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Matching sanitation technology options with the local conditions of Botswana

MASTER THESIS

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«The designer knows he has reached perfection,
not when there is no longer anything to add,
but when there is no longer anything to take away! »

Antoine de Saint-Exupery

Abstract

Botswana has made exceptional progress in providing access to sanitation in the past two decades. Today Botswana is one of the very few African countries that have already met the MDG sanitation target and is considered as a role model for country success. However, limited water resources and the inability to cover for further large investments make the current policy to subsidize waterborne sewerage extremely unsustainable. This raises a pressing need to find more cost-efficient and sustainable alternatives.

In this thesis, a participatory approach was used to match existing technology options with the local context of a rural and a peri-urban village in Botswana. Workshops, interviews and a qualitative survey showed that most households are provided with basic sanitation, but inadequate planning and budgeting has been provided for management, emptying and maintenance of the existing infrastructure. Deficiencies in sanitation services were found to be larger on institutional than on household level. Resources (financial, human, technical, organizational) are usually available, but their mobilisation is a major challenge.

This thesis proposes four systems that address the identified challenges by low technical complexity, high cost-effectiveness and a reduced risk of groundwater contamination. All systems allow for the reuse of greywater and nutrients and do not depend on continuous supply of water. Fossa alterna, the gendarme toilet, greywater tower gardens, diversion and reuse of urine and a jointly used local sludge treatment facility are some of the proposed technologies. It is further emphasized that the creation of public awareness and project ownership is essential for successful implementation of any sanitation system in the local context.

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Acronyms

BWP	Botswana Pula (exchange rate on 30 January 2013: 1 BWP = 0.0920 €)
CLUES	Community-Led Urban Environmental Sanitation
DBES	Department of Building and Engineering Services
DWMPC	Department of Waste Management and Pollution Control
IWRM	Integrated Water Resource Management
JSS	Junior Secondary School
MDG	Millennium Development Goal
NRSP	National Rural Sanitation Programme
OWP	Open Wastewater Planning
PAR	Participatory Action Research
Sida	Swedish International Development Corporation Agency
UDDT	Urine Diverting Dry Toilet
UNDP	United Nations Development Programme
VDC	Village Development Committee
VIP	Ventilated Improved Pit Latrine
WE	Water Efficiency
WUC	Water Utilities Corporation
WWTW	Waste Water Treatment Works

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1 Background and Introduction

1.1 The Global Sanitation Crisis

Sanitation is a human right and a key element of prevention to ensure better health (Montgomery & Elimelech 2007). In Africa, 115 people die every hour from diseases linked to poor sanitation, poor hygiene and contaminated water (WHO 2011). Providing access to improved sanitation has been a challenge for many years. The Millennium Development Goal (MDG) sanitation target aims to halve the proportion of people without access to improved sanitation until 2015 (UN 2003). There is some questioning about the definition[1] used for the MDG target. Some researchers argue that facilities shared by less than four households should also be included in the definition of improved sanitation (Günther et al. 2012); others question the inclusion of toilets connected to a sewer system that releases sewerage without treatment (Baum et al. 2013).

However, using the current definition, 2.5 billion people on the world still lack access to improved sanitation and the MDG target is unlikely to be met by 2015 (Unicef & WHO 2012). The progress is especially slow in Sub-Saharan Africa, where the percentage without access to improved sanitation could only be reduced from 74% in 1990 to 70% in 2010 (Unicef & WHO 2012). However, MDG progress within Sub-Saharan Africa is not off-track everywhere. Botswana is one of the countries having made exceptional progress in the past two decades and has already reached its 2015 sanitation target (UNDP 2010). Nonetheless, the current sanitation policy was only partly successful. 38% of the national population remain without access to improved sanitation (Unicef & WHO 2012) and existing sanitation infrastructure is facing a number of challenges in terms of wastewater treatment, operation and maintenance and the limited availability of water (GoB 2003). To bring sanitation in Botswana to a next level, more advanced sanitation planning approaches are required.

1.2 About Botswana

Botswana is a land-locked country in Southern Africa, sharing borders with South Africa, Namibia, Zambia and Zimbabwe. Diamond mining, cattle breeding and tourism are the main industries. A population of two million is spread on an area comparable to Kenya or France (European parts only), resulting in one of Africa's lowest population densities. Botswana was one of the poorest African countries when it gained independence from the United Kingdom in 1966. But since then, Botswana has faced fast economic growth and is ranked as a middle-income country today. With free and fair elections, low corruption and wise investment of revenue to improve infrastructure, health and education, Botswana is considered a role model for country success nowadays (Robinson 2009).

Similarly, sanitation coverage in Botswana has improved tremendously over the past decades. Today, Botswana is one of only four Sub-Saharan African countries still on track to meet the

[1] Access to improved sanitation is defined as "access to facilities that hygienically separate human excreta from human, animal and insect contact" (UN 2003).

MDG sanitation target. This is thanks to numerous governmental sanitation programmes, the earliest one dating back to 1976. The National Rural Sanitation Programme (NRSP) provided more than 30,000 pit latrine substructures (own calculations; Bolaane & Ikgopoleng 2011b). This substantially increased access to improved sanitation in rural areas from 22% in 1990 to 41% in 2010 (Unicef & WHO 2012). In parallel, the Major Village Infrastructure Programme was aimed to provide waterborne sewerage to the major villages, resulting in 75% access to improved sanitation in urban areas. However, nationwide, 38% still lack access to improved sanitation (Unicef & WHO 2012) and the current policy to subsidize waterborne sewerage cannot be sustained, neither from an economic nor from an ecological perspective.

Financially, Botswana lacks the means to sustain the current policy of heavily subsidizing sanitation infrastructure. Scheduled sewerage projects get delayed by decades and it is unclear if they will ever get realized. Additionally, as shown in a recent study by Bolaane & Ikgopoleng (2011b), the majority of the households have not connected to the sewer even after seven years of existence. The high unemployment rate (26.2% in 2008) and a very high prevalence of HIV (17.6% in 2008) resulting in a drastically reduced life expectancy (54.4 years in 2006; all figures from UNDP 2010) might be some of the reasons for that.

A large ecological problem is the scarce and uneven distribution of Botswana's water resources. Most of the water is situated along the Northern border. Population on the other hand is mainly concentrated in rapidly growing urban centres in the South, where rainfalls are low and erratic (annual precipitation of 200 to 550 mm; see FAO/GIEWS 2013). Climate change is expected to result in a further reduction of rainfalls. Projections by the Intergovernmental Panel on Climate Change (Boko et al. 2007) call for rainfall decreases of 30-40 per cent by 2080-2099 and a recent study (Batisani & Yarnal 2010) found that climate change is already affecting Botswana through decreases in rainfall. While available water resources are getting lower, consumption is increasing. Demand is not only increasing due to economic development of highly water-intensive sectors (diamond mining, cattle breeding and tourism), but also because an increasing number of households are using private connections, which is known to translate into higher water consumption (Swatuk & Rahm 2004).

In the past, Botswana's policy mostly aimed to meet the increasing water demand through the construction of dam reservoirs, a North-South water carrier line, water imports from South Africa and depletion of groundwater aquifers. Surplus capital reinforced the belief that water can be acquired from somewhere, in other words, technology will provide (Swatuk & Rahm 2004). But in fact, suitable dam sites are limited and neighbouring countries are neither able nor willing to export unlimited amounts of water to Botswana (Rahm et al. 2006).

Limited availability of water and financial means raise a pressing need to find more cost-effective and resource efficient sanitation systems in order to be able to ensure a continuing support of water and sanitation services to the population of Botswana in the future.

1.3 The Botswana-Sweden cooperation project

To address these challenges, the Swedish International Development Corporation Agency (Sida) has developed a project in cooperation with the local authorities of Botswana. The aim of this project is to demonstrate a participatory approach on how to design and demonstrate cost-effective and sustainable sanitation systems.

