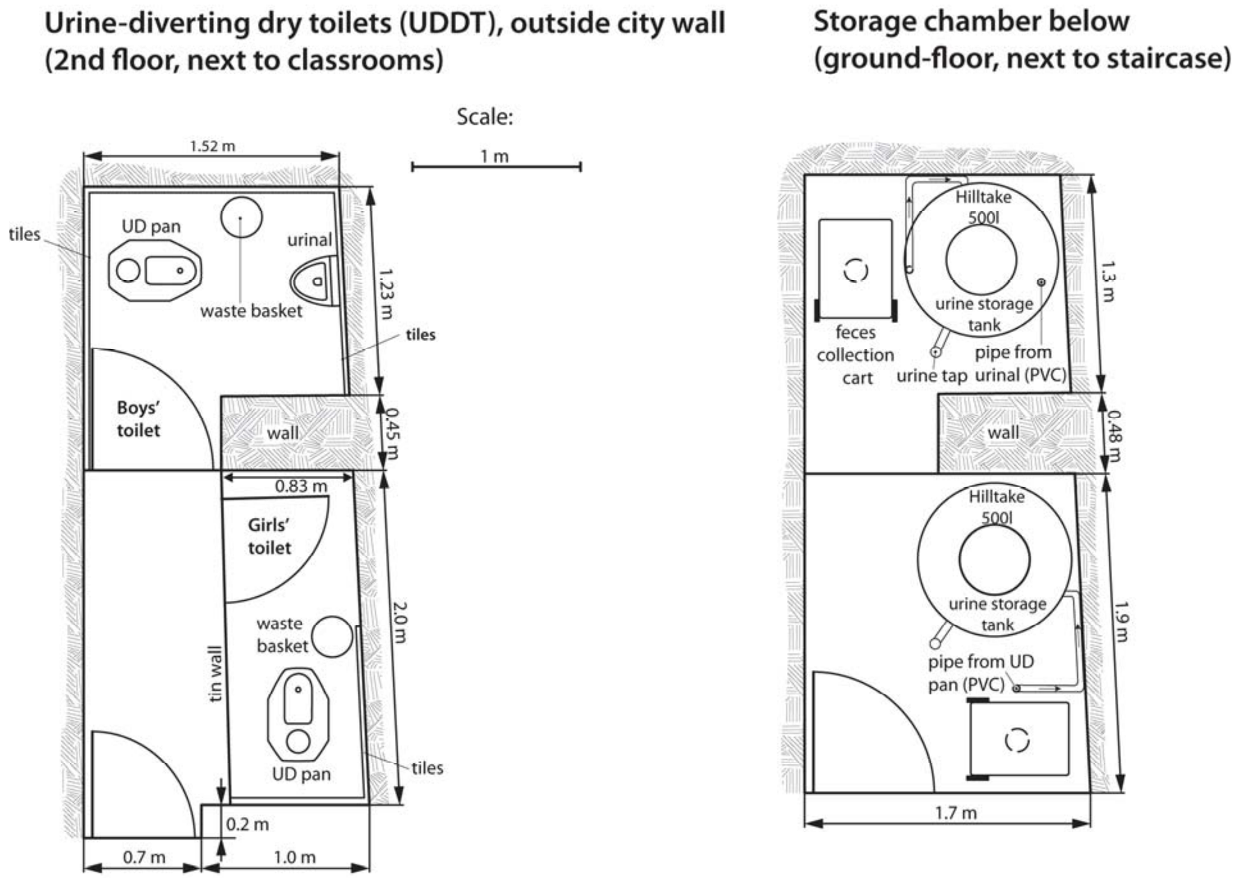


Figure 167: Design for two urine-diverting dry toilets in the location of the current pour-flush toilet; floor plan for toilets on the second floor (left) and storage chamber on the ground-floor below (right)

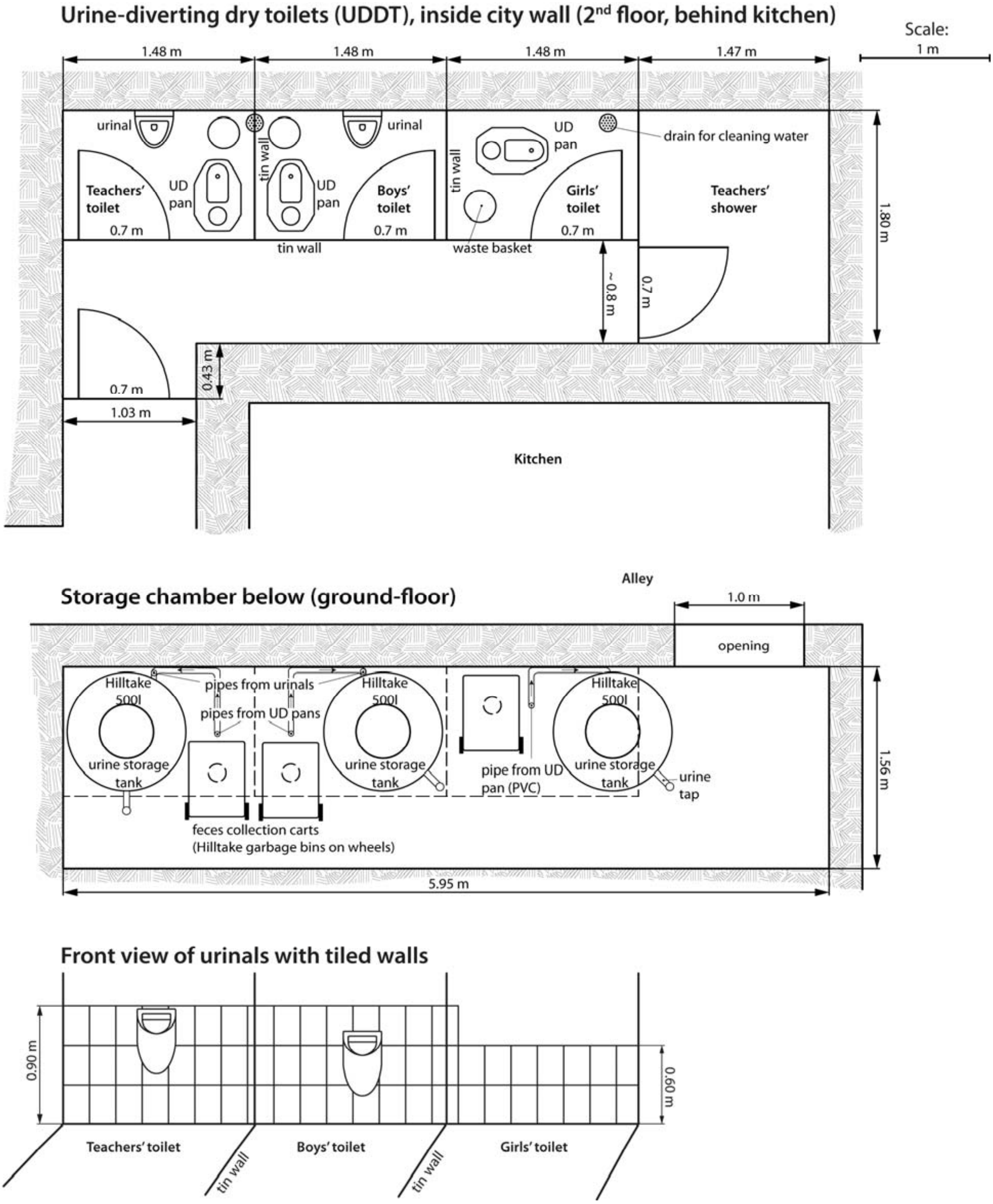


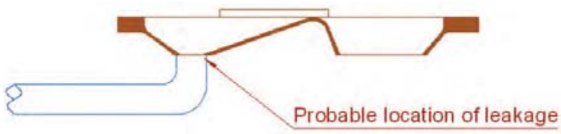
Figure 168: Design for three urine-diverting dry toilets including two urinals in the location of the old dry toilets; floor plan for toilets on second floor (top), storage chamber on ground-floor below (center) and front view to visualize urinals and tiles (bottom)

Features to pay attention to during construction

Despite many manuals on the construction of EcoSan toilets, they are rarely detailed enough to prevent mistakes from happening during installation, which will lead to malfunctioning or inconvenience with the system. Poor construction quality due to a lack of professional supervision and insufficient attention to details have been mentioned among the main problems with UDDTs (Ulrich & Deegener, 2012). Therefore, a few features that will help ensure proper functioning shall be pointed out below.

- The *UD pan* should protrude about 2cm from the toilet floor to reduce the risk of cleaning water entering either collection chamber (WaterAid, 2011), and the floor should incline towards the drain. Besides, care must be taken to place the pans accurately so that they do not obstruct toilet doors from opening (Ulrich & Deegener, 2012) and make it possible for feces storage bins to be located exactly under the feces chute. Schönning and Stenström (2004) also caution that especially in schools, defecation into the urine section is likely if the front part of the pan is too large. Since there are no special UD pans for children in Nepal, correct user habits will need to be established through training and practice. The risk of fecal contamination will be minimized thanks to the separate urinals because the boys will only use the UD pans when defecating into the back part.
- The *lid for the feces* hole will need to be sturdy enough so it covers the hole tightly and does not get displaced easily. The UDDT fiberglass pans from Butwal apparently come with lids (R. Shrestha, personal communication, March 29, 2017), but PVC, plastic and even metal lids tend to be too lightweight to stay in place (WaterAid, 2008a). Therefore, WaterAid reports that current UDDT users prefer cement lids as they are heavier and do not get lost. In order to facilitate removing the lid for defecation, a hook can be attached and a hook rod used to open it without having to bend down and touch it (WaterAid, 2008a, 2011).
- WASH professionals agree that *smooth surfaces* inside the toilet improve cleanliness and reduce resting sites for insects (Adams et al., 2009; Ulrich & Deegener, 2012; WaterAid, 2011). More specifically, WaterAid (2011) recommends that walls should be tiled up to 60cm from the floor. For the Lo Kunphen School, the requirement of tiles for the toilets was calculated based on this recommendation, increasing the tiled height to 90cm for the area surrounding urinals and adding tiles for the floors (see Figure 168 above and Table 16 with the cost estimate in Appendix J).
- *Screens on windows* and *properly closing doors* for the toilets as well as the excreta storage chambers can further minimize flies and smells (Adams et al., 2009; WaterAid, 2008a). The door of the storage room should only be opened for maintenance and emptying.
- For *feces collection*, the largest available garbage bins on wheels only have a combined volume of about 1.25m^3. Furthermore, it will not be possible to fill them to the brim before transporting the content to a different location for further hygienization (see below). Since the exact amount of feces produced by the residents is not known, nor is the volume of added amendments, it is difficult to predict how frequently the bins would have to be emptied because the estimates (mentioned in section *5.1.3*) range between 1.6m^3 and 4m^3 per half year.
- *Proper installation of urine pipes and urine storage drums* will be crucial for good functioning of the system. The pipes and fittings should be made of PVC or plastic to avoid corrosion and at least 50mm in diameter so that salt precipitates will not easily clog them (WaterAid, 2008a). The risk of crystallization and clogging can be further reduced by installing the pipes with a slope of at least 4% and minimal bends to increase flow (Ulrich & Deegener, 2012; WaterAid, 2011). To prevent disturbance or breakage of pipes during maintenance and excreta removal, they should be laid along the ceiling and walls and *not* directly through the free space between UD pans and storage drums, even if the latter would be shorter (R. Shrestha, personal communication, June 16, 2017). Furthermore, the pipes should be sealed well where they are attached to the pans and where they enter the drums as these are common spots for leakage (WaterAid, 2008a; Figure 169).

Figure 169: Connection between urine-diverting pan and urine pipe which is prone to leaking (WaterAid, 2011)



The storage drums also need to be kept tightly covered to avoid N loss through NH_3 volatilization (WaterAid, 2008a) which would lead to distinct smells. NH_3 emissions can also be minimized by building the urine pipes down to just a few centimeters above the bottom of the drums so there will be little splashing and the pipes will soon be submerged in urine (WaterAid, 2008a; 2011; R. Shrestha, personal communication, June 16, 2017).

- Since poor *ventilation* is often the reason for bad odors in UDDTs (Ulrich & Deegener, 2012), the installation of a ventilation pipe is recommended, as described in the sections on dry toilets with and without urine diversion (*5.1.2* and *5.1.3*).
- Sufficient *light* in the toilets should be ensured by building large enough windows and installing electric light for nighttime use. Without adequate light, UDDTs are more likely to be used incorrectly (WaterAid, 2008a).
- All toilets should be covered with *roofs* so that no rain or snowmelt will get into the collection chambers and cause dampness or dilution (WaterAid, 2008a). Since the area behind the kitchen is only partially covered at present, the roof should be extended across all three future toilets.
- All infrastructures should be built with the specific needs of its users in mind. Since most residents at the Lu Kunphen School are children, features such as door knobs, bolts, light switches, urinals and water taps need to be at an appropriate height for them as specified in Nepal's SHMP (GoN, 2010b). Besides, adolescent girls' and female teachers' need for privacy and suitable facilities for menstrual hygiene must be guaranteed. For instance, toilet and shower doors must be lockable, every toilet should have a wastebasket with a lid for disposing of sanitary pads (which are used by some of the teachers), and the showers must be accessible for personal hygiene and washing of reusable cloth pads in private (Adams et al., 2009; GoN, 2010b). Even though menstrual blood does not pose a risk for disease transmission (Schönning & Stenström, 2004), R. Shrestha from ENPHO recommends that instead of using the UD pans, menstruating girls and women could urinate into a separate jerry can with a funnel to avoid blood from entering the urine storage drums (personal communication, June 16, 2017).

Suppliers and training for proper construction, use, O&M and reuse of excreta

Most required sanitary appliances can be purchased from a specialized trader in Pokhara whose contact was given to the Lo Kunphen School. The owner noted down the quotation he gave for the different items in the cost estimate and is informed that the school headmasters might contact him when they are ready to build the system. Only the urinal bowls and solar water heater were cheaper at a different sanitary appliance store along the same road in Pokhara, which was also communicated to the school and the store's business card provided. Hilltake products (water and urine drums and garbage bins) can be ordered through sanitary appliance stores or directly on the company's website, with prices including delivery up to Pokhara. Hilltake's replies to online inquiries were quick and the phone number of a contact person was provided if Lo Kunphen prefers to place an order over the phone rather than in writing.

As for the fiberglass UD pans, the school can get in touch directly with the supplier in Butwal or order them through ENPHO and pay upon receipt. For the latter to be possible, though, the school would have to make use of ENPHO's offer for training and send representative staff and at least one mason to Kathmandu to attend a workshop on the construction and O&M of UDDTs at a nominal fee (R. Shrestha, personal communication, May 9, 2017). The workshop would also include a field visit so that the participants could learn about the safe reuse and application of urine in practice. Alternatively, ENPHO might consider sending an expert to Lo Manthang for advice on construction. However, Shrestha considers this second option of limited benefit as it would only help the Lo Kunphen School, whereas training in Kathmandu could lead to a more widespread effect and potential replication thanks to the skills acquired by the participants, especially the mason(s).

Cooperation with experienced local organizations and individuals will be absolutely required for Lo Kunphen to receive detailed instructions and training. Besides ENPHO, EcoSan activist Shreerendra Pokharel (see section *3.2.1* for more details) also offered training and would be interested in cooperating with the Lo Kunphen School (personal communication, May 11, 2017). He suggested that he could visit Lo Manthang or meet the Lo Kunphen headmasters in Pokhara over the winter to give advice on the construction of UDDTs and training for urine application in the field. Since he is self-employed, he would have to be compensated (NRs 5000/day – US$ 50 – plus transportation, food and accommodation), but he could also try to obtain funding from the DWSS or the WHO as he has conducted workshops with them before. The Lo Kunphen School has all the contact details for requesting training – now it will be the school's responsibility to reach out and get in touch with those experts.

Urine application

After the storage of urine over the winter, it can be used on fields in the spring upon the Lo Kunphen School's return to Lo Manthang. Applying urine in the fall before leaving for Pokhara would have the disadvantage of great N loss and therefore fertilizer value because of dry soils and no vegetation to take it up. Application rates and timing depend on the crop; if the specific requirements are not known, about 1.5 liters of urine/m^2 per growing season are recommended (Richert et al., 2010). Crops suitable for urine application and growing in Lo Manthang include wheat, turnips, carrots, cabbage chard, and lettuce (Tilley et al., 2014).

The fertilizing regime can vary based on the crop but also the availability of urine and the concentration in which it is applied. Undiluted urine can be used before or during sowing and once or twice during the growing season, for example after around 25-30 and 45-50 days, or after ¼ of the time between planting and harvesting (Richert et al., 2010; Tilley et al., 2014; WaterAid, 2011; Winblad & Simpson-Hébert, 2004). Richert et al. (2010) explain that crops need a lot of nutrients at the beginning of the growing season but that their requirement decreases when they enter the reproductive stage. Plants without a reproductive phase such as roots, tubers, spinach and lettuce can be fertilized throughout the growing season (Richert et al., 2010). Urine can also be applied diluted with water, commonly in ratios between 1:3 to 1:5 to avoid having to carry enormously large volumes (Richert et al., 2010). In that case, plants can be fertilized around two times a week (Tilley et al., 2014; Winblad & Simpson-Hébert, 2004), without the risk of poisoning the plants or burning the roots as might happen with concentrated urine (Richert et al., 2010). In any case, fertilization should be stopped one month before harvest for hygiene reasons, that is, to minimize the risk of pathogen transfer (Höglund, 2001; Richert et al., 2010; Schönning & Stenström, 2004; Tilley et al., 2014; WHO, 2006).

When transporting and applying urine, health risks can be minimized through personal protection through appropriate clothing (for example wearing gloves, an apron, and a face mask), using closed containers instead of open buckets, and washing hands afterwards (Richert et al., 2010; Schönning & Stenström, 2004; WHO, 2006). The best time for application is in the morning or evening when there is no wind to avoid spraying and thus potential pathogen transfer and N loss (R. Shrestha, personal communication, May18, 2017). An important measure to reduce smells, aerosols and NH_3 volatilization is to apply urine close to the ground and ideally incorporate or water it into the soil immediately after application (Höglund, 2001; Richert et al., 2010; Schönning & Stenström, 2004; Tilley et al., 2014; WHO, 2006). This is only advisable for crops with edible parts above ground, though; for tubers it is better not to incorporate the urine because pathogens are more easily destroyed on the surface with UV radiation and dehydration (Höglund, 2001). For vegetable crops grown in rows or spaced apart, urine can be poured into small furrows or dug holes near the plant, but not directly onto the plant leaves and not too close to the roots as there is a risk for burning them (Richert et al., 2010; Tilley et al., 2014).

If use of urine on crops is not acceptable or inconvenient because of long transport distances, it could also be added to a compost heap, which greatly increases the quality of the compost (Schönning & Stenström, 2004). The compost heap would have to be covered, though, to reduce N and moisture losses (R. Shrestha, personal communication, May 18. 2017). Since there is no organic waste in Lo Manthang, composting does not seem to be an option.

Improvements for excreta hygienization, handling, and reuse

The safe reuse of feces requires sanitization, that is, the inactivation of pathogens (Langergraber & Muellegger, 2005). Successful pathogen destruction depends on a variety of conditions such as temperature, pH, moisture, and storage time, based on which recommendations have been developed. Storage time starts after the last addition of fresh feces (WaterAid, 2011). If storage is the only treatment, the WHO (2006) guidelines state that 1.5-2 years are needed at air temperatures of 2-20°C to deactivate pathogenic bacteria, protozoa and viruses below risk level. Some soil-born ova may still survive, and

Salmonella and *E.coli* may regrow if urine or water are added (Schönning & Stenström, 2004; WHO, 2006).

Several factors can reduce the required storage time, though (Schönning & Stenström, 2004; WHO, 2006). For example, exposure to sunlight (UV radiation), temperatures >45°C and very dry climates that reduce the moisture level to <20% all contribute to faster pathogen die-off. Another method reducing the storage time is the addition of ash or lime, leading to a pH >9. Provided the temperature is >35°C and the moisture <25%, 6-12 months' storage time will be enough for elimination of pathogens (Schönning & Stenström, 2004; Tilley et al., 2014; WaterAid, 2008a, 2011; WHO, 2006). However, if the pH and temperature are lower or the moisture level higher, the required time for sufficient hygienization will increase (Schönning & Stenström, 2004; WHO, 2006). Nevertheless, a Chinese study found that even in low temperatures (-10°C to 10°C), an ash:feces ratio of 1:3 could reduce fecal coliforms by >7 $\log_{10}$ and *Ascaris* eggs by 99% within six months (Wang et al., 1999 cited in Schönning & Stenström, 2004). This reduction may have been favored by repeated freezing and thawing which affects protozoa and is likely to reduce the number of bacteria, while viruses and oocysts are the most resistant (Höglund, 2001). Pathogen survival also depends on different species' preferred environment and their ease or difficulties to survive outside the human body (Schönning & Stenström, 2004). For instance, while individual viruses may persist in the environment despite adverse conditions, they are not able to multiply without a host, so that they will invariably decrease in numbers. The same is true for protozoa, but bacteria are able to proliferate as long as environmental factors such as temperature and moisture are within their tolerance range (Schönning & Stenström, 2004).

Research by WaterAid Nepal and ENPHO on the pathogen die-off in EcoSan toilets found that 300 days' storage are enough to completely inactivate indicator pathogens (*E.coli*, total coliforms and Enterococci; Rajbhandari, 2008). Whether the same time is required in Lo Manthang's storage and environmental conditions is uncertain. On the one hand, exposure to UV radiation, associated heat development and desiccation on the fields might reduce the sanitization period, but on the other hand low temperatures could delay pathogen inactivation. Further research will need to determine the storage requirements for feces and/or mixed excreta from dry toilets in the specific context of Upper Mustang to ensure their safe reuse in agriculture (see section *6.3.1* below).

Health and pollution risks can also be reduced in various ways. As with urine, wearing protective clothing during handling of feces and hand-washing afterwards lowers the risk of pathogen transfer. Besides, equipment should be cleaned or different tools used for raw and sanitized feces (Schönning & Stenström, 2004; WHO, 2006). To prevent contamination of irrigation channels and the spread of pathogens, excreta should be wisely deposition on the field. A specially designated area, removed from waterways, should be used for storage over the winter. According to the Institutional and Regulatory Framework for Fecal Sludge Management, it will be the local government's responsibility to oversee and enforce transport and disposal "in a safe and hygienic manner without adversely affecting health and safety of emptiers, the public and the environment" (DWSS & MoWSS, 2016b, p. 14). The regulations specify that feces should never be disposed of in the open, but in pits or trenches in the ground. Those should be located to prevent leakage and runoff to surface waters (Schönning & Stenström, 2004), and the feces should be mixed with some soil (B. Nawab, personal communication, April 10, 2017). While covering of fecal sludge disposal sites with soil is recommended (DWSS & MoWSS, 2016b), in Lo Manthang where the feces will be reused, exposure to solar radiation over the winter might be more effective for sanitization.

When feces are used on the fields in the spring, they should be incorporated into the soil and not left uncovered on the ground to reduce the exposure risk of people and animals (Schönning & Stenström, 2004; WHO, 2006). This is already practiced in Lo Manthang as excreta from the dry toilets are applied when plowing the fields. The WHO (2006) guidelines also recommend that not fully sanitized feces should not be used on crops that are eaten raw, such as certain vegetables and root crops. Besides, as with urine, a one-month gap between fertilization and harvest should be maintained to minimize potential disease transmission. Finally, proper cleaning and cooking of produce in a hygienic kitchen environment will act as another barrier to prevent pathogens from reaching people's plates (Schönning & Stenström, 2004).

5.3 Suggestions for Lo Manthang

Already 20 years ago, Banskota and Sharma (1998) reported poor sanitation and health standards in Lo Manthang. They suggested, among others, that ACAP and the local community should cooperate to improve sanitary conditions, develop standards for community sanitation and health, build a sewage system, and establish a mechanism for sustainable mobilization of resources to ensure O&M of public infrastructure. These suggestions are still pertinent today, considering for instance the shortage of health care, the abandoned public toilets and the risk of untreated wastewater disposal into the river.

While many municipal WASH projects in Nepal have copied the Western approach of sewer-based sanitation systems, the SHMP indicates increased attention to onsite sanitation facilities, for public and government buildings as well as individual households (GoN, 2010b). Besides, it emphasizes the need for wastewater treatment before discharge into rivers. The suggestions in this section are in line with these intentions, proposing sustainable onsite solutions for households, guesthouses, public toilets, and a DEWATS in Lo Manthang. While the recommendations might inspire the community, they are also intended to give potential WASH cooperation partners an idea of current gaps and possibilities for intervention. Especially section *5.3.5* is thus more technical, aimed at engineers who might have the task to design a wastewater treatment system for the town. The functioning, performance, benefits and challenges of CWs are explained in more detail because local respondents and the DDC engineer in charge of Lo Manthang's wastewater pipe showed interest but had no experience with such systems.

However, for the local population to take the initiative and be willing to consider these alternative options, increased awareness on WASH and on alternatives to conventional sanitation and wastewater treatment systems are a prerequisite. The section thus starts with recommendations on how to improve locals' overall understanding of WASH and different (ecological) sanitation options.

5.3.1 Raising WASH Awareness

As outlined in the *Hygiene Promotion* section for the Lo Kunphen stakeholders (*5.1.6*), it is recommended that the wider community in Lo Manthang also benefit from further awareness-raising on WASH. Education and participation of the community have been found crucial to the success of WASH interventions (Rao et al., 1997) – people first need to understand and care about an issue before they consider it important. For example, they need to recognize the links between fecal pollution and health problems, how it affects them and their families, such as through expenses for medicine or the reduced ability to study and work. Unless people perceive clear benefits from a change of the status quo or future WASH developments, they might have other priorities.

Also, as Werner et al. (2003) explain, the local population cannot be expected to choose sustainable alternatives which they have never heard of, let alone experienced first-hand. Knowledge of the existence of different sanitation systems and their advantages and disadvantages is essential so that people can make educated decisions among the choices available to them and develop the WASH situation in a sustainable way. Werner et al. (2003) therefore encourage WASH practitioners to inform stakeholders about EcoSan, clarifying that this is "not the same as advocating it as the solution to sanitary problems; it simply supports the process of informed decision making" (p. 32). K. Pudasaini from WaterAid suggests that the local population's support for EcoSan and DEWATS can be gained by pointing out current and future water scarcity and the contamination of rivers for downstream communities (personal communication, April 13, 2017). However, similar to WASH improvements in general, arguments for EcoSan, for environmental protection and altruistic behavior alone might not be convincing enough if people do not see how the technology could directly benefit them.