The project will be conducted in two phases. In the first phase of the project, the local conditions and functional requirements are determined in order to identify possible technology options. In the second phase, a selection of 2-3 appropriate technology options will then be installed to demonstrate and evaluate their acceptance. It is hoped that this approach can then be rolled out, replacing the current governmental top-down planning and resulting in more sustainable and cost-effective solutions.

The project has selected two pilot villages to demonstrate this form of participatory sanitation planning. They are indicated on the map in Figure 1. A description of them is given in Box 1 and Box 2.

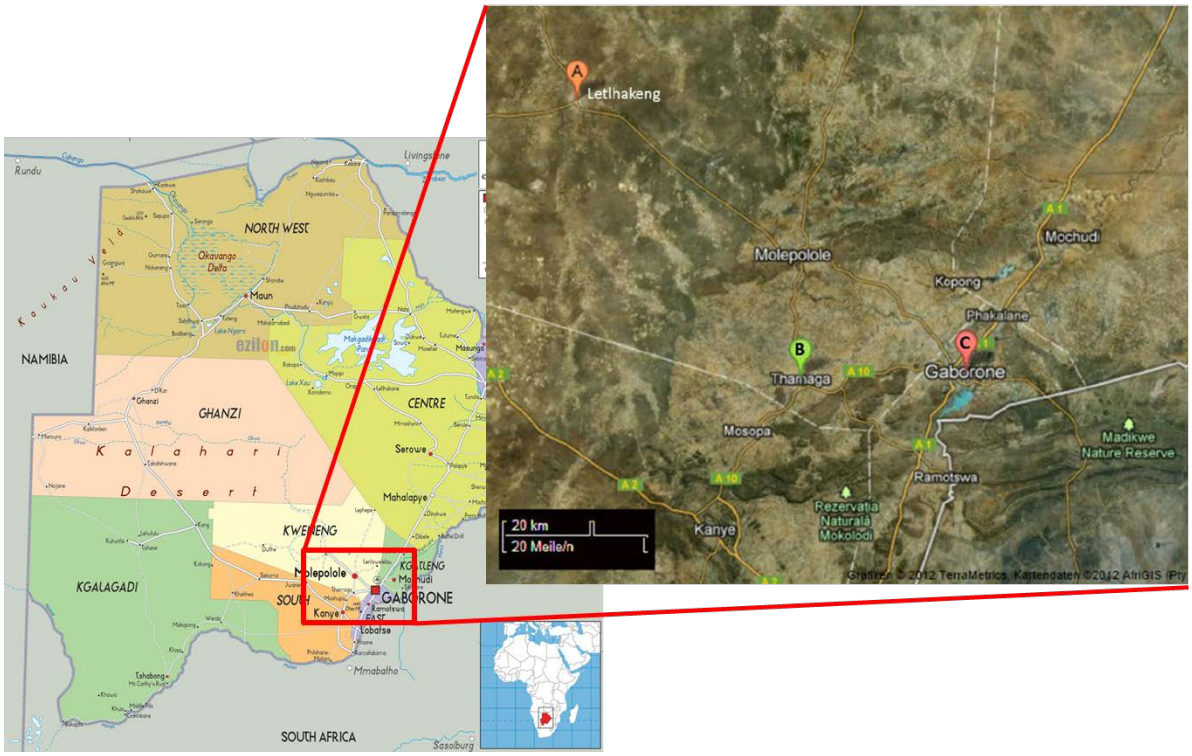


Figure 1. Location map of the pilot villages Letlhakeng (A) and Thamaga (B) in Kweneng District, Botswana, Southern Africa.

Box 1. Rural pilot village: Letlhakeng

Letlhakeng is located in the Western part of Kweneng District, the area confronted with the highest percentage of people below the national poverty line within Botswana (49%; see CSO 2011b). Letlhakeng has a population of 7,229 (2011 Census). Letlhakeng was selected as an example for the poor rural Botswana context. A mere 21.2% of the population is economically active (Loci 2012). The next larger settlement is Molepolole (64 km). The majority of employment includes (in order from high to low) construction, agriculture and government (Loci 2012).

Box 2. Peri-urban pilot village: Thamaga

Thamaga is also located in Kweneng District, but in the Eastern part. The population is 21,471 (2011 Census). It is more urbanized and poverty is below the national average (19%; see CSO 2011b). Thamaga represents a peri-urban setting. 36.8% of the population is economically active (Loci 2012). An increasing number of people is working in the nearby urban centres of Molepolole (35 km) and Gaborone (46 km). Majority of employment includes (in order from high to low) construction, public administration, agriculture, wholesale/ retail and education (Loci 2012).

2 Objectives and Research Questions

This thesis was set up as part of the Botswana-Sweden cooperation project to get a deeper understanding of the opportunities and drawbacks the different technology options pose in the local context. This enables the project partners to make a better-informed selection of technology options that are suitable for demonstration.

The aim of this master thesis is to frame sanitation systems that match with the local conditions, challenges and requirements of the two pilot villages of Thamaga and Letlhakeng. Derived from this objective, the main research question is

What are suitable sanitation systems and appropriate technology options matching with the local conditions of Thamaga and Letlhakeng?

To answer this question the following three sub-questions were defined:

1. What are the existing sanitation systems and the technologies used within each functional group of a sanitation system?
   (discussed in Section 5.1 "Current sanitation conditions")

2. What are the social requirements from local stakeholders?
   (discussed in Section 5.2 "Current sanitation challenges")

3. What are the system and technology requirements given the ambient conditions?
   (discussed in Section 5.3 "Requirements for improved sanitation systems")

3 Research Methodology

In various fields of science, voices have been raised that research should be done "with" people and not "on" or "for" people (Chevalier & Buckles 2013). In an approach referred to as Participatory Action Research and typically used in "hands-on, small-scale research projects" (Denscombe 2010), participation has been integrated into research inquiries. This allows producing knowledge and action directly useful and applicable to the participants (Reason & Bradbury 2008).

Particularly to induce changes in complex settings that keep evolving and do not lend themselves to straightforward technical solutions, incorporation of people-based and evidence-based research methods is needed (Chevalier & Buckles 2013). Sanitation is an example for such a setting and hence to define sanitation technology options with a high chance of long-term success, a thorough understanding of the stakeholders' needs and concerns is essential (Tayler et al. 2003; Tayler 2007; Lüthi, Panesar, et al. 2011). Novel sanitation planning approaches, such as Community-Led Urban Environmental Sanitation (CLUES) (Lüthi, Morel, et al. 2011) or Open Wastewater Planning (OWP) (Kvarnström & af Petersens 2004; Ridderstolpe & Palmér Rivera 2007) therefore include strong stakeholder involvement.

Correspondingly, the approach chosen for this thesis (see Figure 2) includes strong stakeholder involvement and follows the principles of action research by doing research "with" and not "on" or "for" people.

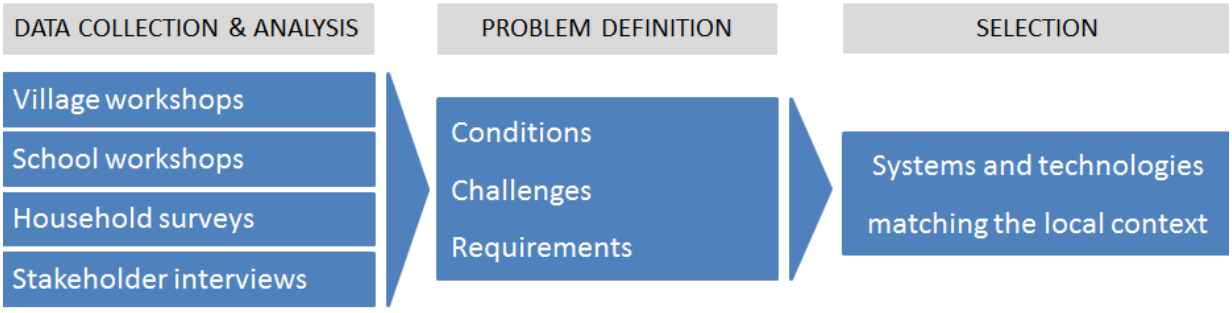


Figure 2. Approach chosen to select adequate sanitation systems for the local context.

Four participatory methods were used for data collection: village workshops, school workshops, household surveys and stakeholder interviews. The following sections give a brief description on how each of the four participatory tools was applied during a three-month field study.

For the problem definition, a thorough understanding of the prevailing conditions and challenges had to be gained (research sub-questions 1 and 2). This was done by combining the findings from group discussions and community walks (workshops), fully structured questionnaires (household survey) and semi-structured questionnaires (stakeholder interviews). Local conditions and challenges then defined the requirements for improved sanitation systems (research sub-question 3).

Based on the terms of requirements, adequate systems and technologies were proposed that match the local context (main research question). Section 3.5 explains in more detail how existing technologies were selected.

3.1 Village workshops

To assess local sanitation conditions and the possibilities for improving these conditions, the Sweden-Botswana project team organized two participatory workshops in each of the two villages.

Around 50 participants from public authorities, utilities, academia and community members were identified as important stakeholders for the first two-day workshop. The first day was dedicated to identify the sanitary problems within the community (step 1 in the OWP approach). Community mapping (Wood et al. 1998) and transect walks (Tayler et al. 2003) were used to identify the problems. To safe time, participants were asked to indicate functionality of sanitation infrastructure directly on large prints of satellite images (the standard method would include the drawing of a map on blank paper first). The transect walk also included visits of some major institutions (i.e. the Primary Hospital in Thamaga and two schools and the clinic in Letlhakeng). During day two, participants were asked to compile a terms of requirement for an improved sanitation system (step 3 in the OWP approach). For the more interested readers, reports have been prepared from each workshop (Kvarnström 2012a; Kvarnström 2012b).

Two months later, another one-day workshop was organized in each village. Given the bad state of institutional facilities encountered on the transect walk during the first workshop, this time also a delegate from the Department of Building and Engineering Services (DBES), school teachers and headmasters were joining the workshops. First, the Swedish project team presented a set of possible solutions that were developed jointly with the author of this thesis, based on the identified boundary conditions (step 2 in the OWP approach). Then, the participants' task was to evaluate these solutions (step 4 in the OWP approach) with the terms of requirement they had set up in the first workshop. Moreover, participants were asked to develop ideas on how to address the vandalism problems encountered in many school toilets in a brainstorming exercise.

3.2 School workshops

During the village workshops it turned out that the situation on institutional level, particularly in schools, is of special concern. To get a better understanding of the situation, it was decided to organize another set of short workshops in schools. The author of this thesis then organized two workshops in Ramaphatle Primary School (Thamaga) and in Mphuthe Junior Secondary School (Letlhakeng). The workshops targeted all the relevant stakeholders for school sanitation. These were students from each grade, teachers, parents, members of the parent-teacher association, caretakers, cleaning staff and the Ministry of Education which is responsible for the construction of toilets in secondary schools. In total, 20-30 participants were expected to join the workshop.

Both workshops lasted for three hours. To minimize technical problems (e.g. power cuts, broken beamer etc.), flipchart slides were prepared beforehand instead of a PowerPoint presentation

(see Figure 3). The program of the workshops is depicted in Figure 3 (left hand side). The workshops started with introductions and a short and simple presentation why sanitation is important in schools (Figure 3, right). After that, all participants were guided by the students to see the toilets. During this walk, there were extensive discussions on for how long things had not been working and who is in charge to fix them. Back from the walk, the participants elaborated criteria of important functions of a school toilet, similar to the group assignment conducted in the first village workshop. This group work took about 50-60 minutes. After that, another group work was focusing on ideas on how to overcome vandalism, equal to the assignment in the second village workshop. In small groups of 2-3 participants, the task was to come up with ideas how the different stakeholders (students, teachers, parents) could address vandalism issues. To keep the participants' concentration high over the whole duration of the workshop, a refreshment break was taken before the last exercise or when people claimed they were tired (for the essential role of flexible refreshment breaks see Tayler et al. 2003, p.152f). To make participants aware of the different tasks needed to keep school toilets clean and working, the workshop ended with a final group exercise. In this assignment, participants were asked to develop an operation and maintenance plan for the toilets. During the presentation of their work, the groups were also asked if the tasks they defined were already in place and working or if they were rather to be thought of as suggestions for improvement. After the workshop, participants asked for a certificate of attendance which was issued to all of them. Moreover, the schools were provided with a set of additional literature on school sanitation (Unicef 1998; Reed & Shaw 2008; Kanyemba 2011) for further reading. For the more interested readers, a report has been prepared from these workshops (Fink 2012).

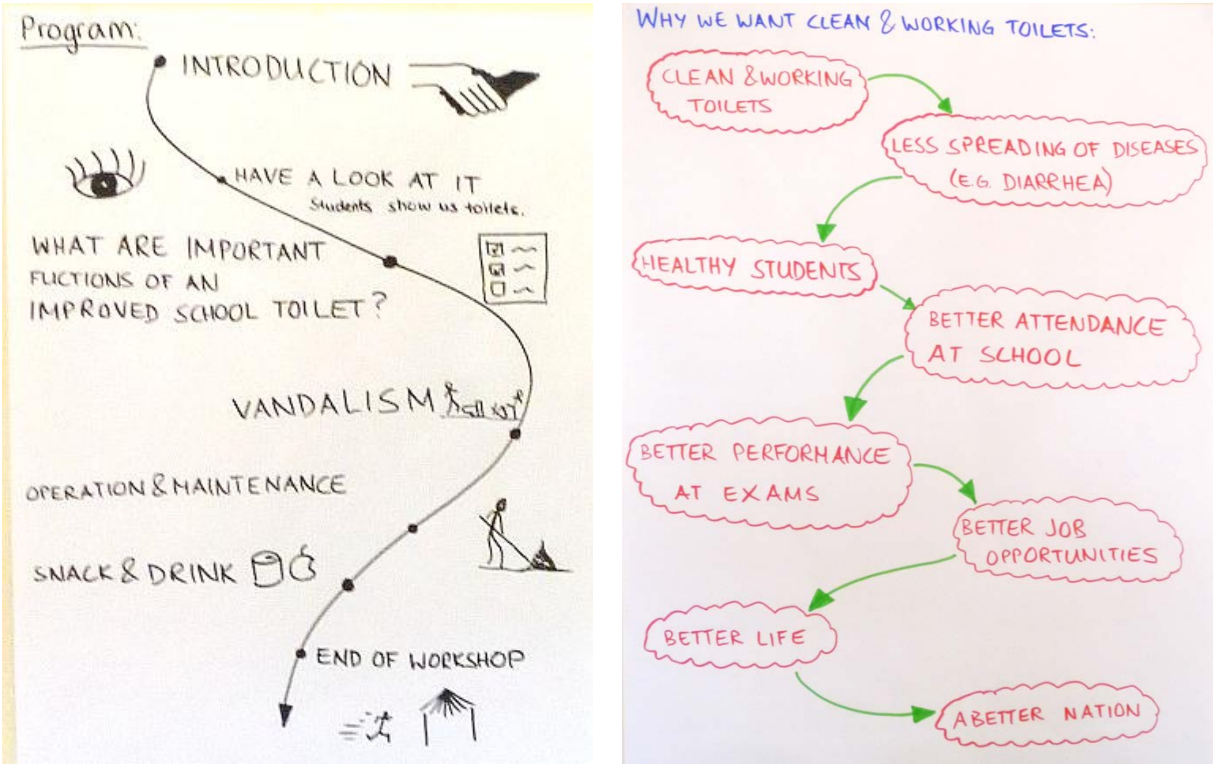


Figure 3. To minimize technical issues, flipchart slides were used instead of a PowerPoint presentation (left side: program of the workshop at Ramaphatle Primary School; right side: simple presentation why sanitation is important in schools).