In order to increase awareness of and interest in closing-the-loop technologies and natural wastewater treatment, different activities may work well, some of which have actually been suggested by Lo Manthang residents themselves. Among them are exposure visits to places where EcoSan and DEWATS are already being used, or the installation of a demonstration unit. People would thus get the chance to have a look at such systems, get accurate information on their functioning and current users' experiences, and – in the case of EcoSan – possibly even try one out themselves. For instance, several Lo Manthang residents welcomed the idea of having a model EcoSan toilet at a guesthouse or in a public space to get to know the system before having to make a decision for or against it.

Furthermore, practical workshops on a range of topics could increase understanding and illustrate the benefits and risks of different sanitary practices. For example, the value of urine as a fertilizer could be illustrated on an experimental vegetable plot where urine is applied to one half while the other half is cultivated in the traditional way, without adding urine. A method to raise awareness on pathogens would be to analyze water samples from different locations for their *E.coli* content – such as in drinking water, in graywater from the channels, and in blackwater from a cesspool. If local people participate in conducting such experiments, the learning effect will be more impressive than if they were just provided with information. From FEDWASUN's experience with community involvement, carrying out water quality tests together with stakeholders has helped raise awareness, and even illiterate people can easily use the test kit put together by ENPHO (D. B. Thapa, personal communication, April 7, 2017).

Training could be conducted by ACAP and other Nepali NGOs or individuals who have ideally worked with mountain communities before, enjoy their trust and have the ability to engage them. Organizations such as WaterAid that are just starting to expand their activities into Mustang District could cooperate with ACAP which has been active in the area for decades. The latter has experience conducting similar types of training, for example study tours for farmers and mothers' groups, health education, and training on vegetable production (Banskota & Sharma, 1998). According to Amchi Tenzin, WASH is not an extremely embarrassing topic and he considers it no problem to address related issues directly, for example advise people to clean the surroundings of a toilet or maintain personal hygiene (personal communication, April 29, 2017). The most important is to involve the local people and let them make the decisions they deem appropriate. As Nawab et al. (2006) have found,

> [p]oor and illiterate people have the potential and capability to make good choices if they are given the opportunity to be involved from inception to completion of sanitation projects. (…) Once they realize the importance of proper sanitation and the problems associated with not having it, people will be motivated to take charge themselves in the development of appropriate technologies (…). (p. 245)

For any WASH project to be successful, initiative and participation has to come from the local population. Even though governments and aid agencies tend to "think that they know better about sustainable development" (Heredge, 2003, p. 16), the motivation for a certain endeavor cannot be imposed but needs to arise voluntarily from within the community. Only with an inclusive, participatory approach will people feel ownership and take charge. The Nepali government has recognized this and suggests in the national SHMP that the involvement of stakeholder organizations such as women's groups and youth clubs is essential for effective and sustainable hygiene and sanitation development (GoN, 2010b). A bottom-up approach might not always work, though, especially if people are not used to such involvement. In that case, it is important to first engage so-called gatekeepers, influential people and decision-makers in the community, which is what some Lo Manthang residents have pointed out and experienced practitioners confirm (Martina Keitsch, professor at the Norwegian University of Science and Technology, personal communication, April 10, 2017). If such people who are respected and listened to become interested in solving a problem in an innovative way, their enthusiasm is likely to spread to the wider community.

Finally, in a handbook for planning and implementing EcoSan projects, the German Organization for Technical Cooperation stresses that participation requires WASH experts to meet the local people on an equal footing (Werner et al., 2003). External agents should not just "instruct" stakeholders about the "correct course of action" and try to force solutions upon them in a one-way process (Werner et al., 2003, p. 31). Instead, the manual advises that both sides must be open to learn from each other, which sometimes means overcoming preconceptions and letting go of hidden agendas.

During the research for this thesis, it was not intended to get a participatory process going in order to comprehensively address and solve WASH problems in Lo Manthang. Consultation with Lo Manthang residents was far from sufficient to develop sustainable solutions together based on local people's needs and aspirations. Nevertheless, at the risk of falling into the trap of seeming patronizing, in the next sections the author will outline some possibilities for sanitary development that the community may want to consider for the future.

5.3.2 Local Households

Recommending a particular sanitation system for households in Lo Manthang is a double-edged sword. Considering Upper Mustang's environmental and climatic conditions, limited water resources, local architecture and most ordinary households' financial constraints, the continued use of traditional dry toilets seems to be the best option. Since families still have ash from dung fires, they do not face the same problems as institutions in terms of amendments. On paper, even the government recognizes that dry sanitation systems have their advantages and justification: The SHMP states that any locally appropriate toilet system may be considered suitable for households and advocates that communities should be able to make an informed choice among different "low cost, hygienic, user[-]friendly and sustainable" technologies (GoN, 2010b, p. 20). While this may be an opportunity for the revaluation and revival of dry toilets, their promotion might clash with local people's views that they are an old-fashioned, backward technology. Many Mustangis do not want to be preserved in tradition but wish to enjoy the same comforts as they have seen in Nepali cities (Heredge, 2003). Therefore, simply recalling the benefits of dry toilets (see sections *5.1.2* and *5.1.3*) might not persuade locals to forego water toilets in the long run. To make dry toilets competitive, they need to be "at least as comfortable (…)[,] easy to maintain" and aesthetically pleasing as what people associate with water toilets (Langergraber & Muellegger, 2005, p. 436).

Therefore, traditional dry toilets may have to be improved in a few ways, also to address the disadvantages users mentioned (Table 6 in section *4.3.1*). For example, the appearance of the user interface could be upgraded, if desired with a squatting pan or even a pedestal (compare Norwegian solar toilet, Figure 118 in section *4.3.3*). If smells are considered a nuisance, more ash should be added and the toilet hole as well as the door to the excreta storage closed. The construction and alternate use of two vaults instead of only one could minimize health hazards as feces could be left to decompose sufficiently before being transported to the fields. As recommended for the Lo Kunphen School (*5.1.2*, *5.1.3* and *5.2.2*), transport could be made easier and more hygienic by using wheelbarrows or similar containers on wheels. Likewise, handling, further storage and field application could be improved.

A more comprehensive strategy will be needed to tackle the interconnected challenges of emptying dry toilets, the declining number of families engaged in agriculture, but also the need for fertilizer. As is already practiced to some degree, households no longer cultivating fields could provide their excreta to farmers to boost agricultural production. In particular, vegetable production could be increased by extending the season through greenhouses especially adapted to high-altitude dry climates. Such greenhouses, built of insulated mud brick walls and covered with a polythene sheet on the south-facing side, are widely used across the Tibetan Plateau (Figure 170), producing vegetables for up to ten months a year despite outside temperatures far below zero (Karli, 2009; Stauffer, 2004).

Figure 170: Greenhouse specially designed for the climate and resources of the Trans-Himalayas (here in Ladakh, India)

Growing more vegetables would have multiple benefits. For one, there would be more local produce for home consumption, which would increase local self-sufficiency, reduce the money spent on imported vegetables, and potentially improve health through a more varied diet. Furthermore, surplus vegetables could be sold in the market, raising farmers' revenue and providing local residents as well as tourists with fresh, organic produce (Banskota & Sharma, 1998; Heredge, 2003).

Since there are few other options for local business development and income generation (Pokharel, 2009), especially the linkage of the agricultural sector with tourism could be a promising way forward that has not been sufficiently addressed so far (Banskota & Sharma, 1998; Nepal, 2000; Sharma, 2000). As explained in section *2.2.7*, the lack of tourism benefits spreading to the wider community has been a point of criticism, potentially causing tensions between those who profit and those who do not. If local vegetables are wisely marketed and advertised for their chemical-free production, local farmers might finally receive a share of the money tourists spend on visiting Upper Mustang. Farmers could diversify, be trained to grow a greater variety of vegetables, and dry them for the winter or for trekkers to purchase

(Heredge, 2003). Tourism would become more sustainable and inclusive by letting previously left-out people play a part in its development. The recognition and appreciation farmers would receive for their work might be an incentive to continue with traditional production techniques, relying on natural instead of artificial fertilizers. In that light, dry toilets might become attractive again – despite or precisely because of their long history which proves their viability. More options to link toilets, tourism and agriculture shall be explored in the next section.

5.3.3 Guesthouses

Guesthouse owners have argued that they need water toilets because tourists request them. This raises a number of questions: Is it actually the flush or more the looks that influence people's preference? Possibly the comfort associated with a pedestal rather than a squatting slab? Maybe the request for a "proper" bathroom reflects tourists' wish to have water for bathing rather than requiring it for the toilet? Does the sanitation system below the user interface matter much to the average tourist, most Westerners being wipers anyway, not using water for anal cleansing? Would tourists insist on using water toilets if they knew about the implications on water resources and the pollution risk?

Which leads to the question: Who are the people that visit Upper Mustang? As Banskota and Sharma (1998) pointedly ask, "What makes tourists want to pay US$ [5]00 (for 10 days) to visit this remote and inaccessible place that lacks almost anything that is modern?" (p. 29). It appears to be the area's unique culture and natural surroundings: "It is reasonable to assume that only trekkers with a special interest in Tibetan Buddhism and culture and the high Himalayan, cold desert environment are the main visitors to the area, besides the 'pure adventure seekers'" (Banskota & Sharma, 1998, p. 35). Those types of visitors might understand and be willing to use more ecological sanitation technologies if they were sensitized and properly informed when booking a trip. According to Heredge (2003), tourists' satisfaction correlates not just with the standard of facilities but also with the accuracy of their expectations based on pre-trip information. Dry toilets could even serve as a unique selling proposition for ecotourism in Upper Mustang: They protect the environment, close the nutrient cycle, and promote agricultural production without spreading pathogens to precarious water resources. Information about their benefits would have to be disseminated widely, for example through travel agents, leaflets, information in guidebooks and simple instructions posted on toilet walls. Two Lo Manthang residents who eagerly discussed the idea advised that ACAP and the Nepal Tourism Board should be involved in related marketing efforts (personal communication, April 30 and May 1, 2017). According to K. Pudasaini, EcoSan and natural wastewater treatment systems have also been used for advertising by eco-resorts elsewhere in Nepal, for example in Bardia National Park (personal communication, April 13, 2017).

Dry sanitation may thus become part of the exclusive experience of visiting Upper Mustang. Special interest tours – as suggested by Heredge (2003) – focusing on the area's ecology could draw further attention to the fragile environment, limited water resources and the need for sustainable sanitation. Thanks to such awareness-raising, tourists might feel good about helping to promote an ancient and sustainable technology. Visitors and guesthouse owners might also be convinced if they see that dry toilets can be just as comfortable as water toilets, depending on the user interface that is installed. Although "rustic" looks might give a more authentic impression of a traditional dry toilet, the sanitation system below works just as well with a Western toilet seat. Those also exist for UD (Figure 171) – though such pedestals might be difficult to obtain and transport to Upper Mustang.

Figure 171: Urine-diverting toilet seat (here in Tingvall, Sweden)

A definite advantage of dry toilets in hotels and guesthouses is that they can also be used in the winter whereas water toilets fail. As indicated in section *4.3.1*, the latter is actually the reasons why one guesthouse owner considers it necessary to build a dry toilet again for guests. On the subject of amendments, she stated that during the winter they would have enough ash as they use one large bag of dung a day for heating. In the summer when they do not need the stove so much, they could buy dung as an amendment (personal communication, April 20, 2017). As long as the dung will be returned to the fields along with human excreta, its use in toilets should not jeopardize the supply of fertilizer to agriculture. However, it would be difficult for *all* guesthouses to purchase sufficient amendments if they chose to switch to dry toilets. In that case, UDDTs could be considered, with clear instructions how to use the system – something tourists might even talk about and propagate upon their return home.

If visitors can set an example by using and appreciating dry toilets, they might positively influence local perceptions of the value of such toilets and inspire locals to keep using them as well. As WaterAid (2011) explains, social acceptance of a certain toilet type is "a flexible parameter that changes with time" (p. 36) – but a shift in preference and behavior requires awareness, not just among tourists but among locals alike. As indicated in section *2.2.7*, tourists' respect for the traditional way of life and the technologies that have helped Mustangis survive for centuries may also spark pride and interest in the traditional culture among local residents themselves.

As explained in the previous section, farming might be one sector that would benefit from the continued or even increasing use of dry toilets. A larger cooperation scheme between guesthouse owners and farmers might develop as they would rely on each other for the production of fertilizer and fresh produce. This could strengthen community cohesion as well as the connection between agriculture and tourism while creating income through the sustainable use of local resources. Not only could this scheme become part of Upper Mustang's marketing strategy for tourism – advertising that visitors would consume local products instead of imported food – but employment opportunities might also be an incentive for young educated people to move back. Observations from Mustang and in European mountain valleys suggest that permanent outmigration may be reduced thanks to tourism (Childs et al., 2014).

If tourism starts benefitting a larger part of the community, the local people will be more inclined to protect the natural environment and promote their cultural heritage – the assets for which visitor travel so far (Banskota & Sharma, 1998; Heredge, 2003). If, on the contrary, the environment and culture in Upper Mustang deteriorate, the area might lose its attraction, leading to a decline in tourist numbers. Sharma (2000) emphasizes that "[t]ourism development has to be conceived not as the development of one particular sector but as an integrated exercise in developing critical sectors, environment being one of the most important, on which tourism depends" (p. 372). For a sustainable future, it will be necessary to maintain ecological concepts and practices from the past and adapt them to the needs and expectations of 21st century locals and tourists.

However, such development will require substantial coordination and cooperation between stakeholders from different sectors and at different levels. Farmers, guesthouse owners, tour guides, travel agencies, entrepreneurs, community organizations, ACAP, possibly other NGOs and the local government would all have to be involved in comprehensive, interdisciplinary planning (Banskota & Sharma, 1998; Pokharel, 2009; Sharma, 2000). Stakeholders should unite to define a systematic tourism strategy – something that is reported to have been missing in the ACA so far (ACAP & NTNC, 2010). It could be an opportunity to develop the supply-side of tourism, focusing on what Upper Mustang can and wants to offer rather than bowing to what travel agencies and tourists might demand. According to Banskota and Sharma (1998), tourism has been mostly demand-driven, which is why they suggest to strengthen the supply side through measures such as the development of "standards for the construction of hotels, lodges, tea shops, and campgrounds that are environmentally safe and in harmony with the local culture and architectural traditions" (p. 63). Upper Mustang might be able to benefit from ACAP's experience of successfully linking tourism to local community development through appropriate interventions (Sharma, 2000). Even the national government could be approached again to support local initiatives aimed at improving WASH, agriculture, livelihoods, and environmental protection in combination. If a larger portion of the permit revenue was returned to the local people, it could for instance be used to retrofit sanitation infrastructure in guesthouses and provide equipment to farmers to facilitate excreta transport to fields.

First and foremost, though, participation of the local population will be crucial to make such community-based ecotourism successful and minimize negative impacts (Heredge, 2003; Nepal, 2000; Sharma, 2000). As has been pointed out for WASH projects on their own, sustainability can only be achieved if the local community is involved and motivated, especially when such wide-ranging interlinked developments as described above are concerned.

5.3.4 Public Toilets

Participation will also be required for the planning and management of public toilets. All 15 respondents in Lo Manthang agreed that public toilets were a good idea, convenient and urgently needed to reduce open defecation by those who currently do not have access to a toilet. Since a lot of people usually gather around the jeep stand at the entrance of town, several respondents thought that would be a good location for public toilets. Two people mentioned that toilets on each side of town would be useful, but closer than the desolate ones which were previously built on the slopes towards the rivers.

The need for toilets with hygiene facilities in public places such as bus stands and market areas are also mentioned in the SHMP (GoN, 2010b) and already exist in various places throughout Nepal. One of the closest examples is a pour-flush public toilet that was constructed in 2016 in Chhaktang, a village in Lower Mustang, along the road up the Kali Gandaki Valley to Jomsom (B. Yadav, personal communication, May 27, 2017). Other major roads across the country have had rest stops with public toilets for many years; there are for instance 17 public toilets along the Prithvi Highway between Kathmandu and Pokhara, (MoWSS, 2016).

The SHMP states that such toilets should be locally appropriate and onsite sanitation would be encouraged, with wastewater discharge only after treatment (GoN, 2010b). While most roadside toilets are of the pour-flush type and do not always have proper disposal systems, a rest stop with community-managed public toilets along the Prithvi Highway has been rated as exemplary and particularly user-friendly. Those toilets, located in a place called Chunpahara, are special because they not only have squatting pans but also separate urinals for men and women to reduce odors and improve decomposition of feces (MoWSS, 2016). Furthermore, they have washbasins outside the toilet blocks for hand-washing.

While the idea of UD toilets in public places is thus not new, would such toilets be possible and acceptable in Lo Manthang? Two thirds of the respondents took to the idea, mentioning some of the various benefits of UDDTs as specified in section *4.3.3* and also said they would use public toilets with UD technology themselves. One of these proponents considered UDDTs an improvement over the existing public toilets as those do not have water anyway and pour-flush toilets would just get blocked again. Four more respondents were also in favor of giving the technology a try, but had some concerns about its acceptability and feasibility in their community. They reminded that local people do not know about UDDTs and would need instructions how to use them properly. Suggestions included posters on the toilet walls explaining about the correct use and benefits, or that a respected person from the village should advertise the toilet to encourage people to try it out. Yet even if people *did* receive instructions, it would be difficult for everyone to use UDDTs correctly. At home the technology might work, one respondent presumed, but not as a public toilet with many different users; it would quickly get dirty and there would be cross-contamination. Two respondents said they would not use such a toilet because they found the double-hole pan inconvenient, and another one remarked that she would only use it if toilet paper was provided as she is used to anal cleansing with water. Finally, one respondent explained that he did not really need a public toilet as his home was close enough. Besides, he argued, urine diversion was definitely a good idea, but the system was not very different from their traditional dry toilets which also produce fertilizer, so they might as well stick to the traditional technology. The question where to get amendments from remained unanswered, though.

Whether UDDTs are the best solution for public toilets in Lo Manthang or if other systems are preferable would have to be assessed with the wider community. In any case, a public toilet could be a good opportunity to present a new, sustainable toilet system to a larger public while eliminating some of the constraints that have restricted the choices at the Lo Kunphen School. For example, if a free-standing location is selected, a solar toilet would be possible, adapted from the Norwegian model which appealed to many locals. Thanks to abundant sunshine year-round, dehydration in a south-facing storage chamber should function even with less bulking material. However, to avoid a large number of imported components that might be difficult to repair and/or obtain, the Norwegian design would have to be simplified and adapted so it can be built with locally available materials. Furthermore, the reuse of excreta should be discussed and cooperation with local farmers initiated from the planning stage, so that convenient, safe and reliable emptying can be guaranteed. For instance, storage chambers must be closed but easily accessible and fitted with storage containers that facilitate transport of (partly) hygienized excreta to the fields. For better sanitization before transport, a double vault system or two storage containers are recommended, where one part is in use while excreta in the other one rest for a few months to a year (Figure 172). A solar toilet can also be combined with urine-diversion, considering that a system based on the Norwegian model still requires amendments which a public toilet operator in Lo Manthang might not be able to provide. To minimize that requirement, a UDDT's south-facing feces chamber can be equipped with a black painted metal flap (also Figure 172). This will increase the transfer of solar radiation and heat up the storage chamber, accelerating dehydration of feces as well as pathogen die-off (WaterAid, 2008a).

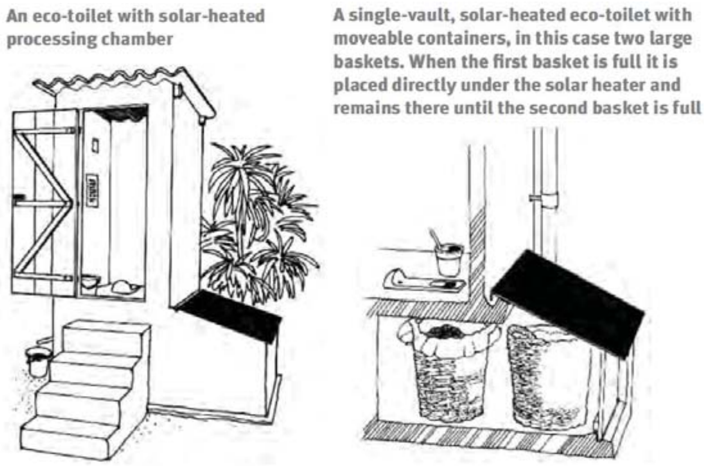


Figure 172: A solar EcoSan toilet with alternately used storage containers (WaterAid, 2011)

Public toilets will only be successful if they are well maintained and managed, something almost half of the respondents brought up. Without a good management committee and a caretaker who regularly cleans the toilets and monitors the storage chamber, the toilets would quickly become dirty and then fall into disrepair and disuse like the previous ones. As one respondent put it, "the investment in building toilets would just be wasted money" (personal communication, May 25, 2017). When asked about how much a caretaker should be paid and by whom, respondents mentioned a salary ranging from NRs 250-800/day (NRs 7,500 – 24,000/month; about US$ 75-240). Several people indicated that the salary might have to be higher than average, or no one would be willing to do the job since it is considered lowly. They suggested that the salary could be allocated by the town from the budget they receive from the government, or a special committee would have to collect and give money to the caretaker. Alternatively, a tax on profits from tourism could be used for the capital and running costs of public toilets, which would also benefit those community members not directly engaged in tourism (Heredge, 2003).

Looking at examples elsewhere, the caretaker at the public toilets in Chunpahara gets paid NRs 12,500/month which is raised through a toilet user fee of NRs 5 (urinating and defecating alike) (MoWSS, 2016). This fee covers not only the caretaker's salary but also minor repairs and even generates a profit. However, as those toilets are located along a busy road, they are frequented by about 400 people per day, which is far more than the user numbers Lo Manthang's toilets would receive. The public toilets in Chhaktang, Lower Mustang, do not charge a fee, but the restaurants providing food and drink maintain them because many of the users are their customers (B. Yadav, personal communication, May 27, 2017). In Lo Manthang, B. Yadav (WSSDO Jomsom) thinks that members of the Youth Club would most likely be in charge and decide how to maintain the facilities; they are also the ones who have apparently been involved in negotiations about building public toilets. Unfortunately, there was no opportunity for the author to get in touch with the Youth Club during her stay in Lo Manthang.

Regarding initial funding of public toilets, T. Chaudhari from the DWSS explained that his department does not offer government funds to construct toilets but only implements awareness-raising programs to motivate people to build toilets (personal communication, April 6, 2017). On the contrary, the SHMP states that in geographically remote areas, support in the form of materials or a revolving fund can be considered for "locally appropriate low cost technological options," on condition that the community also contributes (GoN, 2010b, p. 36). B. Yadav specified that for a public toilet, the community would need to provide land, and construction costs could be divided between the government and the local public. But will toilets be considered important enough for people to invest time and money in them?

Even though most respondents in favor of public toilets declared they would also use them, few would actually be willing to pay a user fee, even though they understand that maintenance would come at a cost. Almost two thirds said that Lo Manthang locals and Nepali workers would only use public toilets if they were free, otherwise they would rather go to the fields. In their opinion, only foreigners would pay for the toilets. Similar findings are reported by Rao et al. (1997): "Those who have been used to going to the fields for many years do not feel like spending money on a latrine" (p. 263). The remaining third of respondents who answered they *would* pay for using a public toilet said a user fee between NRs 5-15 (US$ 0.05-0.15) would be appropriate. The female respondent whose family does not have a toilet said she would pay NRs 20, indicating that the lack of alternative sanitary facilities makes public toilets more valuable, especially for women. Those willing to pay for toilets emphasized that they would have to be clean and – if it was an unfamiliar system – people would need to understand its benefits. However, since even well-maintained and -promoted toilets might be ignored by some, two respondents spoke out in favor of enforcing rules against open defecation so that people would have no choice but to pay for using the public toilets. Once again, improving sanitation will entail much more than just deciding on a type of infrastructure. Financing, maintenance, management, and reuse of excreta will require extensive planning and follow-up by the community itself for smooth operation. Suggestions from outside may merely serve as inspiration.

Unless people know about alternative options, public toilets may be built and managed the same way as before. For example, B. Yadav from the WSSDO stated that he would build pour-flush toilets again, with a soak pit for wastewater (personal communication, May 27, 2017). Upon the subject of EcoSan, he said that such systems had been built in other parts of the country, but not in Mustang so far due to a lack of manpower. If the community chooses water toilets for the new public facilities, wastewater treatment as described below may be relevant, not just for graywater but also for blackwater.

5.3.5 Local Wastewater Treatment

If guesthouses continue to use (pour-)flush toilets and public toilets are likewise operated with water, proper treatment will be necessary as the cesspools alone are not a long-term solution, nor is direct discharge into the rivers. Building a wastewater pipe system underground will be expensive, but has apparently already been decided on by Lo Manthang town. At the time of research there was uncertainty about the type of wastewater the planned pipe would carry. If it is used for blackwater, a treatment system will be absolutely necessary due to the high pathogen and nutrient load with associated health and pollution risks; the disposal of untreated sewage still being the main cause of water pollution in developing countries (Landon, 2006). Even if the pipe is only for graywater, the quantities produced by households and guesthouses will increase as soon as private water connections are built. While graywater is less of a health concern as it does not contain many pathogens (Langergraber & Muellegger, 2005), its treatment still makes sense: Not only can potentially toxic substances from soap, shampoo, detergents, etc. be removed, but the water can also be reused for irrigation on the plateau of Lo Manthang rather than poured down into the river valleys.

Therefore, instead of designing a wastewater pipe with its outlet on the edge of town, the layout of the system should allow for connecting it to a treatment plant, which is officially also required by national standards (DWSS & MoWSS, 2016b; GoN, 2010b). The SHMP specifies that local bodies are responsible to ensure adherence to environmental regulations (GoN, 2010b). They must monitor the disposal of domestic sewage and wastewater, make sure that it is not disposed of in drainage or irrigation channels nor in undesignated areas and impose fines in case of noncompliance (DWSS & MoWSS, 2016b). While local bodies are also in charge of planning, implementing and supervising FSM, they may request technical and managerial assistance from the DWSS and the MoWSS, such as for guidance on procuring land for a treatment plant (DWSS & MoWSS, 2016b). Further roles and responsibilities of key stakeholders – comprising local bodies, WUSCs, the DWSS, MoWSS, other ministries, (I)NGOs and private entrepreneurs – are clearly outlined in the FSM Institutional and Regulatory Framework (DWSS & MoWSS, 2016b). For example, the MoWSS and MoFALD are supposed to integrate FSM into sanitation planning in small towns, including the planning and funding of required infrastructure. However, T. Chaudhari from the DWSS admitted that the subdivision office (WSSDO) of his department had no sewerage system projects so far (personal communication, April 6, 2017).