3.3 Household surveys

The participants of participatory workshops can only express a limited selection of the views about sanitation within the village. Conducting a household survey can be a useful way to make better-informed decisions (UN 2005).

To conduct a representative survey for the two villages, sample sizes in the order of hundreds of questionnaires would have been required (Lüthi, Morel, et al. 2011, tool D2.2). Given the limited resources for this master thesis, such a project exceeded the scope by far. Nevertheless, a small non-representative survey was deemed appropriate for this thesis. In combination with the other methods applied, the survey was used to verify outdated figures about sanitation access from the last census from 2001. Moreover, additional knowledge about the users' problems and preferences could be gained.

After careful review of relevant survey guidelines (UN 2005; Taylor-Powell 1998; Ali 2010) and previously developed sanitation questionnaires for the African context[2], a draft for a questionnaire was prepared. This first draft was then reviewed by two local sanitation consultants and tested in Tlokweng, a peri-urban settlement in the South-East district. The first test run took 48 minutes, far above the anticipated duration of half an hour per household. To reduce the interview time to 30 minutes, the questionnaire was again scanned for dispensable questions and it was decided to skip a series of questions under certain conditions. After two more test runs, the questionnaire was structured into the following sections, including a total of 65 questions:

- Household characteristics
- Agriculture (skipped if household does not grow any fruit or vegetables)
- Access and use of toilet facilities
- Management capacity
- Satisfaction with current toilet facility
- Sanitation costs
- Sanitation service requirements (skipped for households that do have a private toilet and are satisfied with it)

The questionnaire is attached in the Appendix of this thesis (Section 8.1.1).

After having obtained permission from the Kgosi (village chief), 16 households were visited in each village, resulting in a total sample size of 32 households. To conduct the survey, the author was accompanied by a student from the University of Botswana and a member of the Village Development Committee (VDC). The student served as a translator, the VDC member helped to convince reluctant households to participate. To keep the survey as representative as possible, we visited 4 households in each of the 4 political wards of Thamaga, 8 households in the Northern part of Letlhakeng and 8 households in the Southern part of Letlhakeng. The households in each part of the village were then selected by the random walk method (UN 2005). At randomly selected starting points within each ward, we spun a bottle to randomly select one of the surrounding households.

[2] Eight questionnaires from other projects are provided on the attached CD-ROM.

The data was then analysed by means of IBM SPSS Statistics, a software package for statistical analysis. For the reasons stated earlier (purpose to check plausibility of findings from previous census and other participatory approaches and not to analyse a fully representative sample), the survey was of a non-representative nature. Data analysis was therefore rather focusing on qualitative comparisons to the 10 year old census data than on quantitative statistically significant figures.

3.4 Stakeholder interviews

Semi-structured interviews were conducted with 20 key stakeholders as an additional source of information. The following key stakeholders were identified (number of interviewed persons in brackets):

- **Public authorities (6)**
  - Department of Water Affairs (1)
  - Department of Waste Management and Pollution Control (2)
  - Department of Building and Engineering Services (0)
  - Department of Crop Production (1)
  - Kweneng District Council (2)
- **Academic institutions (2)**
  - University of Botswana (2)
- **Non-governmental organizations (1)**
  - Kalahari Conservation Society (1)
  - Sanitation Water and People Trust Botswana (0)
- **Wastewater service providers (6)**
  - Water Utilities Corporation (3)
  - SkipHire (1)
  - Sani Care (1)
  - Multi Waste (Pty) Ltd. (1)
- **Sanitation technology providers (3)**
  - Gendarme Sanitation Systems (Pty) Ltd. (2)
  - PR Green Paradise (Pty) Ltd. (1)
- **Farming sector (2)**
  - Farmers (1)
  - Farmer's Magazine Botswana (1)

A detailed list of all interviewees can be found in the Appendix (Section 8.2.2). Interviews could be conducted with all the above listed stakeholders, except for the Department of Building and Engineering Services (denied participation) and Sanitation Water and People Trust Botswana. Sanitation Water and People Trust Botswana is a new civil society organisation that was not established at the time when the stakeholders interviews were conducted.

A questionnaire was prepared before each interview. The questions were adapted to the interviewee's background but comprised usually the personal background of the interviewee, the organisation he or she was working for, the local context of Thamaga and Letlhakeng and

possible solutions for households and for institutions. An example of such a questionnaire is given in the Appendix (Section 8.2.1). Normally, the interviewee was not provided with the questionnaire, but only with an agenda of the major topics to be discussed. This semi-structured setup allowed for enough flexibility to add or omit questions during the interview, depending on the statements that were made.

After each interview, the interest, influence, impact and support of the interviewed stakeholder were assessed (see table at the end of the example questionnaire, p. 69). Such an analysis table is a useful tool to judge the relevance of the collected information and to develop a strategy for handling stakeholders (Elliott 2001). To structure the large amount of information obtained, a STEEPLED analysis was conducted. STEEPLED analysis is a decision-support tool used to describe external factors that an organization must consider and cannot influence itself (Larsen et al. 2010). STEEPLED is an extended version of the PEST analysis (see e.g. Griffiths & Wall 2004) and has been used successfully for the analysis of stakeholder interviews in similar previous work (Gendre 2012). The analysis comprises social, technological, economic, ecological, political, legal, ethical and demographic aspects. For each of these aspects, a total of 43 potentially relevant factors were chosen, based on literature review (e.g. water availability, education or religion under social aspects). Interviews were then scanned for statements made regarding these factors. A list of all factors and the analysis of the interviews is provided in the Appendix, Section 8.2.3. In analogy to a previous study by Gendre (2012), each factor mentioned by half or more of the interviewees was considered as relevant for the selection of sanitation systems matching the local conditions.

3.5 Selection of sanitation technologies

To select sanitation systems that are suitable for the local context, existing technologies were reviewed based on a terms of requirements defined beforehand. Literature review showed that there is a large variety of sanitation technology options available. The Compendium of Sanitation Systems and Technologies (Tilley et al. 2008) provides a good overview and was therefore selected as a starting point. Morel & Diener (2006) complement the compendium with a review of different greywater treatment systems. In addition, more recently developed technologies and locally produced solutions were also evaluated.

Tilley (2013) outlines how the diversity of technologies can be structured for effective sanitation planning. Wastewater components (urine, faeces, blackwater and greywater) have varying qualities and should therefore be considered as individual input products. Sanitation technologies can then be categorized into different functional groups, depending on the function they perform. Tilley (2013) defines the following five functional groups: (1) user interface, (2) collection and storage, (3) conveyance, (4) treatment and (5) use and disposal. A sanitation system can then be framed by composing product-specific technologies from each of the relevant functional groups.

For this thesis, the structuring approach described above was selected for three reasons. First, by splitting up wastewater into individual input products, material flows could be comprehensibly illustrated. Second, categorization of technologies into different functional groups pointed out the linkages between different technologies applied. Finally, by composing adequate technologies from the different functional groups, sanitation systems both for household and institutional levels could be framed to answer the main research question. In the end, the proposed systems were challenged by discussing various alternatives.

4 Results

4.1 Village workshops

4.1.1 Thamaga

The community mapping showed that most of the households in Thamaga are covered with functioning water supply, on-site sanitation and a well-functioning solid waste collection with donkey carts. Provision of sanitary services on a household level seems to be mainly a (temporary) problem in newly developed areas. However, participants reported numerous problems with the sanitary facilities installed in institutions. This first impression was confirmed during the assessment of the functioning of the different parts of the sanitation system (see Figure 4, left). Least working parts are collection, transport and treatment of sanitary waste and institutional facilities. All these services are provided by the authorities. Moreover, greywater treatment and reuse of treated excreta turned out to be inexistent. Despite the poor provision of services, institutional arrangements were ranked to be functioning well. As argued by Kvarnström (2012b), a reason for that might be the high presence of stakeholders from institutions during that exercise.