A conventional treatment plant would entail large financial investments in infrastructure and electricity, besides requiring skilled workers for maintenance – and in Nepal the systems are often dysfunctional all the same. For those reasons, a treatment system relying on natural processes to remove pollutants from water may be more suitable for Lo Manthang. Such systems are low cost, have few mechanical elements, no need for electricity if operating by gravity, and require little maintenance within local people's capacity (ENPHO & WaterAid, 2008; Jenssen, Maehlum, & Krogstad, 1993; Pandey & Jenssen, 2014; Tilley et al., 2014; UN-HABITAT, 2008). Especially for the maintenance aspect, D. B. Thapa from FEDWASUN considers these decentralized technologies preferable for rural communities, though also cautions that introducing completely new ways may not be accepted immediately (personal communication, April 7, 2017). Two types of DEWATSs, infiltration systems and CWs, shall be presented below and considered as possibilities for Lo Manthang.

Infiltration systems

In infiltration systems, wastewater is treated by first passing through a septic tank (or cesspool for that matter) and then percolating through soil. After the settling of solids, the septic tank effluent is led to infiltration trenches or basins which can either be on the surface or buried underground (Pandey & Jenssen, 2014; Figure 173).

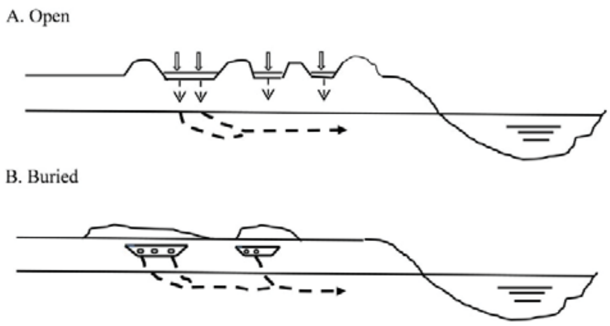


Figure 173: Open and buried infiltration systems (Pandey & Jenssen, 2014)

Unlike in a cesspool where large quantities of water are supposed to infiltrate through a limited surface area, infiltration systems are generally shallow and designed so as to optimize the treatment based on soil properties (Pandey & Jenssen, 2014). They can be built in different sizes, for single households, tourist facilities, whole villages or even towns. Large systems usually consist of open basins as those can be loaded with rates 10-20 times higher than underground systems – the reason being that their infiltration surface can be easily accessed and scraped when it starts clogging (Pandey & Jenssen, 2014). Since open systems will be smellier and pose a greater risk for pathogen transfer, they should be at a safe distance from settlements and ideally fenced (Schönning & Stenström, 2004).

An appropriate distance is also needed between the infiltration surface and the groundwater table to avoid pollution and improve purification. In Lo Manthang where the groundwater level is far below the plateau (compare *4.4.1 (Hydro)geologic and Pedologic Context*), there is little risk of contamination and groundwater mounding would not reach the bottom of the system. An advantage of infiltration systems is that they can actually recharge groundwater resources (Pandey & Jenssen, 2014) – though that argument would be less relevant for the people of Upper Mustang as they do not currently tap groundwater. Regarding treatment, the long distance to the groundwater is beneficial because pollutants are more efficiently reduced in the unsaturated zone (Pandey & Jenssen, 2014). As mentioned earlier (section *4.4.1*), bacteria and viruses can be reduced within a few decimeters, and breakdown of organic matter will be good thanks to soil organisms (Pandey & Jenssen, 2014). P removal through sorption may also be good owing to the soil's Ca content and possibly iron oxides (which were not assessed in the soil samples during this research). Total N removal depends on nitrification and denitrification rates which in turn are influenced by the soil and system design and may range between 30-80% (Jenssen, 1988 in Pandey & Jenssen, 2014). If only graywater is infiltrated, nutrient and pathogen loads will be much smaller to begin with.

According to Pandey and Jenssen (2014), infiltration systems also work well in cold climates as long as other conditions are suitable. Namely, the performance of a system not only depends on the type of wastewater and the soil constituents, but also on the K_{sat} of the soil (Jenssen & Siegrist, 1991). While small systems can work in silty soils with low K_{sat}, sand or gravel are better suited for bigger systems which need to treat larger volumes (Pandey & Jenssen, 2014). Around Lo Manthang, a range of hydraulic conductivities can be found due to layered and heterogeneous deposits. Potential sites for a treatment system should therefore be assessed through further infiltration tests as recommended in section *4.4.3*.

Since Nepal does not have guidelines for wastewater loading rates based on soil type and/or K_{sat} (Pandey & Jenssen, 2014), existing guidelines from other countries with similar conditions can be used. For example, the mean grain size / sorting diagram (Figure 55) or the chart with recommended loading rates based on soil texture and K_{sat} for clean water (Table 5) in section *3.4.3* of the methodology chapter can be applied to determine an appropriate loading rate for a certain soil texture. Those loading rates range from 1 cm/day for finely grained soils to 5cm/day for coarse sand, though loading rates for open systems can be as high as 20-50cm/day (Pandey & Jenssen, 2014; Siegrist et al., 2000).

Especially for soils with low K_{sat}, pretreatment of the wastewater will be essential to remove suspended solids (SS) and prevent quick clogging of the infiltration surface. If Lo Manthang's wastewater pipe is going to carry blackwater, residents should thus continue using the existing cesspools and connect them to the pipe. Direct connection to the main sewer would not only be illegal (compare *4.1.4 Wastewater Pipe Project*) but also jeopardize the functionality of an infiltration system. In addition to settlement of solids in the cesspool, sand filters, biofilters or CWs can improve pretreatment and infiltration: They will further reduce particles and decrease the wastewater's biochemical oxygen demand (BOD), N and pathogen content before it reaches the infiltration system (Jenssen & Siegrist, 1991; Pandey & Jenssen, 2014; Siegrist et al., 2000). CWs for wastewater treatment on their own or in combination with infiltration systems shall be described next.

Constructed wetlands (CWs)

CWs have been used in different localities and for different scales in Nepal since 1997 (ENPHO & WaterAid, 2008). A CW is an eco-technological treatment plant that imitates processes in a natural wetland ecosystem: Wastewater is cleaned by flowing through a shallow basin with or without filter material in which wetland vegetation is planted (UN-HABITAT, 2008). Such systems can be built for various scales: for single households, institutions (hospitals, schools, universities, monasteries), communities and small towns (ENPHO & WaterAid, 2008). For example, in the peri-urban town of Nala in the Kathmandu Valley, a CW has been in use since 2012 to treat the community's domestic blackwater. Apart from blackwater, CWs can also be built for graywater, institutional sewage, wastewater from industries, and even landfill leachate (ENPHO & WaterAid, 2008; Nawab, Esser, Jenssen, Nyborg, & Baig, 2016). However, to avoid clogging of the substrate, the wastewater must undergo primary treatment before reaching the CW (Tilley et al., 2014).

The dimensioning and components of a system depend on the type and amount of wastewater that will be treated. Before designing a system for Lo Manthang, it must therefore be clarified whether it should be for graywater and/or blackwater. For pre- and primary treatment, septic tanks or cesspools at the household level will be necessary, followed by piping to a central collection chamber at the treatment plant. A screen and one or two settling tanks can further reduce the amount of solids and organic matter reaching the filter bed (ENPHO & WaterAid, 2008). In Nala, these settling tanks are followed by a 7-chamber anaerobic baffle reactor (ABR), a component that R. Shrestha (ENPHO) also recommended for a blackwater DEWATS in Solokhumbu District where climatic conditions are more similar to Mustang (personal communication, March 29, 2017). According to Shrestha, digestion will need more space at low temperatures, that is, bigger units, because decomposition takes more time.

A CW in Lo Manthang should be of the horizontal subsurface flow type (Figure 174) the most common type built in Nepal (ENPHO & WaterAid, 2008). Open surface and vertical flow systems would freeze in the winter. The size will depend on the expected wastewater load; the system will need to be dimensioned for estimated population development, taking the peak tourist season with most wastewater generation into account. In Europe, a surface area of around 5m^2 per person are calculated as a rule of thumb, depending on the type of wastewater (Pandey, 2016; Tilley et al., 2014), but the CWs built in Nepal are much smaller. For instance, the system at Sunga (Thimi), designed for 350 households for 200 households, has an area of 375m^2 (ENPHO & WaterAid, 2008), and the system in Nala, though designed for 350 households, is even smaller with a total wetland surface area of 180m^2 (Nala Water Supply and Sanitation Committee (WSSC), personal communication, June 11, 2017). The design and dimensioning for Lo Manthang will need to be made specifically for the local conditions so that an adequate retention time can be ensured.

The wetland filter bed consists of a rectangular, wide shallow basin filled with round, evenly sized washed gravel (3-32mm Ø), with coarser pebbles at the in- and outlet to prevent clogging (Tilley et al., 2014). Sand can also be used as a filter material but will clog more easily (Tilley et al., 2014; UN-HABITAT, 2008). While the depth of the bed is normally no more than 60cm so that plant roots can fully penetrate it, for cold climates such as in Mustang a depth of 1m would be appropriate. This will allow the top to freeze in the winter while the CW remains functional below (Jenssen et al., 1993). An impermeable liner usually seals the bottom, especially where groundwater contamination might be a risk and to ensure maximal contact of the wastewater with plant roots. In Nepal the bottom is often cemented, but clay is also suitable (Tilley et al., 2014). At the outlet, an adjustable pipe controls the water level in the wetland, which should be 5-15cm below the surface in the summer and can be lowered down to 30-40cm in the winter (Jenssen et al., 1993; Tilley et al., 2014; UN-HABITAT, 2008).

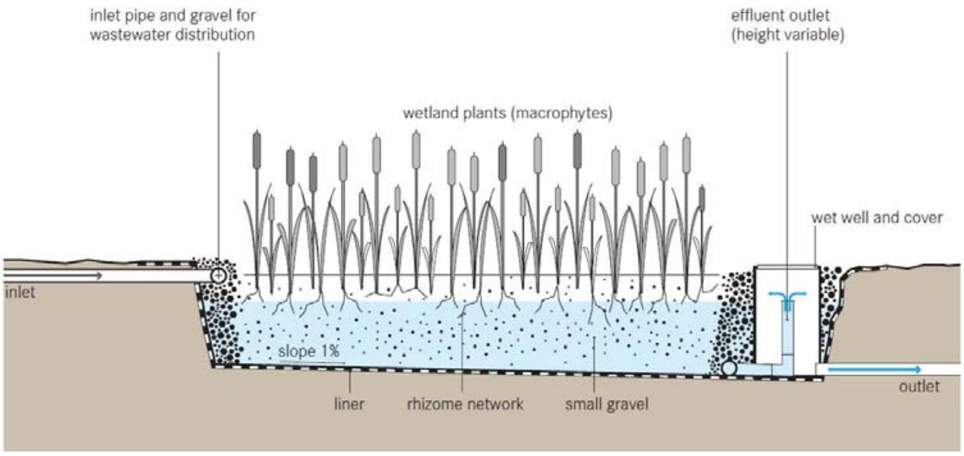


Figure 174: Diagram of horizontal subsurface flow constructed wetland (Tilley et al., 2014)

An innovative possibility is to leave the bottom of the CW open, so that partially treated water can infiltrate into the soil below (Pandey & Jenssen, 2014; Figure 175). Such a system is not only cheaper but also particularly suitable for finely grained soils – such as those around Lo Manthang's agricultural fields – which have a low K_{sat} but very good treatment capacity (Pandey & Jenssen, 2014).

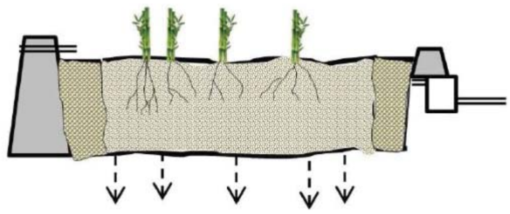


Figure 175: Horizontal flow subsurface constructed wetland with an open bottom (Pandey & Jenssen, 2014)

In terms of the vegetation planted on a CW, "any native plant with deep, wide roots that can grow in the wet, nutrient-rich environment is appropriate" (Tilley et al., 2014, pp. 116-117). In case of an unsealed bottom, the plants should be able to withstand fluctuating moisture levels (Pandey & Jenssen, 2014). In Europe and the United States, common reed (*Phragmites*), bulrush (*Scirpus*) and cattail (*Typha*) are often used (Conley et al., 1991 in Jenssen et al., 1993); in Nepal *Phragmites karka* is common (ENPHO & WaterAid, 2008). For Upper Mustang, suitable species are yet to be identified. Like infiltration systems, a CW which is used for blackwater should be fenced and marked with signs to avoid pathogen transfer from fecally polluted wastewater.

Regarding the functioning and removal mechanisms of the system, wastewater is purified through a combination of physical, chemical and microbial processes (Cooper, Job, Green, & Shutes, 1996; Jenssen et al., 1993; Tilley et al., 2014). Those include filtration, sedimentation, adsorption to the filter matrix, complexation, precitpiation, redox reactions, volatilization, nitrification and denitrification. Pathogens are also removed through natural decay, starvation, predation and death through antibiotics excreted by plant roots (Cooper et al., 1996). The plant roots' most important function, though, is their ability to supply small amounts of oxygen into the filter, thereby creating aerobic zones which enrich the diversity of microorganisms and conditions for the breakdown of pollutants (Jenssen et al., 1993; Tilley et al., 2014; UN-HABITAT, 2008). Apart from those zones around the roots, the saturated zone of the filter is mostly anaerobic or anoxic. Plants also take up some nutrients, maintain the permeability of the filter, and beautify the CW's appearance (Jenssen et al., 1993; Tilley et al., 2014).

The treatment performance of CWs varies for different parameters. The systems can remove a remarkable >90% of SS, 80-90% of organic matter (measured as BOD), and reduce the count of pathogenic indicator organisms down to bathing water quality (Jenssen, 2015; Jenssen et al., 2010; Jenssen et al., 1993). Nutrient removal is variable, however, depending on the substrate and oxygen availability. P sorption is low in gravel whereas sand removes more, especially if it has a high iron oxides content enabling the retention of >90% P (Jenssen et al., 1993). In Lo Manthang, a similar sorption effect could be reached by using local deposits naturally high in Ca as a filter medium. Furthermore, the elevated $CaCO_3$ level measured in the water supply will lead to P precipitates that will then be filtered out in the CW. If the substrate is constantly supplied with P-containing blackwater, though, it will become saturated over the years and then requires replacement. N removal depends on aerobic conditions required for the nitrification of ammonia which precedes the anaerobic denitrification step. Since oxygen inside the filter bed is limited to the zones around the plant roots, removal rates in the saturated zone are generally low with 30-60% (Jenssen, 2015; Jenssen et al., 2010). Without plants or in the winter when the plants are dormant and do not provide oxygen for nitrification and organic matter decomposition, aerobic pretreatment is recommended (Jenssen et al., 1993). In Western countries, pretreatment is often achieved with an aerobic biofilter consisting of a fiberglass dome in which a high pressure pump sprays wastewater through a nozzle onto lightweight aggregate of about 60cm depth (Jenssen et al., 2010). Such an installation would require specialist equipment, electricity and skilled labor for repairs, though. In Lo Manthang, a simple vertical flow sandfilter of 60cm length, 50cm width and 70cm depth can oxygenate the wastewater and improve N and BOD removal rates (Jenssen et al., 1993).

Since most CWs in Nepal have been designed for climatic conditions very different from Upper Mustang, experience from other countries with cold winters is valuable. Studies in Northern Europe have shown that with some adjustments such as a deeper filter bed (see above), aerobic pretreatment, and larger systems to increase detention time, CWs can function and perform comparably to other seasons even in freezing temperatures (Jenssen et al., 1993). For Lo Manthang, the question arises whether a CW would even be used in the winter: At the moment, people report that all water pipes freeze and water toilets do not work anyway. If the few people remaining in town over the winter keep using dry toilets and little water except for consumption, no wastewater treatment might be required. The CW would thus be most needed in the summer and tourist season between April and October – and could also be built shallower as there would be little freezing during that time. Besides, low nutrient removal rates might then even be an advantage: The effluent could help fertilize the fields while being much safer in terms of pathogens than untreated sewage (Pandey & Jenssen, 2014).

CWs have many advantages that make the technology particularly suitable for a remote place like Lo Manthang. A CW can be built with local materials, is less expensive and also simpler to build, operate and maintain (ENPHO & WaterAid, 2008; Jenssen et al., 1993; Tilley et al., 2014; UN-HABITAT, 2008). At the same time, it reliably removes SS, organic matter and pathogens, and human exposure to disease-causing organisms is limited as the system operates underground (Jenssen et al., 1993; Tilley et al., 2014). Besides, if the vegetation grows well and flowers are planted on top of the CW, it will also look pretty – a value not to be underestimated in otherwise barren Mustang. From the experience of the community in Nala, the participation process leading up to the construction of their CW also brought about several benefits (Nala WSSC, personal communication, June 11, 2017): Their project partners provided WASH training, comprising a series of workshops and exposure visits, engaging women, youth, elderly people and health volunteers. This inclusive program increased awareness and understanding, resulting in behavior changes and better hygiene habits. For example, sludge from septic tanks is no longer disposed of in drainage channels, and locals report a reduction in illnesses and diarrhea. If the installation of a CW in Lo Manthang was accompanied by such a comprehensive WASH program, the local community could expect similar benefits.

However, CWs also have disadvantages and requirements that call for attention. Whereas construction costs are low, CWs need large areas of land, which might be expensive depending on the location (UN-HABITAT, 2008). Furthermore, even if the system itself is cost-effective, the underground piping required to convey wastewater will be a major investment. If for that reason a system for Lo Manthang town is too difficult to implement, individual guesthouses could still build small CWs in their backyards for the sewage and/or graywater they generate. Another shortcoming is that unlike EcoSan toilets, CWs do not return all the nutrients to the field but retain some of them: When P from blackwater sorbs to the filter medium, the system's treatment is considered to be efficient because it produces cleaner effluent, but a valuable and scarce nutrient is lost for reuse. Likewise a portion of N will become unavailable due to biochemical transformations. In terms of closing-the-loop, a CW thus performs not nearly as well as EcoSan toilets. High evapotranspiration may also reduce the amount of effluent to be reused in agriculture (Tilley et al., 2014). Another challenge is that the design for a CW must be made and its construction closely supervised by a professional to ensure proper functioning (Tilley et al., 2014). The creation of a suitable design is further complicated by the fact that the technology is still recent in Nepal and "design criteria have yet to be developed for different types of wastewater and climates" (UN-HABITAT, 2008, p. 5). The greatest difficulties with existing CWs, though, are related to their management and maintenance, as communities running such systems have experienced (K. Pudasaini, WaterAid; Nala WSSC; and R. Shrestha, ENPHO, personal communication, April 13, June 11 and 16, 2017, respectively).

Even though maintenance requirements are low compared to conventional treatment plants, the upkeep of CWs *does* require some time and responsibility (ENPHO & WaterAid, 2008). The tasks include checking pipes for blockages, monitoring pretreatment units to notice when they need to be emptied, safely disposing of the sludge, and taking care of the wetland vegetation, that is, planting and harvesting to avoid decomposition back into the wetland. About every ten years the material at the inlet of the wetland filter will need to be replaced due to clogging from solids and biofilm (Tilley et al., 2014). If maintenance is neglected, the system's performance will suffer and it may require major repairs much sooner. Such a scenario has been unfolding at the CW in Nala, and learning from their experience could prevent similar difficulties from arising in Lo Manthang.

One of the challenges with O&M in Nala is that the pretreatment settlers fill up more quickly than expected. According to the Nala WSSC and R. Shrestha (ENPHO) who designed the system, not only blackwater but also runoff from manholes in the fields and along roads ends up at the treatment plant. During the monsoon season, this runoff carries a lot of mud and sand, filling up the settling tanks and ABR, which initially went unnoticed. Without appropriate settling, wastewater and sludge then overflowed into the wetland, so that the gravel in the wetland bed clogged and already had to be washed in the fourth year of operation.

Insufficient maintenance and pretreatment have also led to poor performance of Nala's CW. The community no longer checks the quality of the effluent regularly, but ENPHO samples it once a year, and the laboratory test report from January 2014 shows that four standards were exceeded: (ENPHO, 2014): total suspended solids (TSS), BOD, COD, and fecal coliforms. In 2017, the Nala WSSC reported a BOD of 510 mg/l at the outlet, more than ten times beyond the standard. Such high organic matter content in the effluent might be related to insufficient retention time caused by excessive washing of the filter medium. Besides, the WSSC did not replant the wetland after cleaning the gravel so that there are currently no roots to provide oxygen. In short, without regular monitoring and O&M guidance by experts, the CW may fail to treat the wastewater adequately.

Another problem Nala is facing with their CW is the absence of a sludge drying bed which was not part of the initial construction plans. They have to shovel out sludge from the pretreatment units about once a year, but since a proper disposal site is lacking, the sludge is simply placed on a gravel plot immediately adjacent to the wetland and agricultural fields. The importance to include a sludge drying bed into the design from the beginning was emphasized by both the local committee and engineer R. Shrestha.

Further advice the Nala WSSC provided for Lo Manthang or other communities interested in building a CW concerns stakeholder participation, technical support and supervision, management of the system and financing mechanisms. According to the WSSC, active involvement of the community is the most important to make the right choice and motivate people to dispose of wastewater responsibly. In their case, methods used to achieve this were a sanitation bazaar where different alternative sanitation options were presented, as well as information about the functioning of the treatment plant, and various capacity-building workshops with practical instructions on toilet use, health and hygiene, community-based monitoring and evaluation. Support and supervision during planning and implementation were provided by a range of national and international partners: the Centre for Integrated Urban Development, UN-HABITAT, ENPHO, WaterAid and the Swiss Federal Institute for Aquatic Research and Technology.

The community itself also contributed extensively, bought land and provided unskilled labor during construction. Advice from these expert WASH organizations and inclusion of the local community throughout the process was essential to create ownership and establish a sustainable management scheme. Nala now has a WSSC of 15 members who meet once a month or when the need arises to manage the town's water supply and DEWATS. The committee members change after three years, and the current WSSC forewarns that after such a change it takes a while for the new members to gain knowledge and experience. Besides the voluntary work of the WSSC, the Nala community also pays three employees to look after their water supply and wastewater treatment, one employee specifically in charge of maintenance of the CW. Their salaries are covered through annual service contributions amounting to NRs 500/household (US$ 5) for being connected to the CW and NRs 200/household (US$ 2) for water supply.

If Lo Manthang is interested in a CW, the issue of maintenance funds as well as the initial investment cost and potential funding partners will need to be discussed early on. In Nala, each household paid a construction fee of NRs 8000 which covered the connection pipe and technical support. However, funding for the sewer line and treatment plant was also provided by the above-mentioned implementation partners. At Sunga (Thimi), the construction cost per square meter of the wetland amounted to NRs 2,900 (US$ 29) and average O&M per year was about NRs 20,000 (US$ 200)– but prices may have changed since the system was built in 2005 (ENPHO & WaterAid, 2008). Besides (I)NGOs, could the government be approached for financial support? According to T. Chaudhari from the DWSS, only if sanitation projects are proposed by the government itself would 85% of the cost be covered, with the remaining 15% paid through community contributions (personal communication, April 6, 2017). Self-initiated projects are not generally supported by the government. In order to receive funding for such a project, Lo Manthang would have to follow one of two approved paths: 1) They could approach the WSSDO in Jomsom and place a request for a project which would then be relayed to the DWSS in Kathmandu by the division chief; or 2) the community could propose a project directly to the MoWSS which would pass the application on to the DWSS. Chaudhari could not provide any information as to the chances of approval of such requests. For successful implementation of a DEWATS, a number of different funding partners may have to be approached and funding strategies explored. But the money will be well spent – the WHO reminds that the benefits of improving sanitation go beyond the potential to recycle water, reuse nutrients from excreta and reduce diarrhea cases: According to a WHO study from 2012, "for every US$ 1.00 invested in sanitation, there [is] a return of US$ 5.50 in lower health costs, more productivity, and fewer premature deaths" (WHO, 2017b, second paragraph).

6. CHALLENGES AND LESSONS LEARNED

6.1 Limitations of Research

6.1.1 Time and Financial Constraints

The time available for research in Lo Manthang was mainly governed by financial limitations: Upper Mustang being a restricted area, all visiting foreigners need to pay a daily permit fee of $50, irrespective of the purpose of their visit. To make matters worse, the fee doubles for individual travelers as the permit needs to be paid for a minimum of two people. Inquiries with the authorities in charge as well as numerous foreigners who have experience visiting Mustang for non-touristic purposes such as research, health and community development projects, confirmed that the permit fee could not be waived. It is levied in Kathmandu, and the Lo Kunphen School had no influence whatsoever regarding this regulation. In view of these circumstances, the research plan had to be adjusted to envisage only three trips to Upper Mustang, the minimum number deemed necessary for the stipulated participatory approach.

Despite these adjustments, the funding required for the research (mainly made up of permit costs and two international airfares) amounted to several thousand dollars. Lo Kunphen had made it clear from the beginning that they had no financial resources to support travel and permit expenses, and NMBU could not promise any funding, either. Therefore, drawing up proposals and budgets, searching for and corresponding with potential sponsors, and writing reports after receiving funding took up a substantial amount of the author's time during the preparation period and throughout the research. This time was then lacking for in-depth background studies and the development of sound methodologies before the initial assessment and for evaluation of the data immediately after completing fieldwork. Without an accompanying funding plan and/or financial support, a research project involving such high expenditures seems unsuitable for a master thesis.

Nevertheless, as the cooperation with the Lo Kunphen School had already started by the time the financial burden became clear, the author made every effort to raise the required funds and keep the costs to a minimum. Fortunately, thanks to S. Craig's personal contacts, a travel agent could be found who was willing to obtain permits for a minimal service charge without selling a full package tour including expenses for a trekking crew and pack animals. In order to keep the permit fee at $50 per day, the author also needed to find a travel partner or tour groups who could be joined pro forma for the permit. It was not necessary to remain together during the entire time in Upper Mustang, but the checkpoint at the border of the restricted area had to be crossed at the same time upon entry and exit. The group requirement thus reduced the flexibility in terms of traveling times and the number of days spent in Lo Manthang.

Even though the author was in Nepal for several months, all in all only 33 days could be spent in the restricted area of which six days were used to travel to and from Lo Manthang. These time constraints had several impacts on the conducted research. For one, there was insufficient time for rapport building with the local stakeholders and the community and for thorough investigations of the physical environment, for instance to find suitable locations for pedological assessments. For a project requiring a high degree of participation and cooperation with the local people, more time in the immediate surroundings and with the local people would have been advantageous. It would have enabled the author to familiarize herself more with their dialect and specific indigenous or Nepali terms related to WASH in order to develop more effective communication skills. In addition, more extensive participant observation would have allowed her to gain a deeper understanding of people's motivations, besides learning to navigate cultural norms and coming to be recognized as a research student as opposed to a tourist.

Further limitations arose from unfortunate timing of the research trips. The initial assessment in the summer of 2016 was a good time for the Lo Kunphen School and also the only available time for the author because of compulsory coursework before and after. However, the search for a traveling partner was complicated as the time lay outside the main tourist season, and heavy monsoon rainfalls affected the journey to Upper Mustang due to road damage (see section *6.1.3* below). In the spring of 2017, the timing of both trips coincided with other happenings at the Lo Kunphen School and in the community in Lo Manthang. During the first visit, the school was occupied with renovations and roof construction works, while many key community members were wrapped up in electoral campaigns shortly before the first democratic elections in Nepal in twenty years (Sharma, 2017). The second trip took place during the annual *Tenchi* Festival in Lo Manthang for which tourist numbers peak. This time had been recommended by Amchi Gyatso the year before as it was a good opportunity to join a group permit. The downside was that the town was bustling with people and activity. All guesthouses were fully booked and accordingly busy; everyone at the Lo Kunphen School was rehearsing for cultural performances; and local households including the *amchi* family were hosting numerous guests and relatives who had arrived from other villages to attend the festival. *Tenchi* (short for Tib. *bstan pa spyi rim*) is originally a religious festival that is celebrated for three days with mask dances performed by monks and the display of large cloth scrolls (*thang ka*) depicting Buddhist masters (Banskota & Sharma, 1998). In present times it also comprises evening gatherings with song and dance competitions for school children, local mothers' groups and the youth club. Because of all these other responsibilities and events, the Lo Kunphen headmasters, teachers and students were fully absorbed, as were many townspeople. Discussing sanitation issues was not a priority at that moment – possibly also related to other reasons as described below – which complicated research activities.

6.1.2 Limited Access to the Community

Research among Lo Manthang residents was influenced by several challenges. As the author had not been to the town before, she had no previous contacts or long-standing collaboration partners to rely on. Within the short research period it was difficult to gain the local people's trust and learn more about their concerns through informal interactions, let alone see behind the local politics, social structure, power relations, and other factors at play within the community. Time constraints also impacted the identification and selection of respondents among a previously unknown population. Some of the key informants could be approached by referring to the author's acquaintance with S. Craig. However, the interviews with the wider community only took place after a sudden change of the research focus; they had not been planned initially. Unfortunately, there was no local intermediary who would have assisted with finding suitable, willing and representative respondents. Consequently, the aspiration to involve a diverse range of individuals that would reflect the general views of Lo Manthang residents could not be fulfilled. The interviewed respondents turned out to be disproportionally young and/or well-educated, including more men than women, and especially no woman beyond her thirties.

The search for respondents who were willing to make time for a conversation proved difficult. One of the reasons was definitely that people's time and attention were focused on other events such as the elections and the *Tenchi* Festival. Another possibility is that they may have anticipated discomfort to discuss sanitation-related topics which may potentially have intruded on their privacy and not have been of their greatest personal interest. Whether it was a lack of time or initial reluctance, almost all interviews had to be rescheduled several times before they actually took place, even though they were always arranged according to the respondents' preference. Flexibility being required from an interviewer seems not unusual, though, according to a manual for community studies on hygiene practices (Almedom et al., 1997).

Besides the non-representative group of interview partners, the data gathered from the community was also affected by the way the author communicated and was perceived by the respondents. Language was definitely an issue as the author established contact by using standard Tibetan. She could not engage in further conversations with people only speaking the local dialect of Upper Mustang unless someone knowing standard Tibetan could facilitate. While almost all young and educated people do speak Tibetan, older and illiterate members of the population are not necessarily fluent in it, which limited the choice of respondents. Another factor potentially causing bias in the data was the fact that the author stayed with the *amchi* family, which was soon known in town. This may have helped get in touch with some interview partners, but may also have discouraged others from participating. As it turned out, many of the respondents were supportive of or even active members of the Congress Party, the party for which Amchi Gyatso's daughter was running for the post of vice chairperson of the village council (*Gaunpalika*). Whether this party affiliation was purely coincidental or had to do with political alliances and/or the respondents' demographic background could not be determined. Finally, people's reaction to the author being a foreigner may have influenced their answers compared to a local person inquiring about the same topics. Some respondents seemed to be hoping for some sort of support, while others may have replied or acted in unusual ways because of what they thought would please the author, leading to a so-called observer effect (Almedom et al., 1997). More experience from participant observation would have made it easier to recognize such distortions, but their complete eradication seems impossible: No matter how familiar and well-integrated, the author would still have been identified as a foreigner, which locals often associate with being a wealthy tourist.

In short, the collected information cannot possibly give a comprehensive picture of Lo Manthang residents' views. The presented findings are based on only a small number of interviews with selected community members and only reflect those people's opinions at the time of research.

6.1.3 Accessibility and Infrastructural Challenges

Upper Mustang's remote location and difficult accessibility affected the research in several ways, mainly regarding the availability of equipment and communication infrastructure. The journey to Lo Manthang was long and risky, especially in the summer of 2016 when monsoon rains had destabilized slopes. Landslides and rock fall blocked roads and caused accidents as the author was travelling north up the Kali Gandaki gorge. On several occasions all passengers had to get off the bus or jeep and walk for several kilometers, climbing across boulders and crossing mountain streams on foot while carrying their entire luggage. Upon completion of the fieldwork in Upper Mustang, the road had become completely impassable for vehicles so that the journey down involved several days' trekking on steep muddy terrain. As such difficulties had been anticipated – though not to the experienced extent – the research was planned so as to require hardly any specialized equipment that needed to be brought in from outside. For instance, it would have been unfeasible to carry anything bulky or fragile such as a Mariotte cylinder for infiltration tests. Likewise, soil and rock samples were kept to a minimum to limit the weight of the luggage. While more advanced methods for investigations of the physical environment might have produced more reliable results, they seemed unrealistic to accomplish during a one-person research endeavor.

An additional challenge for planning and conducting research in Lo Manthang was the lack of communication infrastructure. There was no internet and only limited phone signal at times, which complicated contact between the author, local partners and external advisors. During the research planning stage and between field visits, communication with the Lo Kunphen School took place over the phone or by e-mail to their branch in Pokhara. If a phone connection could be established, direct communication with the headmasters was possible, though the signal strength was not always sufficient to allow for a clear, uninterrupted conversation. E-mail correspondence meant that a relative proficient in English had to translate and orally relay the content of the message to the headmasters and vice versa, both because there was no internet reception in Lo Manthang and to bridge language barriers. Such communication challenges may have contributed to misunderstandings that seem to have arisen during the cooperation (compare section *6.2.1* below). Furthermore, communication between the author and advisors outside of Nepal seemed almost impossible during the research period in Upper Mustang. Emerging difficulties could thus not be discussed as they occurred, but only once the author had left the restricted area. As a result, dealing with challenges during fieldwork mostly depended on the author's decisions alone, without the opportunity to consult with more experienced professionals. The research trips to Lo Manthang also needed to be well planned and thought through because there were no public facilities for photocopying or printing in town. This made it necessary for the author to prepare all interview materials, documents for the school, and photos to illustrate alternative sanitation systems ahead of time in Kathmandu or Pokhara, before embarking on the journey to Mustang. It also limited the flexibility to make adjustments or respond to arising needs and interests of the local people spontaneously, such as by printing more photos for explanatory purposes.

6.2 Difficulties and Methodological Shortcomings

6.2.1 Communication Issues, Potential Misunderstandings and Differing Expectations

During the cooperation with the Lo Kunphen School, communication turned out to be a challenge, not only because of the limited phone connectivity and lacking data signal for internet use, but also because of language issues, misunderstandings and insufficient clarity about what each side expected. From early 2016 onwards, only the author herself was in direct contact with the Lo Kunphen headmasters. Due to language barriers – the *amchis* only speak the local dialect, Tibetan and Nepali – no direct conversation could take place between P. Jenssen, the main thesis supervisor, and the local project partners. Furthermore, communication with each headmaster happened separately: With Amchi Gyatso who spends the summers in Lo Manthang, phone calls in Tibetan were the only way to be in touch. E-mails had to be addressed to Amchi Tenzin who lives in Pokhara most of the time. As indicated above, those e-mails were translated orally by one of Amchi Gyatso's sons who also stayed at the school in Pokhara. How much detail from these calls and correspondence the two brothers shared with each other is not known. Two months before the first field visit in 2016, P. Jenssen signed an e-mail sent to Amchi Tenzin in order to clarify the scope of the cooperation, the timeline and funding responsibilities, based on the project proposal drawn up by the author.

Even though both headmasters agreed to the proposal and specifically asked for confirmation that the work would continue in 2017, their interest in the cooperation seemed to have faded by early 2017: When announcing her arrival in Nepal and inquiring about the most convenient time to visit the Lo Kunphen School, the author was informed that she did not need to come to Upper Mustang again in 2017 because the school was busy. This declining commitment to follow the discussed project plan came as a surprise, not least because the cooperation was assumed to have started on the request of Lo Kunphen. Further communication then revealed that Lo Manthang VDC was planning a community wastewater pipe and the headmasters preferred to wait with their sanitation system until they could connect a septic tank to the sewer. However, since the author's fieldwork could not be postponed, S. Craig agreed to mediate and convinced the *amchis* to continue with the cooperation all the same. The author then traveled to Lo Manthang again in 2017 as planned – though the school's priorities seemed to have shifted: Henceforth their involvement in trying to find a sustainable sanitation solution for Lo Kunphen was minimal (compare *6.2.2 Reflection on Methodologies* below). During each of the author's visits to Lo Manthang in 2017, the headmasters allotted only two or three hours towards the end of the stay to learning about and discussing potential solutions, and providing more specifics about their requirements.

In an attempt to gain understanding, potential factors leading to this change of attitude will be explored below. They comprise 1) a lack of time and different priorities on the part of Lo Kunphen, 2) the question of whose idea the project had been in the first place, 3) the participants' expectations in terms of consultancy and cooperation, and 4) possibly underlying hopes in terms of funding.

Regarding the lack of time and different priorities, the spring of 2017 was definitely a busy time for the Lo Kunphen School. Construction and repair work required most of the headmasters' attention, in addition to Amchi Gyatso's daughter's electoral campaign and the *Tenchi* festival during which Amchi Gyatso also had ceremonial functions to fulfill. Improving the sanitation system may have been a minor concern at that time simply because of unfortunate timing. However, cooperating on the development of a sustainable system may also have lost some of its appeal due to the prospect of a wastewater pipe in Lo Manthang which may have seemed to solve the school's problems with storing and treating sewage. The wish to have "modern" toilet facilities (meaning flush toilets) conveniently connected to a sewer may have overridden the previously voiced aspiration to also make the system environmentally sustainable. The cooperation with the author may thus have seemed redundant and no longer worth any burden on the headmasters' limited available time.

Connected to this arose the question how strong the wish to improve the school's sanitation system had been in the first place. Did the initiative really come from Lo Kunphen as assumed by the author, or was it rather outside observers who perceived a need to improve the situation? Upon the author's inquiry how the cooperation had come about, Amchi Tenzin replied in 2017 that he did not really know. He vaguely remembered a meeting with Sushma Joshi in Kathmandu but did not seem to recall her role in the process of connecting Lo Kunphen with NMBU professors. Could the agreement to cooperate have had a different background and incentive for the local partners? In their assessment of the action research approach, Susman and Evered (1978) point out that in order to predict and understand the participants' behavior and actions, the researcher should know not only their aims but also the values and norms that guide them. To make the collaboration more fruitful and prevent some of the misunderstandings, the author should have undertaken more efforts to understand the initial motivation behind Lo Kunphen's interest in cooperating with an NMBU student.

The headmasters' expectations about the consultancy and cooperation may have differed from what NMBU professors had in mind when they first started interacting. According to e-mails exchanged in late 2015, the Lo Kunphen School thought that an experienced professional like P. Jenssen himself would visit Upper Mustang for the assessment and design, with a student possibly supervising construction if P. Jenssen could not stay long enough (S. Joshi, personal communication, November 1, 2015). In the end, a female master student in the course of completing her degree came instead, which may have led the headmasters to question the benefits such cooperation would have for the school. Furthermore, the participatory approach may have been perceived differently by the involved partners. Did the Lo Kunphen headmasters possibly agree to participate without fully knowing what it entailed (see *6.2.2 Reflection on Methodologies* below)? Were they unfamiliar with the participation process, with having their opinions heard and contributing to finding the best option? Were they expecting a ready-made solution without having to invest any time in its development?

Another issue may have been the extended duration of the cooperation project. Even though discussed and agreed on at the beginning of the author's involvement, the assessment and consultation process might have taken longer than the headmasters expected. In the meantime, the school may have become doubtful of the benefits of the outcome. Until early 2017 the headmasters seemed to think that the cooperation would somehow include implementation; only thanks to S. Craig's mediation could it finally be conveyed clearly that this was not going to happen in the scope of this thesis. This may have caused frustration and disinterest in the further development of the cooperation. Such cases have also been reported from the tourism sector: Heredge (2003) mentions that "[l]ack of success in implementing projects [in Upper Mustang] is likely to have generated disillusion with the effectiveness of the participation process" (p. 18). And Nepal (2000) recommends that "caution should (…) be taken not to spend considerable time just collecting information without concrete actions at the local level. For it has been proven elsewhere that without some immediate tangible benefits local communities remain indifferent to long-term development and research activities" (p. 678). This is a trap the author may have fallen into: While documents for the Lo Kunphen School were concise and only comprised the essential content, a lot of time was spent on background research which was not all crucially related to the project. The creation of overly detailed descriptions has also been pointed out by Berg (2008) as a typical mistake of beginning action researchers which makes the process too elaborate to be effective. For future research endeavors with a similar approach, the overall timespan as well as the gap between an initial assessment, problem diagnosis and further steps towards action planning should definitely be shorter to keep the momentum and focus.

Finally, despite unmistakable communication regarding financial responsibilities, the Lo Kunphen headmasters might have hoped that agreeing to a cooperative project would generate funding for the school. Such underlying expectations became obvious through repeated e-mails the headmasters sent to the author, requesting her to find the budget for construction of the water supply and sanitation system. From the beginning of the cooperation and on each subsequent funding request the author explained that it was not in her capacity to assist financially as it was already a challenge to source funding to cover the research expenses, that is, travel and permit costs. Besides, a study by WaterAid on EcoSan toilets in Nepal recommends that users should always contribute to the cost of the toilet by providing money, materials or labor (Rajbhandari, 2008). Facilities provided without any cost to or effort by the users are not considered sustainable in the long run. However, the headmasters kept asking and tried to delegate efforts for budget-related issues to the author. In retrospect, they may have agreed to the cooperation without explicitly stating their wish for donations linked to it from the outset. Unfortunately, the author had not initially recognized how much Lo Kunphen counted on funding support for implementation and what implications that would have. An important lesson learned in the course of the project is that specifying how the "action" will be financed is an essential component that must not be neglected. This realization is in accordance with Bastien et al. (2015) who mention that access to resources needs to receive due attention, especially when working with less affluent communities such as those of Upper Mustang.

Further misunderstandings related to finances may have arisen regarding food and accommodation while the author stayed at the *amchis'* family home during the research period in Lo Manthang. The topic had only been discussed briefly at the beginning of 2016, when Amchi Gyatso had agreed to provide housing for several weeks at a time, not mentioning any compensation that was expected for room and board. The author and supervisors assumed that this was Lo Kunphen's contribution towards the consultancy as the school had no other expenses related to travel costs and permits. Since research in Lo Manthang had to be downscaled to less than a month in total, the author stayed with the headmasters' family for three separate visits of between eight and eleven days. During the last two stays in 2017, though, it seemed to the author as if the family was wondering about the role of the student they were hosting and feeding. Doubts may have arisen because the author's research work brought no immediate visible benefits for the school, let alone the family. This may have led household members to question why they were providing food and accommodation without getting anything in return.

After her final departure from Mustang, the author inquired with three external individuals with links to Lo Kunphen whether the lack of monetary compensation for being hosted may have caused misunderstandings. Opinions varied: Apparently some previous research students had paid for room and board when staying with the *amchi* family, but since the research in this case was done specifically to help improve the Lo Kunphen School's sanitary situation, the headmasters may have felt obliged to host the author. Offering money directly may have offended their sense of hospitality, as another guest and long-term Lo Kunphen supporter had experienced. The author was therefore advised to present an appropriate donation to the *amchi* family before leaving Nepal, to show gratitude for having stayed at their house without making an outright payment. This was done and seemed appreciated based on the headmasters' response by e-mail.

Several factors may have contributed to awkward situations while living in the *amchi* household and this unexpected expense at the end. For instance, the communication between the author and the Lo Kunphen headmasters may have been too vague; the headmasters may not have shared all information with each other, and the other household members seemed to know even less of what the cooperation entailed. Furthermore, the responsibilities between Lo Kunphen as an organization and the *amchi* household as a private family may have been unclear – for instance, why would the household be providing free room and board for a student when the research was only going to benefit the school? In order to prevent such incidents from happening, future research students are advised to clearly discuss compensation for living arrangements in the research community from the beginning.

6.2.2 Reflection on Methodologies

In this section, the methodologies for three distinct parts of this study shall be evaluated: (a) the PAR approach as it was carried out with the Lo Kunphen School (b) the interviews conducted with Lo Manthang residents, and (c) the natural science methods used for geology, soil and water analyses.

a) PAR with the Lo Kunphen School

The attempt to develop the project according to PAR was an ambitious aim, but in practice it could not be attained as anticipated. The author, coming from a natural science background, did not have sufficient skills and experience in social science methodologies to engage the stakeholders to the extent desired and required for successful action research. Not only were there clear shortcomings in the planning of the cooperation, but from the beginning it was also clear that the author would not be involved in the actual "action" – the implementation of the sanitation system at the Lo Kunphen School. Due to this point of departure, the local stakeholders should have been even more engaged than if the full PAR cycle had been accompanied by a facilitator in order to ensure a smooth transition from the cooperative stages to full ownership of the project. However, the degree of cooperation and interactive participation (Pretty, 1995) was insufficient during various phases of the process as shall be outlined below.

While the author made sure the Lo Kunphen headmasters understood that their cooperation was urgently needed and valuable, the ideal participatory approach could not be consistently followed by any of the project partners. For instance, the author only marginally involved Lo Kunphen in the elaboration of the schedule and detailed objectives of the project: After discussing the rough framework of the cooperation with Amchi Gyatso, she drafted the proposal herself and then shared it with Lo Kunphen for feedback instead of cooperatively developing it and letting the stakeholders phrase their own objectives. The author also wrote up question guides and determined what aspects needed to be investigated during the initial assessment, contrary to Fals Borda (2001) who describes that "[s]chedules or questionnaires, for example, ha[ve] to be conceived and crafted differently, with full participation of the interviewees from the very beginning" (p. 30). The unbalanced involvement of the author and local stakeholders should have been recognized and adjusted early on as it was already obvious from the research proposal (Table 3, p. 45).

During the problem diagnosis stage, the Lo Kunphen headmasters, teachers and students were asked to contribute, but the nature of their participation was determined by the research schedule the author had prepared. The stakeholders did not lead the analysis themselves, which according to Swantz et al. (2001), would have been beneficial for a successful PAR project. More active engagement and initiative would have given them the opportunity to learn by doing and use the knowledge acquired in the process for prioritizing their needs, making decisions about the actions that should be taken, assessing their own capacity and identifying the assistance they would require (Swantz et al., 2001). Instead, the research followed more the traditional approach with an outside person (the author) guiding and conducting data collection on the school's behalf.

Unfortunately this pattern continued and even intensified during the action planning stage of the project. The idea had been that the different improvement options put forward by the author would be adapted, refined and/or combined cooperatively in order to find the most suitable solution for the Lo Kunphen School. However, stakeholder participation at this stage had almost ceased so that the solutions ended up being almost entirely developed by the author. Only in terms of choosing the system, the location and number of facilities and selecting between different material options did one of the headmasters contribute. None of the stakeholders provided inputs regarding the sanitation designs or participated in drafting the material list and planning practicalities for O&M.

As mentioned above (section *5.2*), the decision on the preferred system was also taken by only one headmaster, Amchi Tenzin, without the involvement of teachers or students. Though the latter had participated in defining the WASH problems at their school and the author had inquired about their opinion on urine diversion during interviews with some of them, they were not part of the consultation and decision-making process for action planning. This lack of involvement had different reasons: It was partly the author's fault because of the research design and miscommunication about the participatory approach. Besides, it was also related to the hierarchical structure of the local society and top-down decision-making. The headmasters' age and position as school founders, doctors, employers, and – for some of the teachers – older relatives engendered a high degree of respect and authority in the school community, so that equal engagement of teachers and students would have been in contrast to local norms. Even Amchi Gyatso voluntarily left the choice for the sanitation system up to his brother, saying that Amchi Tenzin was better informed. While deference may have played a role due to Amchi Tenzin's status as a monk, this move could simply have been related to time constraints, too: Since the consultation period fell into the busiest time of year for everyone at Lo Kunphen, the school may just not have been able to spare anyone else during renovation works and festival preparations.

Nevertheless, the participation of teachers and students could have been better set up. For instance, the teachers might have expressed themselves differently had the conversations taken place in a "neutral" place and in private, without someone from the *amchi* family present. Although this had been intended by the author, it was difficult to insist on once the headmaster had declared that the interviews would be arranged in their family house instead of the school. It is impossible to speculate whether the content of the answers would have changed, but the respondents' replies seemed more tentative in front of their employer and/or older relative, maybe to avoid embarrassment. Regarding student involvement, it could and should have started at an earlier point in order to build rapport and encourage more students to participate in the focus group interviews. One of the downsides of only few participants and a small number of groups is that the content of the discussions becomes more difficult to interpret: Do the expressed views reflect what would have been found in another group, or have the participants' opinions been influenced in a unique way by the discussion process? If there had been two or three groups of the same characteristics (for example, several groups of girls and boys), a comparison of their discussions could have indicated whether group dynamics were responsible for the outcome (Morgan, 1997). It is important to recognize that the stated findings should not be generalized but understood as the opinions of the participating students in those specific group compositions at that time. While it is normal that not all stakeholders participate to the same extent during all stages of a PAR project (compare section *3.1*), they should at least be updated and given the opportunity to provide feedback *during* the process and not only at the end (Berg, 2008). At the Lo Kunphen School, the author did not ensure that the flow of information reached the teachers and students, and while she conveyed their opinions to the headmasters, it is uncertain how much weight those inputs were given in the decision-making.

Further situations where the project diverged from ideal PAR were the tasks of record-keeping and budgeting. As Swantz et al. (2001) noted, if the participants themselves write down what is discussed and decided, they are less likely to forget it. Otherwise, remembering all the details and useful information becomes impossible over time. With the Lo Kunphen School, however, all written documentation was prepared by the author and supplied both as hardcopies and electronically, whereas the headmasters themselves did not take notes. As the provided documents were written in English and only orally explained in Tibetan, the headmasters needed one of the teachers or Amchi Gyatso's children to translate for them if they wanted to go over the content again. This obstacle may have made the documents seem less useful; they ended up being misplaced or lost several times and had to be resent to the school. The project would have benefitted had all records been in the local language, and ideally taken by the key stakeholders themselves. The same goes for budgeting, which Swantz et al. (2001) identified as an important activity for creating awareness of the costs and encouraging participants to reflect on funding opportunities. However, the headmasters only marginally contributed to drawing up the budget. According to their expectation, the author compiled the list of needed materials and drafted the cost estimate based on information gathered from sanitary appliance stores. All traders' contact details were given to the school, as well as the specifics of Nepali WASH professionals who could – and were eager to – provide advice and training. Despite repeated attempts to convince the headmasters that those experts were essential and waiting to hear from Lo Kunphen, the school did not get in touch with any of them during the research period.

Unfortunately, the stakeholders' limited involvement makes the project prone to failure in the long run. Especially with the chosen urine-diverting system, the Lo Kunphen School's strong commitment will be required for careful implementation, training for consistent, correct use of the toilets, safe handling of feces and appropriate field application of urine. An improperly operated urine-diverting system may lead to malfunctioning, disappointment and health hazards – which would defy the purpose of making it a model for others to learn from. Since the planning of the improvements largely depended on the author, it is uncertain whether the local stakeholders will continue according to the developed suggestions. As Berg (2008) cautions, "such [collaborative] projects tend to be associated with the change agents (those facilitators working in the research); consequently, the interventions may cease to be used when these individuals leave the system" (p. 260).

In action research, "evaluating whether actions produce intended consequences" is the criteria for confirmation of the research, equivalent to "logical consistency, prediction and control" in positivist science (Susman & Evered, 1978, p. 600). In the scope of this thesis no evaluation could be carried out because the author left the project before the implementation stage. Therefore, reflection and assessment of the outcome – that is, the functionality of the implemented WASH improvements – which should lead to learning and knowledge-generation could not be part of the research. Besides the uncertainty whether the urine-diverting toilets, water supply system and graywater disposal will work to the users' satisfaction, it is also not sure whether the cooperation contributed to local capacity building, another goal of PAR (Susman & Evered, 1978). The mutual learning process may have been limited because of little truly cooperative work between the author and the local stakeholders. Furthermore, even if the desired improvements will take place, their applicability to other settings, even in Upper Mustang, may vary. This is due to the inherent aim of action research to develop solutions tailored to a particular group of stakeholders in a specific location. Such solutions can rarely be transferred elsewhere without adjustments, albeit the settings may bear many similarities (Berg, 2008).

An overall challenge of the PAR approach was also its dynamic nature and demands on the author's cross-cultural skills. The process was not linear but kept evolving and changing, much depending on the project partners and outer circumstances. This required flexibility on the author's part to accommodate emerging needs and alter or expand the research focus, respectively. Cooperating with local stakeholders also entailed continuous efforts to bridge the cultural gap, including different ways of communicating (language-wise and regarding social norms), different concepts of time, collaboration and commitment. Fortunately, the author could draw on several years' experience living and working among Tibetans across the Plateau, which had familiarized her with similar challenges and helped her navigate cultural differences and unexpected situations.

b) Interviews with Lo Manthang residents

The information from interviews with Lo Manthang residents needs to be interpreted carefully due to various challenges and potential interferences. Nawab et al. (2006) point out that good communication skills and understanding of the community are necessary when interacting with local people during research. These requirements were difficult to meet: Not only was it the author's first visit in Upper Mustang with limited time for selecting respondents, but it was also her first time to apply social science methodologies. According to Almedom et al. (1997), however, semi-structured interviews require experienced investigators. The author may not have been able to conduct them as professionally as a practiced social scientist would have, for example when preparing the interview schedule, interacting with respondents, and recording and evaluating the data.