During the community walk, the Thamaga Primary Hospital and a private house were visited. In 2002, an activated sludge treatment plant (see Tilley et al. 2008, pp.113–114) with a capacity of 45 m3/day has been installed to treat the wastewater from the hospital and the adjacent staff houses. At first sight, the treated wastewater did not seem to be of the desired quality. Monitoring was not practised by the responsible department (DBES), which does not to have the capacity to do the maintenance either. The effluent is then released into a woodlot, but harvesting is not practised. Moreover the infiltration rate seems to be exceeded. Water is spilling over through the fence to an adjacent field and where cattle is grazing and drinking it (Figure 4, right). The household visited disposed of an indoor WC connected to a septic tank and a VIP as a backup, a typical setup encountered in richer households[3]. All facilities seemed to be working.

While compiling a terms of requirement for sanitation systems in Thamaga, the participants were also asked to assign priorities to the different functions. However, most functions ended up being of highest priority. A solution to determine priorities more clearly the next time would be a pocket voting exercise (Dayal et al. 2002, pp.40–42), where each user is given a limited number of stickers to label criteria of first, second and third priority.

[3] Current sanitary conditions in Thamaga and Letlhakeng will be discussed extensively later on in Section 5.1.

Nonetheless, a certain prioritization can be made by paying special attention to criteria that were brought up by more than one group. The following functions were identified by more than one group and are therefore considered most important:

- Prevent groundwater pollution
- Reuse of water and nutrients
- Affordability
- Low maintenance
- Easy to use for all users
- Easy to clean and operate
- Compliant with legislation

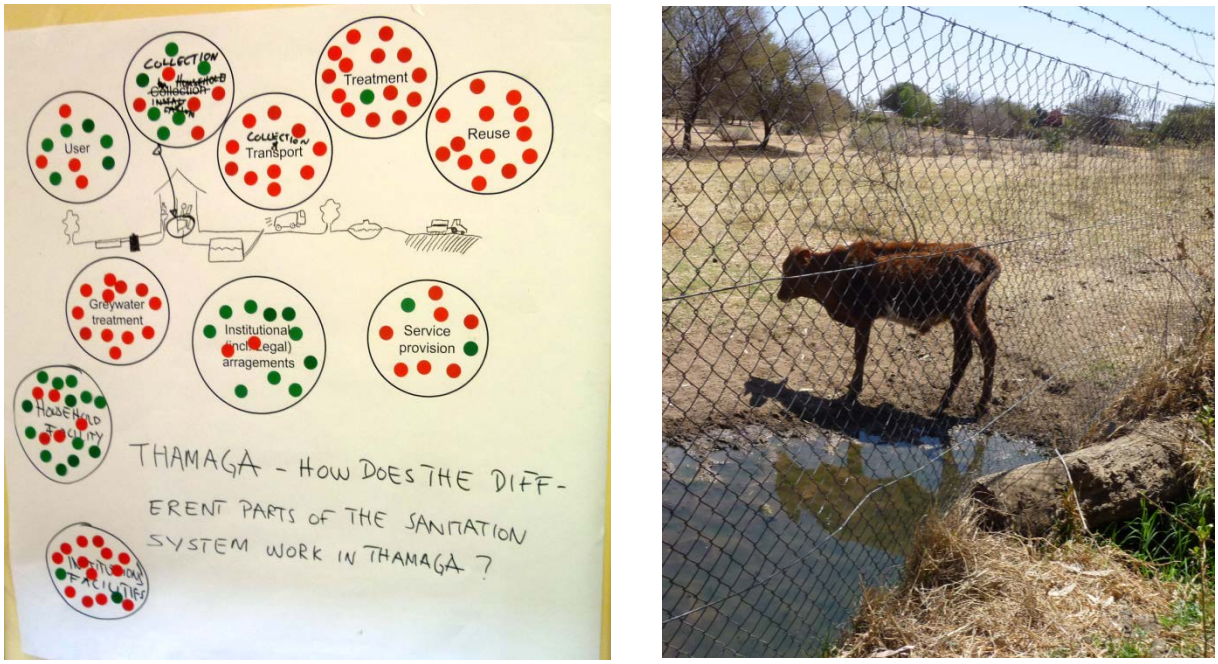


Figure 4. Group work (left) and the community walk (right: effluent at Thamaga Primary Hospital wastewater treatment works) showed that the parts of sanitation handled by institutions are facing most difficulties.

Based on the identified functional criteria, the following set of technologies was then evaluated in the second workshop:

- Solutions for institutions
  - Dry Urine Diversion with waterless urinals
  - Flush toilets with septic tank and irrigation

- Solutions for households
  - Adding urine diversion to existing pit
  - Fossa alterna with two alternating pits
  - Outdoor Urine Diverting Dry Toilet with two alternating pits
  - Gendarme toilet
  - Flush toilet with septic tank, sand filter and irrigation

- Greywater treatment options
  - "Simple" greywater reuse: tower garden
  - "Advanced" greywater reuse:
    - Mulch bed and direct use
    - Mulch bed and planted bed
    - Septic tank, soil filter, collection and reuse

The first three options for households were combined with "simple" greywater treatment, the last two options with "advanced" greywater treatment. In the case of questions being asked about centralized sewerage (a centralized sewer was not considered appropriate for the reasons stated in the introduction and therefore not suggested), the facilitators evaluated a centralized sewer system for comparison in the meantime.

Regarding solutions for institutions, the proposed dry urine diversion system clearly performed better than the flush toilet option (see Figure 5). The only criterion that was not considered as fulfilled was "culturally and socially acceptable". However socio-cultural acceptance is a key element of an enabling environment that needs to be fostered to provide favourable conditions for environmental sanitation planning (Lüthi, Morel, et al. 2011). The red sticker placed for this criterion should therefore under no circumstances be neglected. There is some uncertainty linked to this evaluation, as it was not clear whether all participants understood that these solutions were designed for institutions and not for households.

Regarding solutions for households, the picture obtained was less clear. Both flush toilets and the fossa alterna failed in six of the criteria, the outdoor UDDT failed in four of the criteria. Due to time constraints, the evaluation had to be stopped before all groups were finished. The options "adding urine diversion to existing pit" (2 red stickers) and "Gendarme toilet" (no red sticker) looked both very promising, but were stopped after half of the evaluation.