The gathered information may also have been influenced by other factors. For one, semi-structured interviews may be perceived as intrusive, especially when there is limited time (Almedom et al., 1997) – and when the interview concerns a topic one would not necessarily discuss with a stranger. Furthermore, the answers depend on how the respondents see the interviewer, which may be affected by age, gender, ethnicity, language, comportment, the alleged status of and relation with the interviewer (Almedom et al., 1997; Craig et al., 2010). In some cases, the respondents' opinions were also influenced by other people present during the conversation. They started discussing their views, advantages and disadvantages of different systems and practices, so that the recorded answer is sometimes the product of an interactive opinion-shaping process and not necessarily what would first have come to the individual interviewee's mind. This type of collaborative communication has also been reported by Craig et al. (2010) from their research in Upper Mustang:

> Interviews designed to collect the narrative of an individual usually became family affairs. While such multivocality or lack of privacy might be construed in a Western research context as a breach of confidentiality or as 'noise' in the data, these circumstances actually put interviewees at ease. (p. 14)

On occasions, such discussions led to a group consensus, as was experienced at one of the guesthouses and also with a group of boy students during their focus group interview, where the participants' opinions gradually streamlined along the majority view, often shaped by the most outspoken and respected group members.

In other cases, respondents' answers may not have reflected their actual thoughts and practices, but their attempt to give the "right answers" to the interviewer (Almedom et al., 1997, chapter 6). This so-called observer effect takes place when respondents start to behave differently in the presence of the researcher (Almedom et al., 1997). Such distortion is likely to have happened because interviews were also an opportunity – often the only opportunity – for the author to share information and raise awareness about alternative sanitation systems. Whereas educating potential users is considered essential to increase acceptance of EcoSan infrastructure (Werner et al., 2003), the challenge for the author was to balance it with receiving the respondents' replies in a non-judgmental way without falsifying their original accounts. Sometimes what the respondents learned during the interaction, through pictures or explanations by the author, changed their opinions and subsequent answers were in line with what they might have thought the author wanted to hear.

Related to that is the probability that the author's bias and subjectivity influenced not just the course of the interview but also the way the answers were perceived. Berg (2008) emphasizes that the researcher must approach a PAR study with an unbiased mind – for if he or she already knew the solution, conducting research would be redundant. While even experienced social scientists run the risk of compromising the objectivity of data collection with their own opinions and bias (Almedom et al., 1997), this risk may have been enhanced during the research for this thesis. The author's inexperience with social science methodologies, her background in environmental studies and focus on ecologically sound technologies may have affected interview partners and data collection more than it should have.

c) Natural science methods used for geology, soil and water analyses

Regarding Lo Manthang's geology and pedology, the lack of detailed cartographic material caused the overall assessment to be only rough, while investigations of rocks and soils were very site-specific. For example, the two analyzed rock samples do not reflect the geologic diversity of the area. Identifying a greater number of rocks and studying their possible contribution to the formation of present soils may have provided a more comprehensive background and more precise estimates of soil constituents and properties relevant for wastewater treatment.

Soil analyses were limited to four locations, and infiltration tests could only be done at three of them. Consequently, they cannot offer a representative picture of Lo Manthang's underground, particularly because all three infiltration sites were on (formerly) agricultural land and all tests were conducted at the same depth. Due to clearly layered deposits, a greater variety of locations could have revealed more suitable sites for wastewater infiltration, especially as deeper layers seemed to be coarser and possibly of higher K_{sat} than those close to the surface. However, practicalities such as the availability of water and tools and the prerequisite of not disturbing local farmers limited the selection of test sites. Besides, time constraints made it impossible to explore the availability of land and feasibility of an infiltration system or CW with the community even at the sites where tests *were* conducted.

While field infiltration tests generally provide more accurate K_{sat} values than other types of investigations such as texture analyses and pedotransfer functions, the used pit infiltration method may not be the most precise among different in-situ tests. Using very basic equipment, infiltration could only be measured for a few centimeters. More sophisticated instrumentation, for example a Mariotte cylinder with a device for constant head infiltration, may have produced different results.

The water quality tests were done according to standard methodologies, so the findings should be accurate. Nevertheless, three factors may have affected the validity of some results: The long storage time between sampling and analyses in the DWSS laboratory in Pokhara, the incubation and subsequent evaluation of *E.coli* petri dishes, and the small number of water samples taken. Since two months passed between sampling and analyses at the DWSS in Pokhara, without preservation of the samples, certain parameters such as the nitrate content may have changed. For the *E.coli* analysis done in the field, the procedure up until incubation went smoothly, but it is not sure whether the petri dishes were then removed from the incubator and checked after 24 hours, as the analyst was on the way down to Pokhara together with the test kit. Even though the author requested to be sent the *E.coli* count and pictures of the petri dishes after incubation several times, those pictures were not sent to her until three months later. They had been taken by cell phone on the day the author received them, which leaves questions open whether the photographed petri dishes (Figure 74 in section *4.1.1*) represent the original analyses. Overall, the results are also of limited validity because only one sample was analyzed per sampling point. Three replicates for each site would have made the results more reliable because discordant values due to erroneous measurements could have been more easily spotted.

6.3 Further Research Needs

6.3.1 Feasibility of Urine-Diverting Dry Toilets

Local users' acceptance

To assess whether UDDTs are acceptable to the people of Upper Mustang, a survey beyond the 15 interviewed people in Lo Manthang will be necessary. Respondents should be chosen so as to reflect the make-up of the population, representing the variety of ages, occupations and gender in actual proportions. WaterAid (2011) points out that "[t]he long-term success of EcoSan will depend on the credibility it enjoys with potential users" (p. 40), which requires knowledge and awareness of such alternative systems (Bing, 2014). They must be proven to work, which can be achieved with a demonstration toilet or exposure tours to a well-functioning EcoSan system as suggested in section *5.3.1*. Furthermore, local leaders and opinion makers must be identified; if they accept and promote the technology, people will be more motivated and proud to use it (Bing, 2014; WaterAid, 2011).

Farmers' acceptance of urine as a fertilizer

During the research for this thesis, no interviews were conducted with farmers specifically to find out about fertilizing practices and their views on urine application. Several respondents indicated, however, that liquid fertilizer might face problems with acceptance as it has not customarily been used. Besides cultural and personal reluctance, transportation of urine to the fields might be a hindrance to its widespread use. According to Bing (2014), 85% of EcoSan users in Darechowk encountered problems with urine application. Would farmers in Lo Manthang experience and perceive the same challenges, even though they currently have no alternative fertilizer except dung? Or would urine be considered valuable enough to put up with the extra effort it takes to apply?

Besides, would farmers be willing to use urine from other people? According to WaterAid (2008a), a number of farmers in southern Nepal get urine from neighbors as their own family's production is insufficient to fertilize their vegetable fields. On the contrary, the majority of Bing's (2014) respondents stated that they would not accept urine from other households, which she related to their limited level of knowledge and trust in the sanitizing process. In Lo Manthang, opinions varied on whether using other people's excreta was acceptable, even concerning excreta mixed with amendments from the traditional dry toilets. Further studies should thus explore this question, for if UDDTs or traditional dry toilets were used in guesthouses or public places, farmers' acceptance of other people's urine and feces would be a prerequisite.

Requirement for and availability of amendments

Depending on the location of UDDTs in guesthouses or public places, that is, whether they receive direct solar radiation that improves dehydration, varying amounts of amendments will still be needed. If those amounts are not considerably lower than what is needed for traditional dry toilets, the latter might be a better choice as they function in the winter whereas urine might freeze in the pipes and block them (compare section *5.1.2*). But that means returning to one of the core questions of the Lo Kunphen School's sanitation issues: What amendments can be used in guesthouses and for public toilets if there is no ash from dung stoves? Is there enough dung to be bought from nomads and farmers? Would the latter sell it in exchange for excreta from toilets rather than using the dung directly on their fields without passing through a toilet? Or could more sawdust become available for use in dry toilets? The question of amendments remains a challenge for the long-term and widespread use of dry sanitation systems.

Storage requirements for safe reuse of feces

Further research should also investigate the sanitization of feces or combined excreta stored under Mustang's climatic conditions. An analysis of the pathogen levels during different storage stages and before incorporation into the soil could reveal whether the current practice of storing excreta over the winter is sufficient for pathogen die-off. If it is found not to be enough, longer storage times, different methods or protection measures should be explored to improve the safety of farmers and consumers when reusing feces in agriculture.

6.3.2 Tourists' Acceptance of Dry Toilets

Since the potential and success of dry sanitation in guesthouses partly depends on people's perceptions, further research should assess not just local residents' but also *tourists'* openness to traditional dry toilets and UDDTs. As elaborated in section *5.3.3*, the implications of different sanitation systems, including their connection to the environment and livelihoods would have to be clearly explained. Studies in the U.K. and the U.S.A. (cited in Heredge, 2003) have shown that tourists are willing to pay up to 10% more for environmentally friendly products and services. Surveys and interviews with tourists in Upper Mustang could reveal whether this eagerness to protect the environment also increases their willingness to use dry toilets if they understand the latter's environmental sustainability and adaptation to the local context.

Do tourists really need the "comforts" and "standards" local guesthouse owners think they need to offer? What are visitors' preferences and requirements regarding sanitation systems? What type of user interface do they expect? Would they consider the use of dry toilets a valuable, exceptional experience or rather a discomfort? Would it influence their decision to travel to Upper Mustang? How interested are they in learning more about the region's ecology and ancient sustainable practices?

Such questions should be investigated in cooperation and coordination with guesthouse owners and other actors from the tourism sector, for example guides and travel agents who receive feedback from their customers after trips. Knowing tourists' actual expectations and motivations is important to avoid that far-reaching choices for sanitation systems are based on assumptions. As Sharma (2000) mentions, "[a] key feature in managing sustainable tourism is to remain proactive or to understand and develop programs to deal with problems before they reach crisis proportions" (p. 374). Well-informed stakeholders, including visitors to Upper Mustang, could contribute to a holistic approach to sanitation which will prevent greater challenges in the future.

6.3.3 Location, Design and Dimensioning of a Potential Wastewater Treatment System

If the people of Lo Manthang are interested in building an infiltration system or CW, they might require consultancy to find a suitable location. While the availability of land and local residents' opinions will be decisive factors, a number of legal guidelines and practical criteria will also need to be considered.

Among them is the FSM Institutional and Regulatory Framework which stipulates that the land allocated for a treatment site should be public or acquired by the WUSC "with ownership certificate and without adverse social and environmental impacts for construction" (DWSS & MoWSS, 2016a, p. 1). In order to avoid pathogen transfer, pollution and odors, the regulations continue that such a site should be away from densely populated areas, schools, and water bodies. While fecal sludge must also be disposed of at a distance from agricultural fields, this condition should not affect a CW because its effluent can be reused for irrigation. The FSM regulations *will* apply to the disposal of sludge from private cesspools and pretreatment settlers of a CW, though, requiring that such sites are "at least 300m away from the nearest dwelling, 30m downstream from any drinking water source, not in a protected or religious area, and in relatively flat land with no more than 8% slope" (DWSS & MoWSS, 2016a, p. 1).

From an engineering perspective, a natural treatment system should be located on the terrace (south)east of Lo Manthang to allow for wastewater conveyance without pumping. To reduce the cost for piping and make the effluent available for agriculture, a CW should not be too far from the town. Further site investigations will need to determine where and at what depth the soil's K_{sat} would be sufficient for an infiltration system. For a CW, appropriately sized gravel or sand from the surroundings will need to be selected as filter medium.

Regarding the design and dimensioning, additional research and experimentation will be needed due to the limited experience with natural treatment technologies in Nepal (ENPHO & WaterAid, 2008). For the design of a CW, aspects that will need to be investigated include the particular climatic conditions, the quantity and strength of wastewater, the treatment target, the material used for the filter, whether the bottom should be open or sealed, and what native plant species would work well in Upper Mustang. After implementation of a system, its functioning and treatment efficiency would have to be assessed in order to adapt and improve the design for potential replication in other villages.

6.3.4 Cooperation with Local Institutions and Organizations

WASH improvements in Lo Manthang, including potential EcoSan and DEWATS projects, will require cooperation with local government bodies and NGOs for expertise, capacity building, funding and continuing guidance and monitoring. In the scope of this thesis, it was not possible to establish contact with all relevant offices and potential partners from the WASH sector. Future studies should therefore explore the different WASH actors' approach and type of interventions, so that the local community can be linked with offices and organizations which have the capacity and experience to provide support.

Three organizations and one government office have already shown interest in contributing to WASH projects and/or sustainable sanitation in Upper Mustang: WaterAid, the WSSDO in Jomsom, ACAP, and FEDWASUN. WaterAid was planning to start working in Mustang District in 2017 and advised that the local community approach the organization through the WSSDO to discuss potential cooperation (K. Pudasaini, personal communication, June 7, 2017). WSSDO Chief B. Yadav stated his office would be willing to help facilitate EcoSan if WaterAid had any such plans, for instance for public toilets in Lo Manthang (personal communication, May 27, 2017). The chief of ACAP's Unit Conservation Offices in Lo Manthang and Jomsom also announced that if WaterAid, the newly elected government body or any other organization approached them to cooperate on wastewater treatment, they would be interested (T. P. Dahal, personal communication, May 16, 2017). ACAP's main motivation is nature conservation, which includes water resources. Dahal mentioned that ACAP had limited financial resources but could provide its expertise with local networks and experience at the grassroots level as it has been working with the community in Lo Manthang for 25 years. The request will need to come through official channels, though, not individuals. As for the WWF, the organization does have a river monitoring project along the Kali Gandaki, but it is neither involved in WASH nor in Upper Mustang because the area falls under ACAP's responsibility (G. S. Gurung and R. Sada, personal communication, March 27 and April 4, 2017, respectively). Finally, FEDWASUN indicated interest even though the federation does not have a district chapter in Mustang yet due to financial and geographical difficulties. If a training workshop on WASH was organized in Mustang, they might send one of their trainers for a workshop; their training package is normally five to seven days. (D. B. Thapa, personal communication, April 7, 2017).

Besides, ENPHO and urine-diversion expert S. Pokharel could also be approached, the former for either EcoSan or DEWATS, and the latter especially for UD toilets – even public ones as he has experience with such projects. The possibility of Lo Manthang cooperating with any of these organization and further partners – ideally with several of them through a coordinated approach – should be investigated in order to improve the town's WASH situation and prevent future pollution risks.

7. CONCLUSION

The objective of this thesis – to gain understanding of the WASH context in Upper Mustang and develop sustainable sanitation solutions for the Lo Kunphen School and Lo Manthang in general – proved to be more difficult than expected due to a range of specific conditions and constraints.

While dry toilets seem like a perfectly adapted technology, their continued use is challenged by a combination of factors. One of them is the lack of amendments, related to very limited biomass growth, but also a decrease of animal husbandry and agriculture caused by a change in livelihoods and outmigration. Limited availability of dung and the wish for cleaner air to reduce respiratory illnesses have led to a gradual change from dung to gas as a cooking fuel, so that less ash is produced. Without ash, traditional toilets turn too moist and smelly; excreta do not dehydrate properly and pathogen die-off is slower. At the same time, local residents are exposed to other lifestyles through the influence of tourism and migration to and from other parts of the country or even abroad. Their perceptions of adequate sanitation are changing; traditional dry toilets are often considered backward, whereas water toilets are associated with modernity and comfort. Against this backdrop, local guesthouses and institutions have felt compelled to build (pour-)flush toilets, despite the region's limited water resources which are expected to decrease even more as a result of global warming. Without wastewater treatment, the blackwater from these toilets is likely to cause health risks and environmental pollution in the future. This will either happen when current cesspools fill up and the slurry has to be removed and disposed of elsewhere, or if water toilets are connected to Lo Manthang's planned wastewater pipe which might discharge into the rivers. Besides, the cold winters prevent water toilets from functioning all year round due to freezing of pipes – which also affects the town's water supply.

Further constraints on sanitation improvements are Upper Mustang's remote location, low infrastructure development and most households' financial limitations. The transport of materials to Lo Manthang is costly and electricity is scarce, as is machinery which is commonly used elsewhere in the country, for example, to pump out septic tanks. Since most locals are subsistence farmers and pastoralists, with only few engaged in tourism, they have little capacity to invest in upgrading the existing sanitary systems. At the Lo Kunphen School, additional factors curtail the options: The school is surrounded by roads and other buildings and has no free space for a wastewater treatment system. Moreover, there is no direct solar radiation on the ground-floor to help dehydrate excreta.

The school is in clear need of WASH improvements, though, as it falls behind many of the WHO's minimal standards for schools in low-cost settings (Adams et al., 2009). According to the stakeholders' wishes, running water at the school is given high priority: Water storage drums at the school shall henceforth supply three taps for hand-washing and three showers, the latter also recognizing female residents' privacy needs for personal hygiene. If such infrastructure is accompanied by effective hygiene education and if teachers take their role model function seriously, students will get the opportunity to develop hygiene habits with health benefits long beyond their school years. Regarding sanitation, the school wishes to replace the only functioning pour-flush toilet with five UDDTs, complying with national and international guidelines in terms of residents per toilet and the requirement for gender-separated facilities (Adams et al., 2009; GoN, 2010a, 2016a; MoWSS, 2016). Urine-diversion will reduce the moisture problem which has made the existing dry toilets unusable, and thanks to storage containers on wheels the transport of feces to the fields should become safer and easier.

On the positive side, the objective of environmental sustainability has been achieved to the highest possible extent – at least during planning: The proposed UD sanitation system is in line with EcoSan principles, fits in with the local architecture, and promotes the continuation of the traditional way of reusing excreta. Compared to pour-flush toilets, no water will be wasted or unnecessarily contaminated; instead of producing infectious slurry with the risk of spreading pathogens, the latter will be contained within the limited volume of feces. The system also prevents the loss of valuable nutrients in a place where no alternative fertilizers except dung are available. Practically sterile urine can be used to increase vegetable production for the school, enriching the children's diet and/or reducing the expense for imported produce. When hygienized feces are used on agricultural fields, they act as a soil conditioner, increasing the soils' organic matter content as well as their water- and nutrient-holding capacity. Furthermore, the school's WASH challenges have been approached in a holistic way. Besides "hardware" components, "software" such as O&M and hygiene behavior are extensively addressed in the proposed improvements. For example, FSM including protection measures for feces handling and requirements for maximal sanitization before reuse are explained in detail, and graywater shall be disposed of safely through an infiltration trench. As mentioned above, the proposed water supply infrastructure will create enabling conditions for improved hygiene, and the importance of education to increase awareness of linkages between WASH and health has been clearly emphasized. However, putting all these suggestions into practice will depend on the school's commitment and its residents' practices in daily life.

In terms of cultural acceptability, the outcome is more difficult to predict. While the reuse of excreta has traditionally been practiced and is well accepted in Upper Mustang, locals are unfamiliar with urine application. Their reactions to liquid fertilizer and how they will deal with its transportation challenges are currently unknown. Likewise, the split interface of UD pans is new and may be inconvenient for some; proper use will require understanding and training. Even though the technology has been successfully implemented in other Nepali communities and expertise exists with several NGOs, the Lo Kunphen School would be the first one to build such systems in Lo Manthang, without being able to rely on documented experience with UDDTs at other Nepali schools.

The chosen improvements do also not fully meet the targets of choosing local, affordable options over imported appliances that are more expensive and more difficult to maintain. A completely local solution turned out to be impossible under the given circumstances. Nevertheless, considering the stakeholders' wishes for comfort and cleanliness – such as urinals for male residents, tiled surfaces, and a solar water heater for showers – the suggestions are as reasonable as possible and all materials are available in Nepal. For the UDDTs, conscientious O&M will be crucial, though, as their upkeep is not as simple as the previous dry toilets. As for costs, *any* improvement of the Lo Kunphen School's WASH situation will require an extraordinary budget since the school almost entirely depends on donors. For Western standards, the expenses for the elaborated improvements are modest (around US$ 6,000), but for the school they will be impossible to cover without external support. Funding has thus been a major issue from the beginning, which possibly influenced the course of the project and also stakeholder participation.

This raises the question whether the cooperation was directed by local needs and initiative as stipulated on the outset. Even though the intention was for the Lo Kunphen School to be centrally involved in the assessment of the present situation and the development of solutions, this did not happen in practice. The author had difficulty engaging the stakeholders to the desired and required extent. Possible reason for the turn of events may have been the approach which was more researcher-focused than PAR should be, the fact that implementation was not going to be part of the cooperation, potential misunderstandings about each side's motivation for and perceived purpose of the project, and unfortunate timing with the schools' headmasters having other responsibilities and priorities. This led to limited stakeholder initiative, and the chosen solutions were not widely supported through collective decision-making including staff and students, but based almost exclusively on discussions between one of the headmasters and the author. Due to limited possibilities for interaction, it is unsure whether the Lo Kunphen School fully recognized the need for professional guidance during implementation and the importance of training through experts. Lacking supervision for construction, O&M, and safe reuse of urine and feces may jeopardize the success and long-term viability of the UD sanitation system and lead to disappointment with the technology which requires a high degree of commitment.

While the sanitation system selected by the Lo Kunphen School could become a model toilet, the chances that other locals will replicate it seem limited. UDDTs are definitely an innovation in Lo Manthang, and with proper use, maintenance and management of excreta may serve to demonstrate several advantages. Two of the most relevant aspects in Lo Manthang would be that 1) dry toilets can look clean and modern, and 2) the fertilizer value of excreta, especially urine, makes it worth to collect these nutrients rather than flush them away. Ordinary households may not be interested in UDDTs as their traditional dry toilets still work with the amounts of ash produced. Besides, since one or two members of each family stay in Lo Manthang over the winter, traditional dry toilets are a better option as long as there are sufficient amendments – urine pipes would risk freezing in the mostly unheated dwellings with temperatures far below zero. For guesthouses, however, at least those who only remain open during the summer season, UDDTs might be an interesting alternative, and their installation at the Lo Kunphen School would be an opportunity for guesthouse owners to get to know the technology.

Such knowledge of and exposure to alternative sanitation systems is very much needed in Lo Manthang because the current developments with an increasing number of water toilets is unsustainable. The latter are not adapted to the local context and the generated blackwater is likely to cause greater problems in the future. Despite these drawbacks and the fact that local households continue to use dry toilets, half of the interviewed residents said they preferred water toilets. The most important advantages locals attribute to water toilets are their convenience, easy disposal of excreta, and the perception that they represent progress. Outward looks of a sanitation system seem to play an important role, and "modern" is solely associated with water toilets. The preference for water toilets is also linked to the challenges with traditional dry toilets: Emptying the excreta storage is hard labor, it is difficult to find workers, and those with no fields have no use for fertilizer. On the other hand, the fertilizer value of excreta is considered the main advantage of dry toilets – and its loss among the most-mentioned disadvantages of water toilets, the other ones being freezing and smelly sludge. Few respondents spontaneously mentioned health and environmental concerns related to either type of sanitation system.

Hence, what is the degree of awareness among locals regarding pathogen transfer and the links between sanitation, health and environment? Negative health impacts of discharging untreated wastewater are widely known (two thirds of respondents), but transmission routes apart from contaminated drinking water rarely considered. On the contrary, only about one third of interviewed locals mentioned concern about water or environmental pollution related to the disposal of untreated wastewater – a finding not uncommon among populations with other primary concerns to sustain their livelihoods (Nawab et al., 2006; Rajbhandari, 2008; WaterAid, 2008a). Two thirds of respondents also knew about traditional rules prohibiting urination and defecation near springs to prevent upsetting water spirits – but those beliefs and related practices are declining from generation to generation, especially with children receiving modern education outside the area. Ancient traditions are no longer convincing enough to prevent behaviors or choices that may be less ecological but more convenient. According to some locals, short-term personal gain versus long-term sustainability for the whole community seems to be a recurring issue in Lo Manthang.

Nevertheless, the majority of respondents showed interest in UDDTs and CWs used as examples of sustainable sanitation and wastewater treatment systems. The interest in EcoSan is mainly related to the fertilizer it produces and its waterless operation – bearing in mind that water has to be carried from common taps since private households do not have running water. A minority of locals rejected the technology as they felt the split interface would be inconvenient to use and large quantities of urine difficult to transport. There was broad consent, though, that local people would need more awareness about the benefits and shortcomings of different sanitation systems and wastewater treatment options. UDDTs and CWs were unfamiliar technologies, so that information and education as well as the opportunity to practically learn about them were deemed essential before they could potentially be adopted. At this point, most locals are curious to learn about ecological alternatives, but several mentioned that such systems would not be regarded as important and beneficial enough by and for all community members and the local government to be willing to invest in them. This was also reflected by the locals' response to building public toilets in Lo Manthang: While the great majority thought it was a good idea, only one third would actually pay for their use to ensure maintenance.

Considering the limited enthusiasm to finance WASH improvements, what are other priorities and concerns governing people's lives in Lo Manthang? For 60% of the respondents, WASH *is* one of the most important issues, but mostly related to water supply, especially in the winter due to frozen pipes. However, a variety of other problems also take up people's attention. Among them are poor health services, low living standards and difficult livelihoods, low literacy rates and educational opportunities. Furthermore, bad infrastructure – including roads, electricity and communication services – and bad governance affect locals' lives, in addition to a changing society in which solidarity is perceived to decline.

Based on the research conducted in Lo Manthang, a number of suggestions are proposed to address the town's WASH challenges in a sustainable way. First of all, a community-wide inclusive awareness program could increase people's understanding of WASH links with health and the environment as well as different sanitary options, which will be essential for informed decision-making. For local households it is recommended that they continue using the traditional dry toilets as those are very well adapted to the local climate, building techniques and fertilizer requirements in agriculture. Households no longer engaged in agriculture are advised to cooperate with farmers who could remove excreta from the storage chamber, facilitated by wheelbarrows or similar equipment, and use them on their fields. The nutrients will be needed to maintain soil fertility, and unlike the pathogenic slurry from water toilets, could help increase local production in a safe way. Similarly, guesthouses should consider returning to dry sanitation, either through UDDTs or the purchase of dung as an amendment – as long as it is returned to the fields along with excreta to supply nutrients to crops. With more organic fertilizer, farmers could diversify, increase their vegetable production and sell surpluses to guesthouses and tour groups. Linking tourism and agriculture in such a way could increase the value attached to excreta from dry toilets and strengthen the livelihoods of farmers which have previously not benefitted from tourism. If well-coordinated and advertised through cross-sectoral cooperation, sustainable sanitation technologies and fresh organic produce could even serve to promote Lo Manthang as an ecotourism destination – provided that tourists are willing to use more ecological toilets to protect the area's unique and fragile environment.