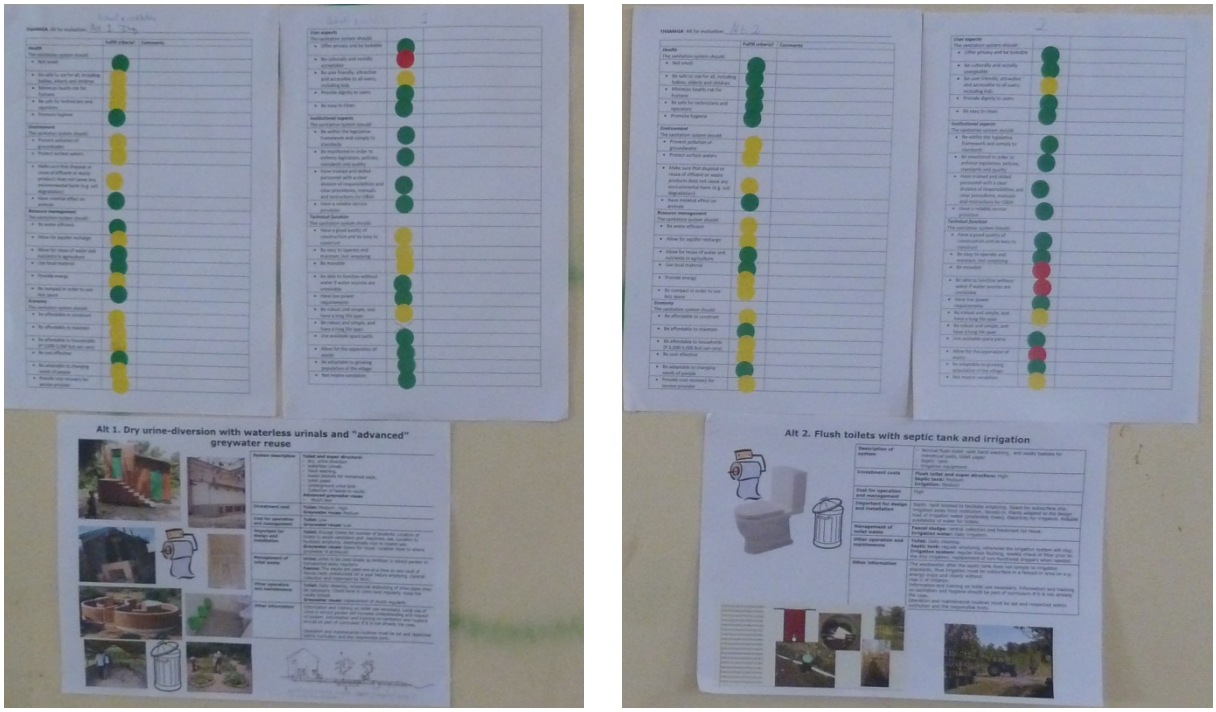


Figure 5. Evaluation of sanitation systems for institutions: Dry urine-diversion with waterless urinals (left); flush toilets with septic tank and irrigation (right).

4.1.2 Letlhakeng

For Letlhakeng, the community mapping showed that the South and North-West of the village are well covered with on-site sanitation. In a previous informal settlement encompassing the Eastern and Northern parts, many houses do not have access to sanitation and therefore practise open defecation. Furthermore, concerns were raised regarding groundwater pollution from improperly constructed pit latrines and regarding the long backlog of the emptying tankers resulting in many filled up pits. Solid waste collection seems to be working fairly well.

The assessment of the functioning of the different parts of the sanitation system showed slightly different results compared to Thamaga. Transport and greywater treatment were perceived in a better condition, but institutional arrangements and institutional facilities were considered malfunctioning by all participants. Again, users and household facilities were not perceived as problematic parts.

During two community walks, the workshop participants visited the Letlhakeng Clinic, a primary school and a Junior Secondary School (JSS). Flush toilets were installed in all three institutions which were found prone to severe maintenance problems. In the clinic, only two or three of the 11 flush toilets were working. In the primary school, none of the flush toilets were in working condition (see Figure 7) and decommissioned pit latrines were used instead. Toilets in the Junior Secondary School were in slightly better state, although there was no working electricity leaving users in total darkness once the toilet door is closed (supposing there is one). Unlike the other facilities visited, wastewater treatment here was not done in septic tanks but in a sequence of six wastewater stabilisation ponds (see Sasse 1998; Tilley et al. 2008, pp.99–100). It turned out that the ponds had not received any wastewater for a long time, although the pump is working (see Figure 6, top right). This leads to the assumption that the connecting pipes are leaking heavily.

Community walks confirmed the disastrous conditions reported in institutions (Figure 6). Contrary to private toilets, users do not feel responsible for institutional facilities and expect the government to take care of operation and maintenance. This could be seen in vandalized infrastructure (lamps hanging down, see Figure 6, top left), misuse of equipment (floating devices from toilets removed to play football; see Kvarnström 2012a) and poor maintenance (clogged toilets, leaking pipes; see Figure 6, bottom).

Figure 6. Maintenance problems at institutional facilities encountered during community walk. Top left: vandalized lamps at Letlhakeng Primary School. Top right: empty sewage ponds at Mphuthe JSS. Bottom: leakage caused formation of a large pool of water outside the toilet block.

Figure 7. Both in the Letlhakeng Clinic (left) and the Letlhakeng primary school (right), most of the flush toilets were in disastrous conditions.

While compiling a terms of requirement, the functions identified did not differ substantially from the one's determined for Thamaga (see section 4.1.1). However it could be noticed that people were more concerned about ground water contamination and the low affordability in Letlhakeng. Moreover, people seemed to be less reluctant to reuse of sanitized excreta for fertilization.

Based on the identified functional criteria, the following sets of technologies were then evaluated in the second workshop:

- Solutions for institutions
  - Dry Urine Diversion with waterless urinals
  - Flush toilet and package plant

- Solutions for households
  - Adding urine diversion to existing pit
  - Fossa alterna with two alternating pits
  - Outdoor Urine Diverting Dry Toilet with two alternating pits
  - Indoor Urine Diverting Dry Toilet
  - Gendarme toilet
  - Flush toilet with septic tank, sand filter and irrigation

- Greywater treatment options
  - "Simple" greywater reuse: tower garden
  - "Advanced" greywater reuse:
    - Mulch bed and direct use
    - Mulch bed and planted bed
    - Septic tank, soil filter, collection and reuse

Again, the first three options for households were combined with "simple" greywater treatment, the last three options with "advanced" greywater treatment.

As for Thamaga, the evaluation of solutions for institutions clearly favoured UDDTs over flush toilets (1 vs. 11 red stickers). Looking at the household level, participants clearly preferred simple outdoor solutions. With increasing complexity, the number of red stickers gradually increased from zero for adding urine diversion to existing pit up to eleven for the flush toilet. Adding urine diversion and fossa alterna were the only toilets considered affordable in the evaluation. With outdoor double vault UDDT and indoor toilets participants associated high costs and did not consider the criteria of affordability as fulfilled. Additionally, fossa alterna and flush toilets were considered problematic in terms of operation and maintenance and it was questioned if the Gendarme toilet would not cause groundwater pollution. This leads to the conclusion that costs and operation and maintenance are key factors that hinder the successful implementation of more complex systems in Letlhakeng.

4.2 School workshops

4.2.1 Ramaphatle Primary School, Thamaga

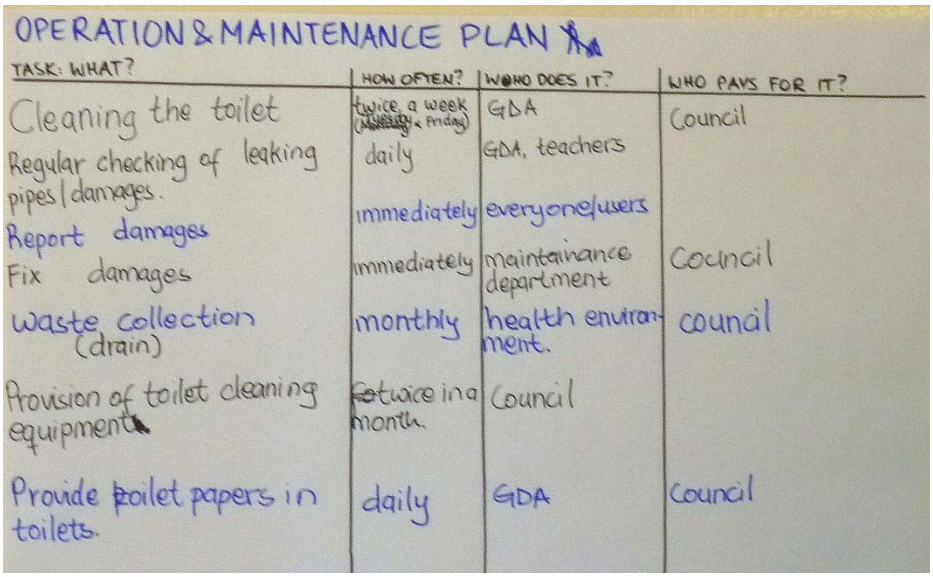
The school built in 2009 has two ablution blocks, but one of them is closed as the connecting pipe to the septic tank is not working properly. Looking at the number of students, this results in 9 students per toilet or 18 students per working toilet.