Coordinated efforts will also be needed to successfully install and run public toilets in Lo Manthang, a project which is regarded favorably among the local community and has apparently already been discussed between stakeholders and potential implementation partners. Functioning public toilets could help reduce open defecation by people who do not have access to other toilets such as tourists, Nepali migrant workers and a small number of local households. Besides, such infrastructure could be an opportunity to demonstrate a type of sanitation system that looks attractive without requiring water, defying the prejudice that dry toilets are outdated. Such a system could either be UD or based on the traditional dry toilet concept, though partly relying on solar radiation for dehydration to reduce the amount of amendments needed. However, such toilets would require good management, allocation of community funds or user fees to pay for an employed caretaker, and cooperation with farmers for reuse of excreta and provision of dry dung to absorb moisture. If the toilets are not well-maintained and people effectively instructed how to use them, the technology might fail and fall into disfavor, ruining the chances of further EcoSan projects in town.

In case guesthouses and institutions decide to keep their (pour-)flush toilets, treatment of blackwater through an infiltration system or CW is recommended. A CW is advisable even if the planned wastewater pipe only carries graywater, to avoid its (untreated) disposal down the rivers when being direly needed for irrigation. An assessment of local soil properties revealed that agricultural soils on the terrace of Lo Manthang at a depth of 0.5m are sandy to silty loams with limited K_{sat} (in the range of 2.2-8.3*10^{-5}m/s). The low infiltration capacity of those soils calls for good pretreatment of wastewater, a low loading rate (1 cm/d) and thus a large area for the system. Their purification capacity would be excellent, though, thanks to their finely grained texture and availability of Ca for P sorption. Observations in the surroundings indicate that the K_{sat} might be much better at greater depths or in other locations due to layered deposits in the area. The risk for groundwater pollution will be minimal as long as a treatment system is built on the terrace where the groundwater table is several dozen meters below. Due to the heterogeneous underground, further infiltration tests will have to determine the specific K_{sat} at potential locations – which are yet to be identified depending on community's preference and availability of land for public use. A CW with a sealed or open bottom would be a better option in order to reuse the treated water and the remaining nutrients therein on agricultural fields. The design and dimensioning of such a system will require further research and adaptation of CWs used elsewhere in Nepal to the climatic conditions, amounts and type of wastewater produced in Lo Manthang.

For successful implementation of any of the above suggestions, two requirements will be paramount: Most importantly, WASH improvements will require the local population's initiative and strong engagement for concerted efforts and planning as well as responsible management and follow-up. Secondly, cooperation with WASH experts will be needed for more detailed development of sustainable solutions and to learn from the successes and failures of similar projects elsewhere in the country. In view of Upper Mustang's limited natural resources and its state of development – at the crossroads of making wide-ranging decisions for the future – local people must be aware of the implications of the path they choose. It is not too late to prevent irreversible damage and to raise living standards in sustainable ways so that the region remains attractive for local residents and visitors alike, not least thanks to its cultural and natural assets.

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List of Figures

List of Tables

Unless otherwise noted, all pictures were taken and tables, graphs and sketches created by the author. The designs in Figures 166-168 were digitalized with Sergii Shyika's help.

APPENDICES

Appendix A: List of Meetings with Experts in Nepal

Table 10: List of meetings with experts from the government and non-governmental sector in Nepal

Organization	Name	Position	Meeting(s)
DWSS Kathmandu	Sujata Joshi	Water Quality Section	April 4, 2017
	Kishor Pandey	Chemist at DWSS Main Laboratory	April 4, 2017
	Tika Chaudhari	Senior Division Officer of Wastewater Treatment Section	April 6, 2017
	Prem Krishna Shrestha	Chief of the Environmental Sanitation Section	June 12, 2017
DWSS Pokhara	Prakash Subedi	Chemist at the Regional Laboratory	April 25 and May 7, 2017
WSSDO Jomsom	Bijay Yadav	Chief of Water Supply and Sewerage Division Office	May 27, 2017
Mustang DDC	Damar Bahadur Tamang	Engineer designing Lo Manthang's wastewater pipe	May 23 and 27, 2017
Tribhuvan University	Iswar Man Amatya	Associate Professor at the Department of Civil Engineering	June 29, Aug. 7&10, 2016; March 30, 2017
ENPHO	Rajendra Shrestha	Director Outreach Division	March 29, May 9 & 18 (phone), June 16, 2017
WaterAid Nepal	Kabindra Pudasaini and Dharma Ratna Chitrakar	Program Manager and Program Officer of the Recovery and Resilient WASH Program	April 13 and June 7, 2017
FEDWASUN	Doren Bahadur Thapa Badbyash Lamichhane	Program Manager of Water Safety Plan Senior Program Officer	April 7, 2017
WWF Nepal	Ghana Shyam Gurung	Director WWF Nepal	March 27, 2017
	Rajesh Sada	Freshwater Program Manager	April 4, 2017
THE SEVA Nepal, Chumlingtar	Shreerendra Pokharel	Founder, EcoSan activist	May 11, 2017
Pioneer Architect & Consulting Engineers Pvt. Ltd.	Kalidas Neupane	Civil engineer, Biogas Program Monitoring	March 21, 2017
ACAP, Jomsom	Neeru Thapa Tulsi Prakash Dahal	Consecutive Chiefs of Unit Conservation Offices Lo Manthang and Jomsom	July 29, 2016 May 16, 2017
ACAP, Lo Manthang	Lhundup Namgyal	Health care provider	July 25, 2016 May 25, 2017
ICIMOD	Madhav Dhakal	Associate hydrologist with experience in Mustang District	April 13, 2017
Pure Vision Healing and Research Center, Boudha	Amchi Sherab Tenzin	Founder, Tibetan doctor	March 31, 2017
Constructed wetland at Nala	Kanchan Shyam Shrestha Yadav Krishna Laxmi Prasad Pode	Paid employee, administration President of Water Users' Committee Treasurer Paid employee, maintenance	June 11, 2017

Appendix B: Demographic Information of Interview Partners in Lo Manthang

Table 11: Demographic information of interview partners in Lo Manthang

Inter-view no.	Gender	Age	Occupation	Education (years)	No. of house-hold members
11	m	24	Teacher	monastic education	36 (at school)
7	f	27	Teacher	12	8
10	m	28	Tour guide (formerly teacher)	12	3
2	f	31	Farmer	2	4
5	m	31	Carpenter	8	4
15	f	31	Vice chairperson of *Gaunpalika*	18	8
1	f	32	Guesthouse owner	no formal schooling	3 (plus guests)
4	f	34	Guesthouse owner	no formal schooling	6
3	m	38	Employed by NGO	12	7
12	f	38	Teacher	17	7
9	m	46	Headmaster, politician	monastic education	6
13	m	47	Employed by NGO	10	5
14	m	50	Guesthouse owner	no formal schooling	5
6	m	65	Guesthouse owner	?	4
8	m	66	Farmer, businessman	7	8

Appendix C: Interview Schedule for Consultation with Lo Manthang Residents

Self-introduction, purpose of the research, confidentiality assurance. Asking for basic information, small talk about family/work to warm up. Inquiring about water supply before delving into sanitation.

Name མིང་།:

Village གྲོང་ཚོ།:

Age རང་ལོ།:

Occupation འཚོ་ཐབས།:

No. of household members ཁྱིམ་མི་ག་ཚོད།:

Education level རིག་གནས་ཆུ་ཚད།:

Contact no. ཁ་པར་ཨང་གྲངས།:

<u>Household Sanitation</u> *ཁྱིམ་ཚང་གི་གསང་སྤྱོད།*

1. What type of toilet do you use? ཁྱིམ་ཚང་ནང་གསང་སྤྱོད་གང་འདྲ་ཞིག་བེད་སྤྱོད་གཏོང་གི་ཡོད།

a) Traditional dry toilet སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད། ༼ཆུ་མེད་པའི་གསང་སྤྱོད།༽

b) Pour-flush toilet ཆུ་ཡོད་པའི་གསང་སྤྱོད། ༼ཆུ་སོ་སོས་བླུགས་དགོས་པ།༽

c) Flush-toilet ཆུ་ཡོད་པའི་གསང་སྤྱོད། ༼མཇུབ་མོ་མནན་ཙམ་གྱིས་ཆུ་ཐོན་པ།༽

d) None (open defecation / someone else's toilet) ཁྱིམ་ནང་ལ་གསང་སྤྱོད་མེད། ཕྱི་ལོགས་སུའམ་མིའི་གསང་སྤྱོད་བེད་སྤྱོད་བྱེད་དགོས་པ།

2. Are you satisfied with the toilet you use? Yes No
ད་ལྟའི་གསང་སྤྱོད་དེ་ལ་ཁྱེད་རང་འདོད་བློ་ཚིམ་པོ་འདུག་གམ། འདུག མི་འདུག

3. Are there any problems with your toilet? ཁྱེད་རང་གི་བསང་སྤྱོད་ལ་སྐྱོན་འདུག་གམ། འགྲེལ་བཤད་སྐྱོན་རོགས།

4. What are the advantages of this type of toilet?
ཁྱེད་རང་གིས་གསང་སྤྱོད་དེ་རིགས་ལ་དགེ་མཚན་ག་རེ་མཐོང་གི་འདུག

5. Schools, guesthouses and the monastery have replaced the traditional toilets with water toilets. What do you think the reason is?
དེང་སང་སློབ་གྲྭ་དང་མགྲོན་ཁང་། དགོན་པ་སོགས་ལ་སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་ཀྱི་ཚབ་ལ་ཆུ་ཡོད་པའི་གསང་སྤྱོད་བཟོ་ཡི་ཡོད་རེད།
ཁྱེད་རང་གིས་བྱས་ན་དེ་ལྟར་བཟོས་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

a) "Modern" དུས་དང་བསྟུན་པ།

b) More convenient སྟབས་བདེ་བ།

c) More attractive/cleaner/less smelly བལྟས་ན་སྙིང་རྗེ་བ། གཙང་བ། དྲི་མ་ཞུང་བ།

d) Traditional toilet not suitable for these institutions
སྒྲིག་འཛུགས་དེ་དག་ལ་སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་འཚམས་པོ་མེད་པ།

e) Lack of amendments གསང་སྤྱོད་ནང་དུ་བླུགས་རྒྱུའི་གོ་ཐལ་སོགས་མེད་པ།

f) Difficult to remove excreta from the dry toilet སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་ནས་ལུད་འདོན་ཁག་པོ་ཡོད་པ།

g) Other reasons: རྒྱུ་མཚན་གཞན་དག

6. What type of toilet would you prefer? Dry Flush
ཁྱེད་རང་གསང་སྤྱོད་ཀྱི་རིགས་གང་ལ་དགའ་བ་ཡོད། སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད། ཆུ་ཡོད་པའི་གསང་སྤྱོད།

7. Can you think of any problems/disadvantages with water toilets?
ཁྱེད་རང་གིས་བྱས་ན་ཆུ་ཡོད་པའི་གསང་སྤྱོད་ལ་གནད་འགག་དང་སྐྱོན་ག་རེ་འདུག་གམ།

a) Using scarce water resources ཆུ་འཕྲོ་བརླག་གཏོང་བ། ༼ཆུ་དཀོན་པ།༽

b) Polluting water ཆུ་བཙོག་པ་བཟོ་བ།

c) Pathogen transfer → illnesses བཙོག་པའི་ནང་གི་འབུ་ཕྲ་ནས་བྱུང་བའི་ན་ཚ་ཁྱབ་པ།

d) Loss of nutrients / fertilizer value ལུད་ཀྱི་བཅུས་དང་རིན་ཐང་མེད་པར་འགྲོ་བ།

e) Others: གནད་འགག་དང་སྐྱོན་གཞན་དག

In other parts of Nepal, some people use a new toilet system that doesn't use water but separates urine and feces. Such toilets don't smell, the urine can be used as an excellent fertilizer in vegetable gardens and the feces dried and composted. (Show pictures of Nepali urine diverting toilets and explain functioning.)

བལ་ཡུལ་གྱི་ས་ཆ་གཞན་ལ་མི་ཁ་ཤས་ཀྱིས་གསང་སྤྱོད་ཀྱི་རིགས་གསར་པ་ཞིག་བེད་སྤྱོད་གཏོང་གི་ཡོད་རེད། གསང་སྤྱོད་དེ་ལ་ཆུ་ཡོད་མ་རེད། ཡིན་ནའང་གཅིན་པ་དང་བཙོག་པ་འགྲོ་ས་སོགས་དགར་རེད། གསང་སྤྱོད་དེ་འདྲ་ལ་དྲི་མ་ངན་པ་མེད་པ་མ་ཟད། ད་དུང་གཅིན་པ་དེ་རྣམས་ཚལ་ཞིང་ཁ་ལ་བེད་སྤྱོད་བྱེད་པའི་ལུད་ཧ་ཅང་ཡག་པོ་ཞིག་ཆགས་ཀྱི་རེད། བཙོག་པ་རྣམས་སྐམ་རྗེས་ཀྱང་ཞིང་ཁ་ལ་གཏོར་ཐུབ་ཀྱི་རེད།

8. Would you be willing to use a urine-diverting toilet in your home? Yes No
ཁྱེད་རང་གི་ཁྱིམ་ནང་གསང་སྤྱོད་དེ་འདྲ་ཞིག་བེད་སྤྱོད་གཏོང་རྒྱུར་བློ་འདོད་ཡོད་དམ། ཡོད། མེད།

9. Why or why not? ཡོད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ། མེད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

Public Urine-Diverting Toilet *གཅིན་པ་དང་བཙོག་པ་སོགས་སུ་ཕྱེ་བའི་སྤྱི་པའི་གསང་སྤྱོད།*

10. What do you think of having a public toilet that functions this way?
ཁྱེད་རང་གིས་བྱས་ན་སྤྱི་པའི་གསང་སྤྱོད་དེ་འདྲ་ཞིག་བཟོས་ན་གང་འདྲ་འདུག

11. Would you use it? Yes No
ཁྱེད་རང་གིས་སྤྱི་པའི་གསང་སྤྱོད་དེ་འདྲ་ཞིག་བེད་སྤྱོད་གཏོང་འདོད་ཡོད་དམ། ཡོད། མེད།

12. Why or why not? ཡོད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ། མེད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

13. Would you be willing to pay for using it to ensure maintenance? Yes No
སྤྱི་པའི་གསང་སྤྱོད་དེར་སུ་མཐུད་ནས་གཙང་སྦྲ་དང་ཉམས་བཟོ་ཡོང་ཆེད་ལྷ་རྟོག་བྱེད་མཁན་ཞིག་དགོས་རེད།
ཁྱེད་རང་གིས་གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་རྒྱུའི་རིན་པ་སྤྲད་རྒྱུར་བློ་འདོད་ཡོད་དམ། ཡོད། མེད།

14. How much would users be willing to pay for a public toilet?
བློ་སྨོན་ཐང་གི་མི་ཚོས་སྤྱི་པའི་གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་རྒྱུར་ཐེངས་གཅིག་ལ་དངུལ་ག་ཚོད་སྤྲད་ཐུབ་ཀྱི་རེད།

Lo Manthang Sewage Pipe *བློ་སྨོན་ཐང་གི་བཙོག་ཆུ་འགྲོ་སའི་ཆུ་སྦུག་གི་སྐོར།*

I have heard that Lo Manthang is planning to build a wastewater pipe now. Have you heard about it?
ངའི་གོ་ཐོས་ལ་བློ་སྨོན་ཐང་ལ་བཙོག་ཆུ་འགྲོ་སའི་ཆུ་སྦུག་ཅིག་བཟོ་ཡི་རེད་ཅེས་ཟེར་གྱི་འདུག ཁྱེད་རང་གིས་དེའི་སྐོར་གོ་ཐོས་བྱུང་ངམ།

15. What do you think about it? ཁྱེད་རང་གིས་དེའི་སྐོར་ལ་བསམ་ཚུལ་ག་རེ་ཡོད།

16. If there was a wastewater pipe, would you consider changing your toilet system in the future?
གལ་སྲིད་ཆུ་སྦུག་དེ་འདྲ་ཞིག་ཡོད་ན། ཁྱིམ་གྱི་སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་དེ་ཆུ་ཡོད་པའི་གསང་སྤྱོད་ལ་སྒྱུར་རྩིས་ཡོད་དམ་
Yes No
ཡོད། མེད།

17. Why or why not? ཡོད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ། མེད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

18. What do you think will happen to the wastewater from the pipe? Where will it go?
ཁྱེད་རང་གིས་བྱས་ན་ཆུ་སྦུག་ནས་ཐོན་པའི་བཙོག་ཆུ་དེ་ས་ཆ་གང་དུ་རྒྱུག་གི་རེད་དམ།

19. Are you concerned about negative effects? བཙོག་ཆུ་དེར་གནོད་སྐྱོན་གང་ཡོད་ལ་ཁྱེད་ཀྱི་བསམ་ཚུལ་གང་ཡོད་དམ།
a) Health འཕྲོད་བསྟེན།
b) Environmental pollution ཁོར་ཡུག་འབག་བཙོག
c) Smells དྲི་མ་ངན་པ།
d) Upsetting local spirits ས་བདག་དང་ཡུལ་ལྷ་ལ་སོགས་པ་མ་མཉེས་པ་བཟོ་བ།
e) Others: གནོད་སྐྱོན་གཞན་དག

Wastewater Treatment – a Priority? *བཙོག་ཆུ་གཙང་མ་བཟོ་རྒྱུ་དེ་གནད་དོན་གལ་ཆེ་ཤོས་ཡིན་ནམ།*

There are systems in which wastewater can be treated naturally by flowing through a planted gravel bed. Such systems are already used elsewhere in Nepal, e.g. at Kathmandu University, for communities in Thimi and Nala, at some hospitals and eco-resorts in Pokhara and Bardia National Park. (Show pictures, explain).
གཙོག་ཆུ་གཙང་མ་བཟོ་རྒྱུ་ཐབས་ཤེས་ཤིག་ནི་བཙོག་ཆུ་དེ་རྩི་ཤིང་བཏབ་པའི་བྱེ་མའམ་ཤག་མ་བརྒྱུད་ནས་བཏང་ན་རང་བཞིན་གྱིས་གཙང་མ་ཆགས་ཀྱི་རེད། བལ་ཡུལ་གྱི་ས་ཆ་གཞན་ཁ་གཅིག་ལ་ཐབས་ཤེས་དེ་ད་ལྟ་ནས་བེད་སྤྱོད་གཏོང་གི་ཡོད་པ་རེད། དཔེར་ན། ཀཋ་མན་དུའི་སློབ་གྲྭ་ཆེན་མོ་དང་། ཐི་མི་དང་ན་ལའི་གྲོང་ཚོ། སྨན་ཁང་ཁ་ཤས། ད་དུང་པོ་ཁ་རའི་དང་བར་དི་ཡ་ཁོར་ཡུག་སྲུང་སྐྱོབ་ཐུལ་གྱི་རང་བྱུང་ཁམས་དོ་སྣོམས་ཀྱི་མགྲོན་ཁང་ཁ་ཤས་ལ།

20. Do you think Lo Manthang should invest in such a system to avoid discharge of untreated wastewater?
ཁྱེད་རང་གིས་བྱས་ན་བློ་སྨོན་ཐང་གྲོང་ཚོས་བཙོག་ཆུ་ཐད་ཀར་གཙང་པོའི་ནང་དུ་མ་བླུགས་པ་དང་། གནོད་པ་མེད་པར་བཟོ་ཆེད་མ་ལག་དེ་འདྲ་ཞིག་རྒྱག་རྒྱུར་མ་དངུལ་གཏོང་དགོས་ཀྱི་རེད་དམ།

21. Why or why not? ཡོད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ། མེད་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

22. Do you think other issues are more important than clean water and sanitation?
ཁྱེད་རང་གིས་བྱས་ན་ཆུ་དང་གསང་སྤྱོད་ཀྱི་གནད་དོན་དེ་ལས་གལ་ཆེ་བའི་གནད་དོན་གཞན་དག་ཡོད་དམ།

Yes No
ཡོད། མེད།

23. What are those issues?
གནད་དོན་དེ་དག་གང་དང་གང་ཡིན་ནམ།

Your answers will only be used for academic purposes and for designing a sustainable sanitation system. Would you feel comfortable to be cited or do you wish to remain anonymous?
ཁྱེད་རང་གི་ལན་དེ་དག་རྒྱུན་མཐུད་ཀྱི་གསང་སྤྱོད་ཀྱི་མ་ལག་ཞིག་འཆར་འགོད་བྱ་ཆེད་དང་ཞིབ་འཇུག་གི་དགོས་མཁོ་པོ་ནར་མ་གཏོགས། གཞན་གྱི་ཆེད་དུ་བེད་སྤྱོད་གཏོང་གི་མ་རེད། ངའི་དཔྱད་རྩོམ་ནང་ཁྱེད་རང་གི་མཚན་བྲིས་ན་འགྲིག་གམ། ཡང་ན་མིང་མ་སྨོས་པར་བཞག་ན་འགྲིག

Do you have any further comments or questions?
ཁྱེད་རང་ལ་ད་དུང་ཁ་གསབ་བྱ་རྒྱུ་དང་འགྲེལ་བཤད་རྒྱག་རྒྱུ། ཡང་ན་སྐད་ཆ་འདྲི་རྒྱུ་གཞན་དག་ཡོད་དམ།

Thank you very much for your time and information, and feel free to contact me again.
ཁྱེད་རང་གིས་བཅར་འདྲི་འདིའི་ཆེད་དུ་དུས་ཚོད་མང་པོ་བེད་སྤྱོད་གནང་བ་དང་གནས་ཚུལ་མཁོ་འདོན་གནང་བར་ངས་ཐུགས་རྗེ་ཆེ་ཞུ་ཡི་ཡིན། རྗེས་མར་ཉུ་མཐུད་ང་དང་འབྲེལ་བ་གནང་འདོད་ཡོད་ན་དགའ་བསུ་ཞུ་ཡི་ཡིན།

Appendix D: Question Guide for Consultation with Lo Kunphen Headmasters

1) ***Existing toilets*** *ད་ཡོད་གསང་སྤྱོད་ཀྱི་སྐོར།*

a) How many toilets are there at your school? Separate ones for men and women? Separate ones for teachers and students? Is the number of toilets sufficient? Are all of them in use simultaneously?
ཁྱེད་རང་ཚོའི་སློབ་གྲྭར་ད་ལྟ་གསང་སྤྱོད་ག་ཚོད་ཡོད་པ་རེད། བུ་དང་བུ་མོའི་གསང་སྤྱོད་ལོགས་དགར་རེད་དམ། དགེ་རྒན་གྱི་གསང་སྤྱོད་ལོགས་དགར་རེད་དམ། ད་ཡོད་གསང་སྤྱོད་འདང་ངེས་ཡོད་དམ། གསང་སྤྱོད་ཚང་མ་དུས་གཅིག་ལ་བེད་སྤྱོད་གཏོང་གི་ཡོད། ཡང་ན་རེས་མོས་བྱས་ནས་བེད་སྤྱོད་གཏོང་གི་ཡོད།

b) What is the type of sanitation system? (dry/wet, open/with roof, storage system, building materials, construction cost, how long in use, hand-washing facilities with soap…?)
ད་ཡོད་གསང་སྤྱོད་དེ་ཚོ་གང་འདྲ་ཞིག་རེད། ༼སྐམ་པོ་/ཆུ་ཡོད་པ། ཐོག་ཡོད་པ་/མེད་པ། བཙོག་གཅིན་བསགས་ས། གསང་སྤྱོད་ཀྱི་རྒྱུ་ཆ། གསང་སྤྱོད་བརྒྱབ་པའི་འགྲོ་སོང་། གསང་སྤྱོད་བེད་སྤྱོད་བྱས་ནས་དུས་ཚོད་རིང་ལོས་ཕྱིན་སོང་། ལག་པ་འཁྲུས་ས་དང་ལག་པ་འཁྲུ་བྱེད་ཡོད་དམ་མེད།༽

c) What are the monthly/annual repair and maintenance costs, who is bearing that cost and how?
ལོ་རེ་དང་ཟླ་བ་རེ་རེར་ཉམས་བཟོ་དང་བདག་ཉར་བྱེད་རྒྱུའི་འགྲོ་སོང་ག་ཚོད་གཏོང་གི་ཡོད་དམ། འགྲོ་སོང་དེ་སུས་གཏོང་གི་ཡོད། དངུལ་དེ་གང་ནས་ཡོང་གི་ཡོད།

d) Are there any problems with the current toilets? (odors, comfort, cleanliness, privacy, emptying of storage, excreta handling, adequate decomposition, pollution, etc.)
ད་ཡོད་གསང་སྤྱོད་ལ་གནད་དོན་གང་འདུག་གམ། ༼དྲི་མ་ངན་པ། སྟབས་བདེ་པོ་མེད་པ། གཙང་མ་མེད་པ། མི་གཞན་གྱིས་མཐོང་བ། བཙོག་གཅིན་བསགས་ས་ནས་འདོན་མི་བདེ་བ་དང་ཕྱི་ལོགས་སུ་འཁྱེར་མི་བདེ་བ། བཙོག་པའི་ནང་གི་འབུ་ཕྲ་མེད་པ་ཆགས་རྒྱུའི་དུས་ཚོད་མི་འདང་བ། ཆུར་འབབ་བཙོག་ཡོད་པ་སོགས།༽

e) What issues are users facing (students, staff, … females in particular)? Any social or health implications?
གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་མཁན་ལ་གནད་དོན་ག་རེ་འཕྲད་ཀྱི་ཡོད་དམ། ༼སློབ་མ་དང་ལས་ཀ་བྱེད་མཁན། ལྷག་པར་དུ་བུད་མེད་ལ།༽ དེའི་རྐྱེན་གྱིས་སྤྱི་ཚོགས་ཁྲོད་དང་ཡང་ན་འཕྲོད་བསྟེན་དང་། གཟུགས་པོའི་བདེ་ཐང་ལ་གནོད་སྐྱོན་ཡོད་དམ།

f) What environmental issues are there related to water and sanitation?
ཆུ་དང་གསང་སྤྱོད་དང་འབྲེལ་ཡོད་ཀྱི་ཁོར་ཡུག་གི་གནད་དོན་གང་དང་གང་ཡོད།

g) What is your overall satisfaction with the toilets? (from 1-5; 1 worst, 5 best)
ཁྱོན་ཡོངས་ནས་བཤད་ན་ཁྱེད་རང་གིས་ད་ཡོད་གསང་སྤྱོད་དེ་བློ་ཡིད་ཚིམ་པོ་འདུག་གམ། ༼ཡག་ཤོས་༥ སྡུག་ཤོས་༡༽