During the site walk, one tap in the boys toilet was running, which lead to a short discussion about saving of drinking water. The open ablution block was in a very clean condition. All toilets were working. Soap or toilet paper were not provided and waste bins for sanitary pads were also lacking in the girls toilets. The school garden was not really used because of termites destroying the plants and lacking means to buy insecticides.

Costs, groundwater contamination and operation and maintenance were the biggest concerns that were raised in the function deployment exercise. Participants emphasized the importance of providing equipment for basic hygienic needs, namely toilet paper, hand soap and dust bins. Participants also considered it important that toilets can be used by disabled people.

In both schools, participants saw a need for action from each stakeholder to overcome the current problems of vandalism. Students should mainly report vandals and encourage each other to keep the toilets clean. Teachers should educate the students about the proper use of the toilets and punish vandals. Parents should educate their children that school property should not be vandalized and support the schools policy (e.g. pay for damages caused by their children). It was suggested to also include the nightwatch in the monitoring of school facilities and to involve doctors or nurses in the education of the students.

In their operation and maintenance plans, participants defined cleaning, regular checking for leaking pipes, provision of toilet paper and desludging of the septic tank as the major tasks. An example of such a plan is given in Figure 8.



OPERATION & MAINTENANCE PLAN

TASK: WHAT?	HOW OFTEN?	WHO DOES IT?	WHO PAYS FOR IT?
Cleaning the toilet	twice a week (Tuesday & Friday)	GDA	Council
Regular checking of leaking pipes/damages.	daily	GDA, teachers	
Report damages	immediately	everyone/users	
Fix damages	immediately	maintainance department	Council
Waste collection (drain)	monthly	health environment.	council
Provision of toilet cleaning equipment	twice in a month.	Council	
Provide toilet papers in toilets.	daily	GDA	Council

Figure 8. Operation and maintenance plan developed in a group work.

4.2.2 Mphuthe Junior Secondary School, Letlhakeng

The school built in 2008 has three ablution blocks in use. Half of the toilets in each block are permanently locked to prevent vandalism. Looking at the number of students, this results in 23 students per toilet or 47 students per working toilet. Wastewater from the school and the staff houses is supposed to be collected and pumped to sewerage ponds next to the school. From there, the treated water would be reused in a school garden close the ponds.

The site walk revealed that there are some severe toilet maintenance problems. For instance, electricity in the toilets was not working. The toilets were therefore completely dark, once the doors were closed. Toilet paper, soap or dust bins were not provided either. In some toilets, the cistern flush was not working and watering cans were used to flush instead. Some toilets were lacking a door, several taps were not working. Others were working, but the water was not captured but just running onto the floor (see Figure 9, left). One toilet was completely clogged and not usable (Figure 9, right). Students reported that some of the maintenance problems had been there for a year already. The person responsible for maintenance stated that these problems just appeared 2-3 days ago. Another problem already discovered during the village workshops is that there is no water arriving at the sewerage ponds, although the pump is working. As there is no water arriving at the ponds, the reuse of the treated effluent in the school garden is not happening either. The school gardens have therefore been abandoned.

Figure 9. Maintenance issues in Mphuthe JSS toilets: water running from sinks straight onto the ground (left); clogged toilet (right).

Cleanliness, groundwater contamination and easy operation and maintenance were the biggest concerns raised in the function deployment. Again it was considered important that toilets allow for use by disabled people as well. In this workshop, participants did not only call for the provision of equipment for basic hygienic needs, but also came up with innovative solutions on how to raise funds for it. One idea was to sell excreta as a fertilizer and use the revenue to buy toilet paper.

In their operation and maintenance plans, participants also suggested many new tasks not being carried out yet, such as the daily monitoring of the facilities by students or the weekly provision of soap and toilet paper to every student.

4.3 Household surveys

This section will focus on the main qualitative findings from the survey. The full survey results can be found on the attached CD-ROM.

4.3.1 Household characteristics

Nearly all households visited were willing to respond unless no one was home. In Thamaga, 14 out of 16 interviewees were female whereas the survey in Letlhakeng was more or less gender balanced (J03[4]). On average, one household comprised five adults and three children below age sixteen (B03). The total household size in Letlhakeng was nearly two persons smaller than in Thamaga. However, given the large variation within the sample, the difference is not statistically significant.

4.3.2 Agriculture

Regarding agricultural and gardening practices, the survey revealed the following points:

- Less than half of the households visited grow fruit or vegetables (B05a). This is not due to water scarcity but rather due to the lack of proper fencing (poultry would destroy the plants) and the lack of time (B05b).
- For those who do gardening, crop manure is the commonly used fertilizer (C06).
- 9 of the 10 visited gardeners irrigate their plants (C02), mainly with fresh water from the tap (C03).
- About half of the households approve the use of greywater for gardening (C04). Households do not seem to have too many concerns about their neighbours when it comes to reuse of greywater. In Thamaga, a minority of households would also approve the reuse of blackwater and sewage sludge. In Letlhakeng, blackwater and sewage sludge applications did not get any approval by the visited households (C05/C07).

4.3.3 Access and use of toilet facilities

In both villages, 10 out of 16 households were not connected to electricity (D01). Greywater reuse from kitchen and laundry is not common. 15 out of 32 households do not reuse any of their greywater (D05). It is mostly disposed in the backyard or toilets (D05).

The majority disposed of an outdoor standpipe as their source of water (D03). For Thamaga, the results are well in line with the 2001 census data (see Figure 10). In Letlhakeng however, the results from the survey are substantially different from the last census data. Most of the households visited during the survey disposed of an outdoor standpipe on the plot whereas the census stated public standpipes as the most common source of water. This is in line with Loci (2012) reporting that plot connections in Letlhakeng have more than doubled over the past decade. However, progress in connecting households was similar in Thamaga where the survey results were well in line with the 2001 census data. A possible explanation for these differences could be that the survey samples were not representative enough.

[4] Survey results are referred to the corresponding queries in the questionnaire.

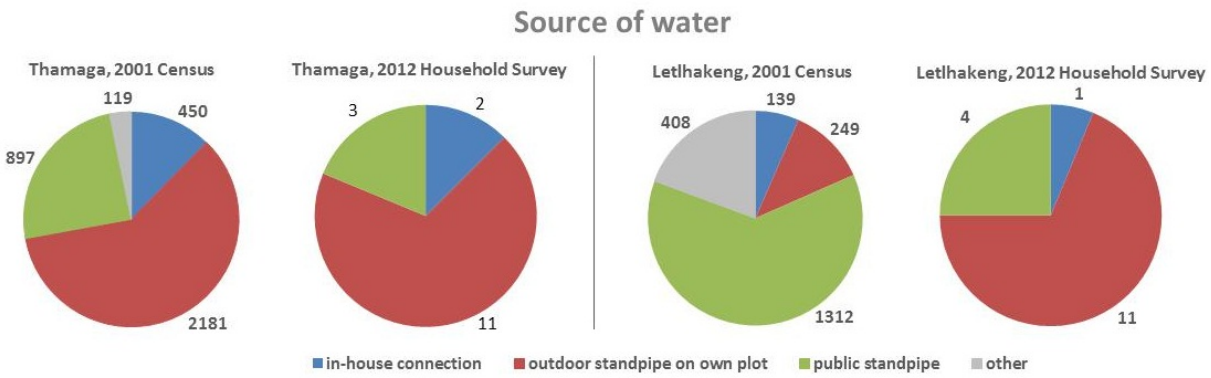


Figure 10. Source of water for households in Thamaga and Letlhakeng. Comparison of survey results to 2001 census data.