2) ***Users*** *གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་མཁན་གྱི་སྐོར།*

a) How many people use the toilets? How many men/women?
གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་མཁན་ག་ཚོད་ཡོད་དམ། སྐྱེས་པ་དང་བུད་མེད་ཁག་སོ་སོར་ག་ཚོད་ཡོད་དམ།

b) Do the users live there (residential use) or only come for a few hours during the day? Do they also use other toilets?
བེད་སྤྱོད་གཏོང་མཁན་རྒྱུན་དུ་སློབ་གྲྭའི་ནང་སྡོད་ཀྱི་ཡོད་དམ། ཡང་ན་ཉི་མའི་རིང་སློབ་ཚན་དང་ལས་ཀ་ཡོད་པའི་སྐབས་སུ་ཆུ་ཚོད་ཁ་ཤས་མ་གཏོགས་ཡོང་གི་མ་རེད། ཁོ་ཚོས་ད་མིན་གསང་སྤྱོད་གཞན་བེད་སྤྱོད་གཏོང་གི་ཡོད་དམ།

c) Do external people also use the toilets?
ཕྱི་ལོགས་ཀྱི་མིས་སློབ་གྲྭའི་གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་གི་ཡོད་དམ་མེད།

d) What age groups are there? Do patients and elderly people also use the toilet?
བེད་སྤྱོད་གཏོང་མཁན་ཚོ་ལོ་ན་ཆེ་ཆུང་གང་འདྲ་རེད། ནད་པ་དང་རྒན་ཁོག་གིས་ཀྱང་བེད་སྤྱོད་གཏོང་གི་ཡོད་དམ།

e) Are the toilets used all year round or only during the summer months? How many people remain there in the winter?
གསང་སྤྱོད་དེ་དག་ལོ་ཧྲིལ་པོར་བེད་སྤྱོད་གཏོང་གི་ཡོད་དམ། ཡང་ན་དབྱར་ཁ་གཅིག་པུར་བེད་སྤྱོད་གཏོང་གི་ཡོད། དགུན་ཁའི་རིང་ལ་སྡོད་མཁན་མི་ག་ཚོད་ཡོད་དམ།

3) ***Toilet practices*** *གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་ཚུལ།*

a) Do people squat / sit / stand when using the toilet?
གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་དུས་ཙོག་ཙོག་ལ་སྡོད་ཀྱི་ཡོད། རྐུབ་སྙེགས་ཀྱི་སྟེང་སྡོད་ཀྱི་ཡོད། ཡང་ན་ཡར་ལངས་ནས་སྡོད་ཀྱི་ཡོད།

b) Are any amendments / bulking materials thrown down after each use? What? (ash, soil, straw, goat droppings, , …) Is there enough?
གསང་སྤྱོད་བེད་སྤྱོད་བཏང་རྗེས་དེར་གོ་ཐལ་སོགས་ཀྱིས་ཁེབས་རྒྱག་གི་ཡོད་དམ་མེད། ༼དཔེར་ན། ས་དང་། རྩྭ་སྦུ། སོག་མ། ར་ལུག་གི་རིལ་མ་ལ་སོགས་པ།༽ འདང་ངེས་ཡོད་དམ་མེད།

c) Is there a garbage bin for other waste? (toilet paper, plastic, female hygiene products, …) Does paper and other garbage end up in the excreta storage?
གསང་སྤྱོད་ནང་ཤོག་སྙིགས་བླུག་ས་ཡོད་དམ། ༼གཙང་ཤོག་དང་འགྱིག་ཤོག བུད་མེད་ཀྱི་འཕྲོད་བསྟེན་གཙང་ཤོག་ལ་སོགས་པ༽ དེ་དག་བཙོག་གཅིན་བསགས་སའི་ནང་དུ་དབྱུག་གི་རེད་དམ།

d) Do girls come to school when menstruating or do they stay at home?
བུ་མོར་ཟླ་མཚན་ལྷིབས་དུས་སློབ་གྲྭར་ཡོང་གི་ཡོད་དམ། ཡང་ན་ཁྱིམ་ལ་སྡོད་ཀྱི་ཡོད།

e) About what percentage of the users wash their hands after using the toilet?
གསང་སྤྱོད་བེད་སྤྱོད་བཏང་རྗེས་ལག་པ་འཁྲུས་མཁན་རྒྱ་ཆ་ག་ཚོད་ཙམ་ཞིན་གྱི་ཡོད།

f) Who cleans the toilet and how often?
གསང་སྤྱོད་ལ་གཙང་སྦྲ་སུས་བྱེད་ཀྱི་ཡོད། དུས་རྟག་ལོས་བྱེད་ཀྱི་ཡོད།

4) ***Rules, customs, cultural preferences, taboos*** *སྒྲིག་ལམ་དང་ལུགས་སྲོལ། འཛེམས་ཆའི་སྐོར།*

a) Are there any toilet "rules"? Dos and don'ts for the users? How are they communicated? Does everyone know?
གསང་སྤྱོད་བེད་སྤྱོད་གཏོང་རྒྱུར་གང་ཞིག་ལ་སྣང་འཛོག་བྱེད་དགོས་སམ། འཛེམས་བྱ་གང་དང་གང་ཡོད། དེའི་སྐོར་གང་འདྲ་བྱས་ཏེ་ཤེས་རྟོགས་བྱེད་ཀྱི་ཡོད། འཛེམས་བྱ་དེ་ཚོ་མི་ཚང་མས་ཤེས་ཀྱི་ཡོད་དམ།

b) Is it uncomfortable/ embarrassing / shameful to discuss / clean out / handle excreta in Mustangi culture?
གློའི་ལུགས་སྲོལ་ལ་བཙོག་པ་དང་གསང་སྤྱོད་ཀྱི་སྐོར་ཤོད་པ་དང་། གསང་སྤྱོད་གཙང་མ་བཟོ་རྒྱུ་དང་བཙོག་གཅིན་ཕྱིར་འདོན་པའི་ལས་ཀ་དེ་དག་ངོ་ཚ་བའི་ལས་ཀར་རྩིས་ཀྱི་ཡོད་དམ།

c) What might be the reason for that?
དེ་ལྟར་རྩིས་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ།

d) What are your suggestions to deal with cultural taboos in an acceptable way?
ལུགས་སྲོལ་ལ་ཡོད་པའི་འཛེམས་ཆ་དེ་དག་ལ་འོས་འཚམས་ཀྱི་སྒོ་ནས་ཁ་གཏད་གཙོག་ཆེད་ཁྱེད་རང་ལ་ཐབས་ཤེས་གང་ཞིག་འདོན་རྒྱུ་ཡོད།

5) ***Storage and disposal of excreta*** *བཙོག་གཅིན་བསགས་སྟངས་དང་འདོན་ཚུལ།*

a) How long do excreta remain in the storage space? (storage time)
བཙོག་གཅིན་གསང་སྤྱོད་འོག་ཏུ་དུས་ཚོད་ག་ཚོད་ཙམ་ཉར་གྱི་ཡོད་དམ།

b) How frequently does the storage need to be emptied? (What's the capacity? For how many people/months?) Is the toilet above used until emptying or is there a "rest period" before emptying? (for pathogen die-off)
ལོ་གཅིག་ལ་གསང་སྤྱོད་ཐེངས་ག་ཚོད་ཙམ་འདོན་དགོས་ཀྱི་ཡོད་དམ། (ཤོང་ཚད་ག་ཚོད་རེད། མི་ག་ཚོད། ཟླ་བ་ག་ཚོད།) གསང་སྤྱོད་སྟོང་པ་མ་བཟོས་བར་དུ་བེད་སྤྱོད་གཏོང་གི་ཡོད་དམ། ཡང་ན་སྟོང་པ་མ་བཟོས་གོང་ལ་དུས་ཚོད་གང་ཙམ་རིང་དུ་འཇོག་རྒྱུའི་ལུགས་སྲོལ་ཡོད་དམ། (འབུ་ཕྲ་མེད་པ་ཆགས་རྒྱུའི་ཕྱིར།)

c) Where are the excreta disposed of? How? (Handling, transport) By whom?
བཙོག་གཅིན་བསགས་ས་ནས་བཏོན་རྗེས་ག་པར་སྐྱེལ་གྱི་ཡོད། ཇི་ལྟར། (བཙོག་གཅིན་དབོར་འདྲེན།) སུས་བྱེད་ཀྱི་རེད།

d) Has field application been practiced? What is the acceptability of excreta use in agriculture?
གསང་སྤྱོད་ཀྱི་ལུད་དེ་ཞིང་ཁ་ལ་གཏོང་རྒྱུའི་ལུགས་སྲོལ་ཡོད་དམ། གསང་སྤྱོད་ཀྱི་ལུད་དེ་ཞིང་ཁར་བེད་སྤྱོད་གཏོང་རྒྱུ་དེ་ཁས་ལེན་ཀྱི་ཡོད་དམ། (སྲོལ་རྒྱུན་གྱི་བྱེད་སྟངས་/ བསམ་བློ་དང་མཐུན་པོ་ཡོད་མེད།)

e) Are there any advantages/disadvantages with excreta use in agriculture?
གསང་སྤྱོད་ཀྱི་ལུད་དེ་ཞིང་ཁར་བེད་སྤྱོད་གཏོང་རྒྱུ་དེར་དགེ་སྐྱོན་ག་རེ་ཡོད་དམ།

6) ***Current graywater situation*** *ད་ལྟའི་ཆུ་སྙིགས་ཀྱི་གནས་ཚུལ་གྱི་སྐོར།*

a) How much graywater is produced daily? What are the main sources of graywater? (laundry, kitchen, hand-washing, shower?)
ཉི་མ་རེ་རེར་ཆུ་སྙིགས་ག་ཚོད་ཙམ་ཐོན་གྱི་ཡོད་དམ། ཆུ་སྙིགས་ཀྱི་འབྱུང་ས་གཙོ་བོ་གང་རེད། (གྱོན་གོས་འཁྲུད་པ། ཐབ་ཚང་། ལག་པ་འཁྲུད་པ། ཁྲུས་ཁང་།)

b) How is graywater currently disposed of? (drainage channels, infiltration, open disposal, directly in stream…)
དེང་སང་ཆུ་སྙིགས་དེ་ཇི་ལྟར་མེད་པ་བཟོ་ཡི་ཡོད་དམ། (ཡུར་བའི་ནང་དུ་གློད་པ། སའི་ནང་དུ་ཐིམ་པར་བྱེད་པ། ས་སྟོང་ལ་བཤོས་པ། ཐད་ཀར་རྒྱུག་ཆུའི་ནང་དུ་གློད་པ་སོགས།)

c) Are there ditches for rain/snowmelt/storm water? Do those pass near the toilet?
ཆར་ཆུ་དང་དྲག་ཆར། གངས་ཆུ་བཞུར་སའི་ཡུར་བ་ཡོད་དམ་མེད། ཡུར་བ་དེ་དག་གསང་སྤྱོད་ཀྱི་འཁྲིས་སུ་ཡོད་དམ་མེད།

7) ***Ideas for a new sanitation system / Attitudes*** *གསང་སྤྱོད་མ་ལག་གསར་པ་བཟོ་རྒྱུའི་བསམ་འཆར།*

The system we are going to develop shall be sustainable and serve as a model for others in Upper Mustang to replicate if they wish. It is therefore important to think carefully about how to design it so that it is acceptable for the people, does little harm to the environment, is affordable to build and easy to use and maintain.

ང་ཚོས་མཉམ་ལས་བྱས་ནས་གློ་ལ་གསང་སྤྱོད་ཀྱི་མ་ལག་རྒྱུན་མཐུད་ཐུབ་པ་དང་། དཔེ་མཚོན་རང་བཞིན་ལྡན་པ་ཞིག་བཟོ་འདོད་ཡོད་པས། གསང་སྤྱོད་ཀྱི་འཆར་གཞི་མ་བཟོས་གོང་ལ་བེད་སྤྱོད་གཏོང་མཁན་གྱི་རེ་བ་དང་མཐུན་པོ་ཡོད་པ། རང་བྱུང་ཁམས་ལ་གནོད་པ་མེད་པ། འགྲོ་སོང་ཆེན་པོ་མེད་པ། འཛུགས་སྐྲུན་དང་བེད་སྤྱོད་བྱེད་དུས་སྟབས་བདེ་བ། ཉམས་བཟོ་བྱ་རྒྱུ་སྟབས་བདེ་བ་བཅས་ཀྱི་ཐད་ལ་བསམ་བློ་ཞིབ་ཕྲ་གཏོང་དགོས།

c) What ideas do you have to improve the problems you mentioned earlier with the current toilets?
ཁྱེད་རང་གིས་གོང་དུ་བཤད་པའི་ད་ཡོད་གསང་སྤྱོད་ཀྱི་གནད་དོན་དེ་དག་སེལ་ཆེད་ཁྱེད་ལ་ཐབས་ཤེས་ག་རེ་ཡོད།

d) Have you seen other/better systems that you are interested in? What kind?
ཁྱེད་རང་གིས་དགའ་པོ་བྱེད་པའམ་འདི་ལས་ཡག་པའི་གསང་སྤྱོད་མཐོང་མྱོང་ཡོད་དམ། གསང་སྤྱོད་གང་འདྲ་ཞིག་རེད།

e) What options do you see for excreta / graywater treatment and disposal?
ཁྱེད་རང་གིས་བལྟས་ན་བཙོག་གཙིན་སྙམ་པོ་བཟོ་བ་དང་ཆུ་སྙིགས་པ་གཙང་སེལ་བྱ་རྒྱུའི་ཐབས་ཤེས་ག་རེ་ཡོད་པ་རེད་དམ།

f) What are the users' preferences for the toilet interface? (squatting, sitting, urinals)
བེད་སྤྱོད་གཏོང་མཁན་ཚོས་གསང་སྤྱོད་གང་འདྲ་ཞིག་ལ་དགའ་པོ་བྱེད་ཀྱི་ཡོད། (ཙོག་པུར་སྡོད་པ། རྐུབ་སྙེགས་ཡོད་པ། ཡར་ལངས་ནས་གཅིན་པ་གཏོང་ས།)

g) What cleaning and bulking materials are most acceptable to use?
གསང་སྤྱོད་ནང་རང་སོ་སོ་གཙང་སྦྲ་བྱེད་རྒྱུར་ཆུ་དང་ཤོག་བུ་སོགས་གང་ཞིག་བེད་སྤྱོད་བྱེད་རྒྱུར་འདོད་མོས་ཆེ་བ་བྱེད་ཀྱི་ཡོད་དམ། གསང་སྤྱོད་ནང་ལ་བླུགས་རྒྱུའི་གོ་ཐལ་ལ་སོགས་པ་དངོས་པོ་གང་ཞིག་དང་ལེན་བྱེད་ཀྱི་ཡོད་དམ།

h) What materials do you envision the toilet to be made of?
ཁྱེད་རང་གིས་བྱས་ན་གསང་སྤྱོད་བཟོ་རྒྱུའི་རྒྱུ་ཆ་ག་རེ་བེད་སྤྱོད་བཏང་ན་ཡག་པ་ཡོད་དམ།

i) What are the financial constraints? How much money could a family afford to spend on a toilet?
དཔལ་འབྱོར་གྱི་ཚོད་བཀག་གང་འདྲ་ཡོད། ཁྱིམ་ཚང་གཅིག་གིས་གསང་སྤྱོད་བཟོ་རྒྱུའི་ཐད་དུ་འགྲོ་སོང་ག་ཚོད་གཏོང་ཐུབ་ཀྱི་རེད།

j) How many cubicles should there be for the school? For boys/girls/teachers?
སློབ་གྲྭའི་ནང་སློབ་ཕྲུག་བུ་དང་བུ་མོ། དགེ་རྒན་བཅས་ལ་གསང་སྤྱོད་ཀྱི་སྤྱོད་མིག་ག་ཚོད་ཙམ་དགོས་ཀྱི་འདུག

k) Is there anything else you feel we should consider when designing the sanitation system?
གསང་སྤྱོད་འཆར་འགོད་བྱེད་སྐབས་ང་ཚོས་ད་དུང་ཕྱོགས་གང་ལ་དོ་སྣང་བྱེད་དགོས་ཀྱི་རེད།

8) __Awareness__ ཤེས་རྟོགས་དང་དོ་སྣང་།

I am also interested in health in the community and would like to ask some questions about that.
དེ་མིན་ང་རང་ཁྱེད་རང་ཚོའི་སྡེ་ཁུལ་གྱི་འཕྲོད་བསྟེན་སྐོར་ཤེས་རྟོགས་རྟོག་ཙམ་བྱེད་འདོད་ཡོད། དེར་བརྟེན་དེའི་སྐོར་བཀའ་འདྲི་ཁ་ཤས་ཞུས་ན་འགྲིག་གམ།

a) Are there many cases of diarrhea and gastrointestinal diseases? Have they been increasing or decreasing in recent years?
སྡེ་ཁུལ་ནང་གྲོད་པ་བཤལ་བ་དང་། ཕོ་བ་དང་རྒྱུ་མའི་ན་ཚ་ཅན་གྱི་ནད་པ་མང་པོ་འདུག་གམ། ཁྱེད་རང་གིས་བྱས་ན་ཉེ་བའི་ལོ་ཤས་ནང་ནད་དེ་དག་མང་ཏུ་ཕྱིན་འདུག་གམ། ཉུང་དུ་ཕྱིན་ཡོད།

b) What do you think is causing these diseases? *(without suggesting any link to sanitation)*
ཁྱེད་རང་གིས་བྱས་ན་ནད་དེ་དག་གང་ལ་བརྟེན་ན་ཡོང་གི་ཡོད་དམ།

c) Do you think it could have something to do with the water?
ཁྱེད་རང་གིས་བྱས་ན་ནད་དེ་དག་དང་ཆུའི་བར་ལ་འབྲེལ་བ་ཡོད་དམ།

d) Where does the water supply come from?
སློབ་གྲྭའི་འཐུང་ཆུའི་འབྱུང་ཁུངས་ག་ནས་རེད།

e) Is water drunk cold or only after boiling?
མི་ཚོས་ཆུ་གྲང་མོ་འཐུང་གི་ཡོད། ཡང་ན་ཆུ་འཁོལ་མ་ཁོ་ན་འཐུང་གི་ཡོད།

f) Do you think water could be polluted from somewhere?
ཁྱེད་རང་གིས་བྱས་ན་ཕྱོགས་གང་ནས་ཆུ་ལ་འབག་བཙོག་ཤོར་གྱི་ཡོད་དམ།

g) Could there be a link between the toilets and water pollution?
ཁྱེད་རང་གིས་བྱས་ན་གསང་སྤྱོད་དང་ཆུའི་འབག་བཙོག་དབར་ལ་འབྲེལ་བ་འདུག་གམ།

Appendix E: Questions for Consultation with Lo Kunphen Teachers and Students

For Teachers:

1) How is the current water supply at the school? Are there any problems with it?
ད་ལྟ་ཁྱེད་རང་ཚོའི་སློབ་གྲྭའི་ནང་ཆུའི་གནས་སྟངས་གང་འདྲ་འདུག ཆུ་མགོ་འདོན་བྱེད་པའི་ཐད་གནད་དོན་གང་འདུག་གམ།

2) How is the current sanitary situation? Are there any problems with the toilets?
ད་ལྟ་གསང་སྤྱོད་ཀྱི་གནས་ཚུལ་གང་འདྲ་འདུག གསང་སྤྱོད་ལ་གནད་དོན་འདུག་གམ།

3) Are there problems with hygiene at the school?
སློབ་གྲྭའི་ནང་གཙང་སྦྲ་དང་འཕྲོད་བསྟེན་གྱི་ཐད་ལ་གནད་དོན་ག་རེ་འདུག་གམ།

4) What solutions do you see to solve the above-mentioned problems? What improvements would you suggest?
གོང་གསལ་གནད་དོན་དེ་དག་སེལ་རྒྱུའི་ཐབས་ཤེས་ག་རེ་ཡོད་དམ། ཁྱེད་རང་གིས་བྱས་ན་ཡར་རྒྱས་གང་འདྲ་ཞི་གཏོང་དགོས་འདུག་གམ།

5) Do you see any issues / disadvantages with pour-flush toilets and/or with the disposal system ("septic tank"), with disposing sewage sludge in general?
ཁྱེད་རང་གིས་སྤྱིར་བཏང་བྱས་ན་ཆུ་ཡོད་པའི་གསང་སྤྱོད་དེ་རིགས་ལ་གནད་དོན་དང་སྐྱོན་མཐོང་གི་འདུག་གམ། ས་འོག་གི་བཙོག་ཆུ་བསགས་ས་དང་། བཙོག་ཆུ་དེ་ཕྱིར་འདོན་རྒྱུར་དཀའ་ངལ་ག་རེ་འཕྲད་ཀྱི་འདུག་གམ།

6) Which type of toilet do you prefer: traditional dry toilets or pour-flush toilets? What are their advantages/disadvantages?
ཁྱེད་རང་གསང་སྤྱོད་ཀྱི་རིགས་ག་གི་ལ་དགའ་བ་ཡོད། སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་སྐམ་པོ་ལ་དགའ་བ་ཡོད། ཡང་ན་ཆུ་ཡོད་པའི་གསང་སྤྱོད་ལ་དགའ་བ། དེ་དག་སོ་སོར་དགེ་མཚན་དང་སྐྱོན་གང་དང་གང་ཡོད།

For Students:

1) Are there any problems with water at your school?
ཁྱེད་རང་ཚོའི་སློབ་གྲྭར་ཆུའི་ཐད་ལ་དཀའ་ངལ་ག་རེ་འདུག་གམ།

2) Are there any problems with the toilets at your school?
སློབ་གྲྭའི་གསང་སྤྱོད་དེ་ལ་གནད་དོན་ག་རེ་འདུག

3) What would be your wish to improve the situation?
དཀའ་ངལ་གྱི་གནས་ཚུལ་དེ་དག་ཡར་རྒྱས་གཏོང་ཆེད་ཁྱེད་རང་ལ་རེ་བ་ག་རེ་ཡོད།

a) Running water? (for washing hands / a shower? / for dish-washing / laundry) སློབ་གྲྭའི་ནང་ལ་ཆུ་ཀ་ལ་དགོས་ཀྱི་འདུག་གམ། (ལག་པ་དང་གཟུགས་པོ་འཁྲུས་རྒྱུ་དང་། དཀར་ཡོལ་དང་དུག་ལོག་འཁྲུས་རྒྱུ།)

b) More toilets? How many? གསང་སྤྱོད་མང་ཙམ་དགོས་ཀྱི་འདུག་གམ། ག་ཚོད་ཙམ་དགོས་ཀྱི་འདུག

c) Separate toilets for girls and boys? བུ་དང་བུ་མོར་གསང་སྤྱོད་ལོགས་དགར་དགོས་ཀྱི་འདུག་གམ།

4) Can you wash hands now? Why is hand-washing important? Do you learn about this at school?
ཁྱེད་རང་ཚོ་དེང་སང་ལག་པ་འཁྲུས་ས་ཡོད་དམ། ལག་པ་འཁྲུས་རྒྱུ་དེ་གལ་ཆེན་པོ་ཡིན་པའི་རྒྱུ་མཚན་གང་ཡིན་ནམ། ཁྱེད་རང་ཚོས་དེའི་སྐོར་སློབ་གྲྭའི་ནང་སྦྱངས་མྱོང་ཡོད་དམ།

5) Which type of toilet do you prefer: traditional dry toilets or pour-flush toilets? Why?
ཁྱེད་རང་གསང་སྤྱོད་ཀྱི་རིགས་ག་གི་ལ་དགའ་བ་ཡོད། སྲོལ་རྒྱུན་གྱི་གསང་སྤྱོད་སྐམ་པོ་ལ་དགའ་བ་ཡོད། ཡང་ན་ཆུ་ཡོད་པའི་གསང་སྤྱོད་ལ་དགའ་བ། རྒྱུ་མཚན་གང་ཡིན་ནམ།

Show pictures of urine-diverting toilets; explain how they are used and why.

6) What do you think of such a toilet? How about having such toilets at your school?
དེ་ལྟ་བུའི་གསང་སྤྱོད་ཀྱི་ཐད་ལ་ཁྱེད་རང་ལ་བསམ་ཚུལ་ག་རེ་ཡོད། ཁྱེད་རང་ཚོའི་སློབ་གྲྭར་གསང་སྤྱོད་དེ་འདྲ་ཞིག་ཡོད་ན་གང་འདྲ་འདུག

7) For boys: Do you sit or stand when urinating? Would you need a separate urinal? *(Show picture.)*
ཁྱེད་རང་ཚོ་གཅིན་པ་གཏོང་དུས་ཡར་ལངས་ཀྱི་ཡོད་དམ། ཡང་ན་མར་སྡོད་ནས་གཏོང་གི་ཡོད། གཅིན་པ་དང་བཙོག་པ་ལོགས་སུ་གཏོང་སའི་གསང་སྤྱོད་ལ་ཡིན་གཅིག་མིན་གཅིག་མར་སྡོད་དགོས་ཀྱི་རེད། དེ་འདྲ་ཡིན་པས་ཁྱེད་རང་ཚོར་ཡར་ལངས་ནས་གཅིན་པ་གཏོང་ས་ཞིག་དགོས་ཀྱི་འདུག་གམ།

Appendix F: WASH in Schools – Assessment Checklist (Adams et al., 2009)

5.1 Water supply, sanitation and hygiene in schools

A checklist is given below with a set of assessment questions for each of the guidelines presented in Section 4. The numbers in the checklist relate to the guidance notes given under each guideline.

The checklist is intended to be used to measure the extent to which the guidelines are followed and to identify areas for action. In answering the questions in the checklist, users may find it helpful to read the qualitative and quantitative indicators under the relevant guideline. Questions may be answered with a "yes", a "no" or a "not applicable". A "no" answer to any question should alert the assessor to remedial action required, either in the design and construction of facilities or their operation and maintenance. Guidance on action to take can be found in the guidance notes under each guideline in Section 4.

Guideline 1 Water quality

Water for drinking, cooking, personal hygiene, cleaning and laundry is safe for the purpose intended.

	Design and construction	Operation and maintenance
1	• Is water from a safe source (free from faecal contamination)? • Is water protected from contamination during transport from the source and in the school?	• Is the safety of the water source monitored regularly? • Is the quality of the water supplied to the school monitored regularly? • Are water storage, distribution and use facilities at the school adequately maintained to avoid contaminating the water?
2	• If necessary, can water be treated at the school?	• If water is treated at the school, is the treatment process operated effectively? • Are there sufficient supplies and adequately trained staff to carry out treatment?
3	• Does the water supply meet WHO guidelines or national standards regarding chemical or radiological parameters?	• If necessary, are measures in place to avoid overexposure of susceptible children to chemical contaminants?
4	• Is water acceptable (smell, taste, appearance)?	• If the water is not acceptable to some or all the schoolchildren and staff, do they use a safe alternative supply of drinking-water?
5	• Is the school water supply designed and built so that low-quality water cannot enter the drinking-water supply and cannot be drunk?	• Are procedures for protecting drinking-water in the school followed consistently?

Guideline 2 Water quantity

Sufficient water is available at all times for drinking, personal hygiene, food preparation, cleaning and laundry.

	Design and construction	Operation and maintenance
1	• Does the water supply have the capacity required? • Is there a suitable alternative supply in case of need?	• Is sufficient water available at all times for all needs? • Is the water supply operated and maintained to prevent wastage?

Guideline 3 Water facilities and access to water

Sufficient water-collection points and water-use facilities are available in the school to allow convenient access to, and use of, water for drinking, personal hygiene, food preparation, cleaning and laundry.

	Design and construction	Operation and maintenance
1	• Are there sufficient water points in the right places for all needs (drinking-water, handwashing, anal cleansing, washing and cleaning)?	• Is water accessible where needed at all times? • Is there always soap or a suitable alternative at handwashing points?
2	• Are there sufficient, clearly identified, safe drinking-water points? • Are there water points for disabled staff and children?	• Are drinking-water points properly used and adequately maintained? • Are water points for disabled staff and children accessible, properly used and adequately maintained?
3	• In boarding schools, are there sufficient showers or other places for body washing?	• Are showers properly used and adequately maintained?
4	• In boarding schools, are there sufficient laundry facilities?	• Are laundry facilities properly used and adequately maintained?

Guideline 4 Hygiene promotion

Correct use and maintenance of water and sanitation facilities is ensured through sustained hygiene promotion. Water and sanitation facilities are used as resources for improved hygiene behaviours.

	Design and construction	Operation and maintenance
1	• Is hygiene education part of the school curriculum? • Are staff trained in providing hygiene education?	• Is hygiene education actually provided? • Are hygiene-education methods used effectively?
2	• Is responsibility for promoting hygiene in the school identified clearly and supported?	• Is hygiene promoted systematically? • Do schoolchildren participate actively in maintaining hygiene? • Do staff provide positive role models for hygiene behaviours?
3	• Are school facilities designed to be easily and hygienically used and maintained? • Do school children know how to use the facilities correctly?	• Are school facilities maintained so as to be easy to use hygienically? • Have the children been shown how to correctly use the toilet and water point, and how to wash their hands correctly?

Guideline 5 Toilets

Sufficient, accessible, private, secure, clean and culturally appropriate toilets are provided for schoolchildren and staff.

	Design and construction	Operation and maintenance
1	• Are there sufficient toilets at the school for girls, boys and teachers? • Are there separated blocks?	• Are there sufficient toilets actually in use?
2	• Are the toilets situated in the right place?	• Are access paths kept in good condition?
3	• Do the toilets provide privacy and security? • Are they safe to use?	• Are there working locks on the toilet doors and lighting?
4	• Are the toilets appropriate to local culture and social conditions, gender and age of the children? • Are they appropriate and accessible for children with a disability? • Is there one accessible toilet cubicle for disabled females and one for disabled males?	• Are the toilets being used properly? • Are there sufficient toilets for use by males, females and children with disabilities?
5	• Are the toilets hygienic to use and easy to clean?	• Is anal cleansing material available at all times? • Are the toilets clean and without too much smell? • Are flies and other insects controlled?
6	• Are there handwashing facilities close by?	• Is there water and soap available?
7	• Is there a cleaning and maintenance plan?	• Is there an effective cleaning and maintenance routine in operation?

Guideline 6 Control of vector-borne disease

Schoolchildren, staff and visitors are protected from disease vectors.

	Design and construction	Operation and maintenance
1	• Is the site for the school protected from disease vectors? • Are school buildings designed and built to exclude disease vectors?	• Are local vector-breeding sites avoided or controlled? • Are inbuilt protective measures used effectively and maintained? • Are barriers and/or repellents used to reduce exposure to vectors?
2		• Are schoolchildren and staff with vector-borne diseases kept at home and treated rapidly? • Are there regular inspections to detect and treat body lice and fleas? • Are the school grounds kept free from faecal matter? • Is excess vegetation cut back regularly?

Guideline 7 Cleaning and waste disposal

The school environment is kept clean and safe.

	Design and construction	Operation and maintenance
1	• Are floors smooth and easy to clean? • Are buildings designed and built to avoid damp and moulds?	• Are teaching areas cleaned regularly? • Are teaching areas clean?
2	• Are buildings designed and built to minimize physical hazards?	• Are the school premises free from sharp objects and other physical hazards?
3	• Are there adequate bins and other equipment for managing solid waste?	• Is solid waste collected daily and disposed of safely? • Is hazardous waste managed appropriately?
4	• Is the wastewater drainage system correctly designed and built?	• Is the wastewater drainage system used correctly and maintained?

Appendix G: Water Quality Test Results

Government of Nepal
Ministry of Water supply &Sanitation
Department of Water Supply & Sewerage
Regional Monitoring & Supervision Office, Pokhara
Ph: 061-463086

Regional Water Quality Laboratory

Water Quality Test Report

Sample Details:	
Sample Name: Drinking Water (Old System) - Lomanthan	**Sample Type:** Gravity
Location: Lomanthan, Mustang	**Sampling point:** Tap (Jeep stand)
Sampling Method: Grab	**Sampled by:** Martina
Contact person: Martina	**Contact No.:**
Received date: 2074/01/13	**Completed date:** 2074/03/24

Analyzed Parameters

Physical Parameters:

S.N.	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	pH	8.6	6.5-8.5	Instrumental
2.	Electrical conductivity (µs/cm)	313.0	1500	Instrumental
3.	Turbidity (NTU)	<5	5(10)	Instrumental
4.	Taste & odor	unobjectionable	Unobjectionable	Perception
5.	Color (TCU)	-	5(15)	Spectrophotometry
6.	TDS (mg/lit)	164.0	1000	Instrumental

Chemical Parameters:

S.N	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	Total Hardness as $CaCO_3$ (mg/lit)	152.0	500	Titrimetry
2.	Calcium (mg/lit)	43.3	200	Titrimetry
3.	Chloride (mg/lit)	12.0	250	Titrimetry
4.	Fluoride (mg/lit)	0.9	0.5-1.5	Spectrophotometry
5.	Ammonia (mg/lit)	0.0	1.5	Spectrophotometry
6.	Nitrate (mg/lit)	1.2	50	Spectrophotometry
7.	Iron (mg/lit)	0.04	0.3(3)	AAS
8.	Manganese	<0.01	0.2	AAS
9.	Arsenic (mg/lit)	<0.01	0.05	AAS
10.	Total Chromiun (mg/lit)	<0.01	0.05	AAS
11.	Copper (mg/lit)	-	1.0	AAS
12.	Lead (mg/lit)	-	0.01	AAS
13.	Cadmium (mg/lit)	-	0.003	AAS
14.	Zinc (mg/lit)	-	3.0	AAS
15.	Sulphate (mg/lit)	-	250	Gravimetry
16.	FRC (mg/lit)	0.0	0.1-0.2	Tritimetry

Microbiological parameters:

S.N	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	*E. coli* (CFU/100 mL)	Nil	Nil	Membrane filter
2.	Total Coliform (CFU/100 mL)	-	Nil	Membrane filter

Remarks: : **pH of water sample was found to be slightly higher and rest of the tested parameters were found to be in accordance with National Drinking Water Quality Standard Guidelines, Nepal, 2005.**

ND: Not Detected

Prakash Chandra Subedi
Chemist

Note:

- The entire test was conducted as per the National Drinking Water Quality Standard Guideline, 2062 BS (MPPW/GoN)
- For microbiological test, the water sample in sterilized containers is only accepted.
- If the received sample water volume is inadequate, it will be rejected for analysis.
- We are not compelled to accept the water samples in leak and damage bottles for analysis.

Government of Nepal
Ministry of Water supply &Sanitation
Department of Water Supply & Sewerage
Regional Monitoring & Supervision Office, Pokhara

Ph: 061-463086

Regional Water Quality Laboratory

Water Quality Test Report

Sample Details:	
Sample Name: Pipeline from bog - Lomanthan	**Sample Type: Gravity**
Location: Lomanthan, Mustang	**Sampling point: Pipeline (Black pipe)**
Sampling Method: Grab	**Sampled by: Analyst**
Contact person: Martina	**Contact No.:**
Received date: 2074/01/13	**Completed date: 2074/03/24**

Analyzed Parameters

Physical Parameters:

S.N.	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	pH	8.7	6.5-8.5	Instrumental
2.	Electrical conductivity (µs/cm)	443.0	1500	Instrumental
3.	Turbidity (NTU)	<5	5(10)	Instrumental
4.	Taste & odor	unobjectionable	Unobjectionable	Perception
5.	Color (TCU)	-	5(15)	Spectrophotometry
6.	TDS (mg/lit)	234.0	1000	Instrumental

Chemical Parameters:

S.N	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	Total Hardness as $CaCO_3$ (mg/lit)	200.4	500	Titrimetry
2.	Calcium (mg/lit)	72.1	200	Titrimetry
3.	Chloride (mg/lit)	14.0	250	Titrimetry
4.	Fluoride (mg/lit)	1.1	0.5-1.5	Spectrophotometry
5.	Ammonia (mg/lit)	0.0	1.5	Spectrophotometry
6.	Nitrate (mg/lit)	1.5	50	Spectrophotometry
7.	Iron (mg/lit)	0.04	0.3(3)	AAS
8.	Manganese	<0.01	0.2	AAS
9.	Arsenic (mg/lit)	<0.01	0.05	AAS
10.	Total Chromiun (mg/lit)	<0.01	0.05	AAS
11.	Copper (mg/lit)	-	1.0	AAS
12.	Lead (mg/lit)	-	0.01	AAS
13.	Cadmium (mg/lit)	-	0.003	AAS
14.	Zinc (mg/lit)	-	3.0	AAS
15.	Sulphate (mg/lit)	-	250	Gravimetry
16.	FRC (mg/lit)	0.0	0.1-0.2	Tritimetry

Microbiological parameters:

S.N	Parameters	Observed value/s	NDWQS, 2005	Analyzed Method
1.	*E. coli* (CFU/100 mL)	Nil	Nil	Membrane filter
2.	Total Coliform (CFU/100 mL)	-	Nil	Membrane filter

Remarks: : **pH of water sample was found to be slightly higher and rest of the tested parameters were found to be in accordance with National Drinking Water Quality Standard Guidelines, Nepal, 2005.**

ND: Not Detected

Prakash Chandra Subedi
Chemist

Note:

- The entire test was conducted as per the National Drinking Water Quality Standard Guideline, 2062 BS (MPPW/GoN)
- For microbiological test, the water sample in sterilized containers is only accepted.
- If the received sample water volume is inadequate, it will be rejected for analysis.
- We are not compelled to accept the water samples in leak and damage bottles for analysis.

Ph: 061-463086

Government of Nepal
Ministry of Water Supply & Sanitation
Department of Water Supply & Sewerage

Regional Monitoring & Supervision Office, Pokhara

Regional Water Quality Laboratory

Microbiological Test Report

Sample details:
Sampling Method: Grab
Sampled from: Lomanthan Drinking Water (Old System)
Sampled by: Analyst
Location: Lomanthan, Mustang **Date of analysis:** 2074|01|13

***E.Coli* Test**

S.N.	Sample Name	Sample Type	Sampling Point	Observed Value (CFU/100 mL)	NDWQS,2005 (CFU/100mL)	Analyzed Method
1.	Lomangthan old water supply system	Gravity	Tap (Jeepstand)	Nil	Nil	Membrane filtration
2.	Lomangthan old water supply system	Gravity	Pipeline (Black pipe)	Nil	Nil	

Remarks: Water sample was found to be free from *E.coli.*

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Prakash Chandra Subedi
Chemist

Note:

- The entire test was conducted as per the National Drinking Water Quality Guideline, 2062 BS (MPPW/GoN)
- For microbiological test, the water sample in sterilized containers is only accepted.
- If the received sample water volume is inadequate, it will be rejected for analysis.
- We are not compelled to accept the water samples in leak and damage bottles for analysis.

Appendix H: Grain Size Distribution Test Results

Table 12: Weight fractions and percentages of GSD by sieving; infiltration test sites

Mesh size [mm]	**Site 1** 0.5m depth [g] passing	**Site 1** 0.5m depth [%] passing	**Site 2** 0.5m depth [g] passing	**Site 2** 0.5m depth [%] passing	**Site 3** 0.5m depth [g] passing	**Site 3** 0.5m depth [%] passing
31.000			52.2	100.00		
19.000	9.5	100.00	39.4	94.72		
12.500	14.9	99.10	46.9	90.73	10.30	100.00
6.300	2.9	97.70	6.9	85.99	1.30	99.03
5.600	9.1	97.43	21.6	85.29	3.10	98.91
4.000	7.5	96.57	11.2	83.10	4.50	98.62
3.150	3.6	95.86	6.8	81.97	1.50	98.20
2.800	10.0	95.52	20.2	81.28	7.20	98.06
2.000	1003.5	94.58	783.1	79.24	1038.00	97.38
0.600	Results from pipette method (Table 13 below)	89.85	Results from pipette method (Table 13 below)	71.23	Results from pipette method (Table 13 below)	94.27
0.200		81.72		58.24		85.89
0.060		60.25		41.20		62.52
0.020		40.67		27.57		41.58
0.006		27.90		19.02		23.96
0.002		16.36		11.65		17.24
Total weight [g]	**1061.0**		**988.3**		**1065.90**	

Table 13: Weight percentages of grain size fractions by pipette method; infiltration test sites

Fraction passing [mm]		**Site 1** weight % of pipette method	**Site 1** overall weight %	**Site 2** weight % of pipette method	**Site 2** overall weight %	**Site 3** weight % of pipette method	**Site 3** overall weight %
sand	2.000	100.00	94.58	100.00	79.24	100.00	97.38
	0.600	95.00	89.85	89.90	71.23	96.8	94.27
	0.200	86.40	81.72	73.50	58.24	88.20	85.89
silt	0.060	63.70	60.25	52.00	41.20	64.20	62.52
	0.020	43.00	40.67	34.80	27.57	42.70	41.58
	0.006	29.50	27.90	24.00	19.02	24.60	23.96
clay	0.002	17.30	16.36	14.70	11.65	17.70	17.24

Table 14: Weight fractions and percentages of GSD by sieving; construction pit

Mesh size [mm]		**Construction pit** 1.9m depth [g] passing	**Construction pit** 1.9m depth [%] passing
gravel	40.000	147.358	100.00
	25.000	148.530	88.37
	19.000	175.896	76.64
	12.500	93.484	62.75
	9.510	161.167	55.37
	4.750	112.905	42.65
sand	2.000	45.949	33.74
	1.700	153.972	30.11
	0.850	92.469	17.96
	0.600	106.035	10.66
	0.250	5.041	2.28
	0.210	10.850	1.89
	0.150	11.180	1.03
silt	0.063	1.868	0.15
Total weight [g]		**1266.704**	

Appendix I: Infiltration Test Results

Table 15: Measurements from infiltration tests and corresponding infiltration rates at three test sites

Site 1

	water level drop [cm]	time [s]	time [min]	infiltration rate [cm/min]	infiltration rate [m/s]	infiltration rate [m/d]
first run	0	0	00:00			
	-1	85	01:25			
	-2	175	02:55			
	-3	280	04:40			
	-4	400	06:40			
	-5	508	08:28			
	-6	640	10:40			
	-7	765	12:45	**0.33**	**5.52E-05**	**4.77**
	-8	925	15:25			
	-9	1105	18:25			
	-10	1300	21:40			
	-11	1490	24:50			
second run	-0.5	1620	27:00			
	-1	1665	27:45			
	-2	1770	29:30			
	-3	1890	31:30			
	-4	2030	33:50			
	-5	2160	36:00			
	-6	2310	38:30			
	-7	2470	41:10	**0.32**	**5.26E-05**	**4.55**
	-8	2640	44:00			
	-9	2820	47:00			
	-10	3020	50:20			
	-11	3230	53:50			
third run	0	3300	55:00			
	-1	3440	57:20			
	-2	3545	59:05			
	-3	3685	1:01:25			
	-4	3825	1:03:45			
	-5	3970	1:06:10			
	-6	4140	1:09:00			
	-7	4300	1:11:40	**0.29**	**4.76E-05**	**4.11**
	-8	4500	1:15:00			
	-9	4660	1:17:40			
	-10	4895	1:21:35			
	-11	5140	1:25:40			

Site 2

	water level drop [cm]	time [s]	time [min]	infiltration rate [cm/min]	infiltration rate [m/s]	infiltration rate [m/d]
first run	0	0	00:00			
	-1	15	00:15			
	-2	45	00:45			
	-3	78	01:18			
	-4	105	01:45			
	-5	140	02:20			
	-6	175	02:55			
	-7	215	03:35	**1.26**	**2.11E-04**	**18.19**
	-8	260	04:20			
	-9	300	05:00			
	-10	345	05:45			
	-11	405	06:45			
second run	0	540	09:00			
	-1	570	09:30			
	-2	605	10:05			
	-3	640	10:40			
	-4	670	11:10			
	-5	705	11:45			
	-6	540	12:30			
	-7	795	13:15	**1.12**	**1.86E-04**	**16.07**
	-8	840	14:00			
	-9	892	14:52			
	-10	950	15:50			
	-11	1010	16:50			
third run	0	1080	18:00			
	-1	1110	18:30			
	-2	1147	19:07			
	-3	1180	19:40			
	-4	1215	20:15			
	-5	1260	21:00			
	-6	1300	21:40			
	-7	1345	22:25	**1.09**	**1.82E-04**	**15.71**
	-8	1395	23:15			
	-9	1455	24:15			
	-10	1505	25:05			
	-11	1565	26:05			

Site 3

	water level drop [cm]	time [s]	time [min]	infiltration rate [cm/min]	infiltration rate [m/s]	infiltration rate [m/d]
first run	0	0	00:00			
	-1	14	00:14			
	-2	26	00:26			
	-3	44	00:44			
	-4	62	01:02			
	-5	109	01:49			
	-6	245	04:05			
	-7	360	06:00	**0.35**	**5.88E-05**	**5.08**
	-8	525	08:45			
	-9	684	11:24			
	-10	890	14:50			
	-11	1040	17:20			
second run	0	1140	19:00			
	-1	1150	19:10			
	-2	1165	19:25			
	-3	1182	19:42			
	-4	1206	20:06			
	-5	1285	21:25			
	-6	1440	24:00			
	-7	1590	26:30	**0.30**	**4.94E-05**	**4.27**
	-8	1778	29:38			
	-9	1980	33:00			
	-10	2190	36:30			
	-11	2400	40:00			
third run	0	2460	41:00			
	-1	2470	41:10			
	-2	2482	41:22			
	-3	2497	41:37			
	-4	2528	42:08			
	-5	2610	43:30			
	-6	2760	46:00			
	-7	2940	49:00	**0.29**	**4.85E-05**	**4.19**
	-8	3125	52:05			
	-9	3335	55:35			
	-10	3540	59:00			
	-11	3765	1:02:45			

Note: These results are only based on the water level drop during the experiments and do not account for three-dimensional infiltration. The soils' K_{sat} based on infiltration through the pit bottom *and* side walls (assuming homogeneous conditions) are presented in section *4.4.3*, Table 9.

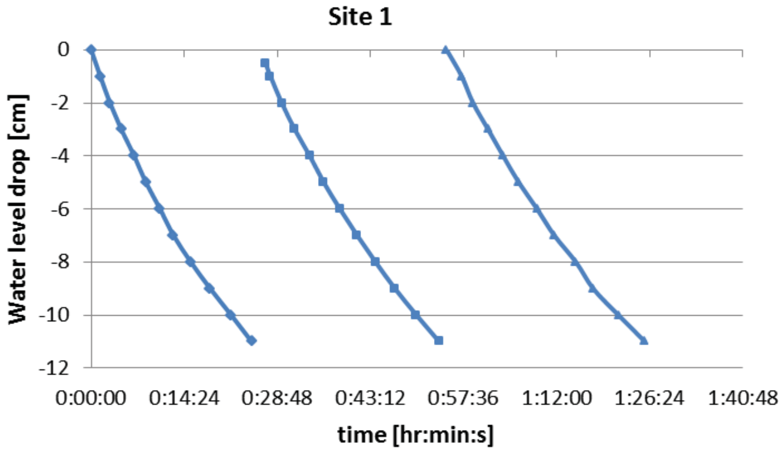

Figure 176: Drop in water level per time at infiltration test site 1, three consecutive runs

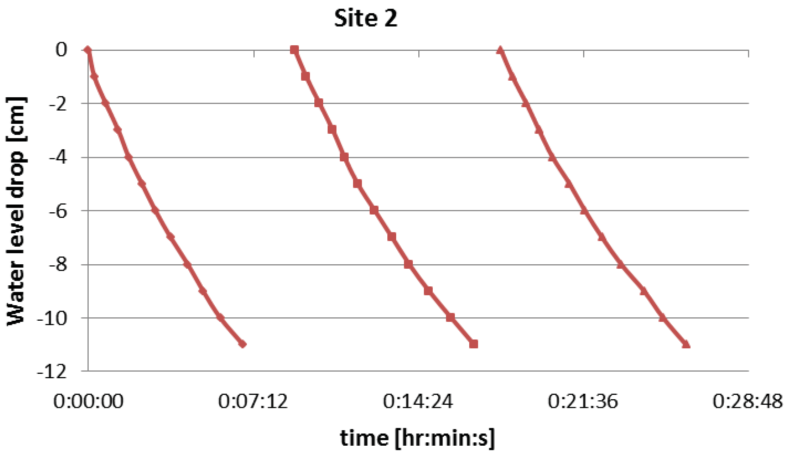

Figure 177: Drop in water level per time at infiltration test site 2, three consecutive runs

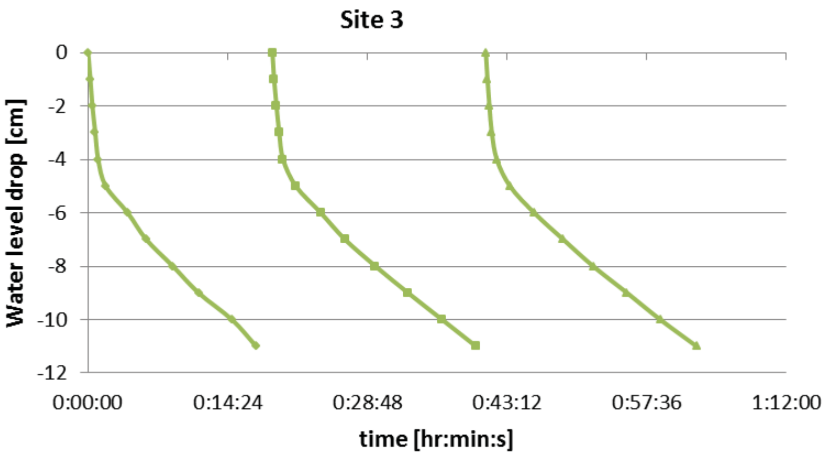

Figure 178: Drop in water level per time at infiltration test site 3, three consecutive runs

The bend in the curves at test site 3 is due to the backfill of the inner pit which had been dug slightly too large for the sponge to fit tightly. The backfill material was less compact than the original soil structure, so that water infiltrated more quickly for the top few centimeters. However, this did not affect K_{sat} calculations as those only relied on the last 5cm of the infiltration measurements.

Appendix J: Cost Estimate for WASH Improvements at the Lo Kunphen School

Table 16: Cost estimate for WASH improvements at the Lo Kunphen School (May 19, 2017)

(all prices in NRs, including value added tax, purchased in Pokhara)

Toilets	**Cost per unit**	**Quantity**	**Price**
Urine-diverting fiberglass pans	1,000	5	5,000
Urinals for boys'/teachers' toilet (small)	1,650	3	4,950
1.5" PVC pipes connecting pan to urine storage tank	440	10	4,400
45°bends (elbows)	70	16	1,120
Hilltake PVC drums for urine storage (500 liters)	6,000	5	30,000
Taps on storage drums (incl. connecting pipe, plastic)	400	5	2,000
Hilltake big dust bins with wheels and lid for feces ($0.26m^3$)	8,000	7	56,000
Tiles for walls and floors (plain white, 8*12 inches)	50	250	12,500
Round grating to drain cleaning water	45	4	180
PVC pipes to connect toilet drains to graywater channel (2.5", 3m/pipe)	675	4	2,700
Wastebaskets for toilet paper	500	5	2,500

Tap stand	**Cost per unit**	**Quantity**	**Price**
Hilltake PVC drums 500 liter (two on shower, one above kitchen)	6,000	3	18,000
Metal wash basins	2,500	3	7,500
Jason taps	400	3	1,200
T-joints (GI) for taps	80	3	240
Nipples	40	3	120
Coupling with folding pipe	350	3	1,050
45°bend (elbow)	70	1	70
T-joints (PVC) for graywater	140	3	420
Connecting graywater pipes (2.5", length 3m/piece)	675	2	1,350
Pipe for infiltration trench (minimum 3", length 3m/piece)	850	2	1,700

Showers	**Cost per unit**	**Quantity**	**Price**
Shower heads (small size)	650	2	1,300
Solar water heater (400 liters)	75,000	1	75,000
Taps with hot/cold mixing device (cheaper)	4,600	2	9,200
Plumbing behind shower (concealed pipes)	300	2	600
Tiles (25 tiles per side wall 1.00m width, 1.50m height)	50	150	7,500
Round grating	45	2	90
Nahani trap (PVC)	350	1	350
Multi floor trap (PVC), connecting shower & tap stand drains	435	1	435

Further materials	**Cost per unit**	**Quantity**	**Price**
Water pump to lift water to storage drums	19,000	1	19,000
Hose to connect to public tap	1,200	2	2,400
Galvanized iron pipes between PVC drums, water heater, showers (per m)	700	40	28,000
"White cement" to attach tiles in toilet (bags)	1,800	2	3,600
Cement for structure around wash basins (bags)	1,500	2	3,000
Cement for 3 side walls, back wall, ceiling and floor of showers	1,500	15	22,500
Sand (one tractor load)	3,000	1	3,000
Tin for front wall of showers, partition between toilets, and 6 doors (3'x8')	1,600	12	19,200
Wood for 6 door frames for showers and toilets (wood planks 12' long)	2,500	9	22,500
Windows above shower doors (incl. wooden frame)	6,000	2	12,000
Jerry cans for urine transport to field (35 liters)	1,200	4	4,800
Watering cans for urine application	250	4	1,000

Additional costs	**Cost per unit**	**Quantity**	**Price**
Skilled labor (plumber/day)	2,500	15	37,500
Semi-skilled labor (construction worker/day)	1,500	15	22,500
Unskilled labor	1,000	30	30,000
Transport of materials to Lo Manthang	125,000	1	125,000

TOTAL (estimate)	**NRs**	**603,475**
	US$	**~6,034**

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