Most of the visited households dispose of a private toilet (D06; see Figure 11, left). Considering the progress that has been made over the past years, these findings are well in line with the 2001 census data (see also Section 5.1, Table 3 & Table 4). As typical for rural areas (Unicef & WHO 2012), the share of households without private toilets seems to be higher in Letlhakeng (5 out of 16) than in Thamaga (1 out of 16). Only three households we visited had a septic tank. All 3 septic tank users disposed of a pit or VIP as a backup in case of water shortages. The rest used VIPs or conventional pit latrines. Households without septic tanks did not dispose of a second pit/VIP. Looking at defecation practices (Figure 11, right) two households in Letlhakeng stated practising open defecation, none in Thamaga (D12). Open defecators were only found in the eastern wards of Letlhakeng. This is well in line with the results from community mapping, showing that there are many plots in this area without toilets (see also Figure 23).

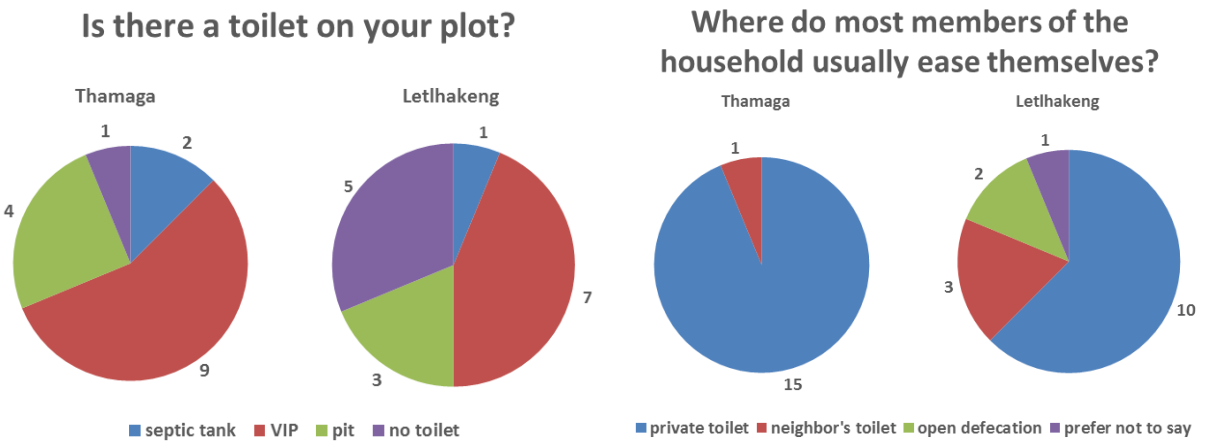


Figure 11. Access to sanitation facilities (left) and defecation practices (right) in Thamaga and Letlhakeng.

4.3.4 Management capacity

Limited management capacity was found to be a serious problem hindering the successful operation of pit latrines:

- Complaints were raised about the long waiting times (E05).
- Most of the toilets and septic tanks visited had never been emptied (E02).
- Only three households had their tanks/pits ever emptied (two in Thamaga, one in Letlhakeng).
- These three facilities were all emptied by the council (E03).

The reported filling states give no indication on whether emptying is working better or worse in one village (E01).

4.3.5 Satisfaction with current toilet facility

The following findings were obtained regarding satisfaction of toilet users with their current facilities:

- Satisfaction was slightly higher in Thamaga than in Letlhakeng (F01), but still being within the 95% confidence interval and therefore not statistically significant.
- Among households with flush toilets satisfaction was highest, all users being very satisfied. Looking at the different facilities people were using, satisfaction followed the expected orders: “private > shared > no toilet” and “flush > VIP > pit” (F01).
- When asked about disadvantages of their toilets, many pit users mentioned problems with the construction (no proper door, no proper seat, no pipe, hole too small, standards that are not met; F03), a problem often encountered when the construction is paid fully by the household (Evans et al. 2009). In Thamaga, one could also see many NRSP funded VIPs with broken vents. It seems that there was a fault in the material used.

4.3.6 Sanitation costs

Regarding costs, the survey revealed the following facts:

- Construction and maintenance is usually paid by the household or the landlord. Only two households in Letlhakeng received money from the government or through a project (G01).
- Lack of financial means was reported as the main reason why households do not dispose of a private toilet (G05).
- Less than half of the households said they were willing to pay for connection or use of a sewer network. 10 households did not know or were not able to answer this question (G04).

4.3.7 Sanitation service requirements

Households that were not happy with their sanitary situation or did not dispose of a private toilet were asked how important different properties of a toilet are for them. In both villages, aspects of privacy and hygiene were ranked most important (see Figure 12). In Thamaga, people considered it least important that the toilet was inexpensive, regardless of their limited ability to pay for it. In Letlhakeng, gender separation was the least important property.

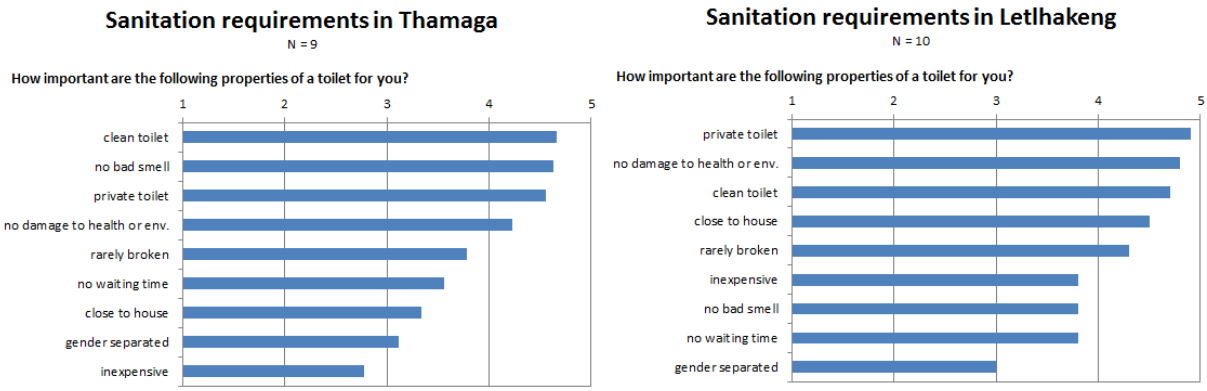


Figure 12. Sanitation service requirements of unsatisfied users in Thamaga (left) and Letlhakeng (right). Arithmetic means, ordered by decreasing importance of the criteria from 5 (very important) to 1 (very unimportant).

4.4 Stakeholder interviews

4.4.1 Relevance of collected information

After each interview, the interest, influence, impact and support of the interviewed stakeholder was assessed in a table, based on the methodology suggested by Elliott (2001). Table 1 shows the averaged values obtained for each stakeholder group. It is questionable how meaningful these values are, as the assessment is potentially biased depending on which person was interviewed within the organisation. Nevertheless the table reveals some general patterns. It can be seen that public authorities are highly supportive and influential, but their interest could be higher. Especially DBES did not seem to have a high interest, as no one there could be interviewed. Looking at the values for wastewater service providers, it has to be distinguished between public and private service providers. All interviewees at WUC, the public service provider, showed high interest and support. Private operators did not see very promising opportunities for them. However, their impact was assessed rather high, given that WUC has the intention to outsource the emptying services to private operators. If private operators are then suddenly refusing to service pit latrines (both interviewed private operators stated high dissatisfaction with provision of this service) this would have a tremendous impact on the local sanitary conditions. The interviewed technology providers were very interested in promoting their solutions. Summing up all four fields, public authorities achieved the highest total relevance. Especially the Department of Water Affairs and the Department of Waste Management and Pollution Control (DWMPC) were assessed highly important in all categories.

Table 1. Levels of interest, influence, impact and support of the different stakeholder groups. After each interview, interest, influence, impact and support were assessed on a scale of 1 to 4: 1=none; 2=minimal; 3=average; 4=significant. For each stakeholder group the arithmetic mean was calculated from the different interviews conducted. Total indicates the sum of the four categories. (Methodology adapted from Elliott 2001)

Stakeholder group	Interest	Influence	Impact	Support	Total
Public authorities[a]	2.83	3.50	3.17	3.83	**13.33**
Academic institutions	3.00	2.50	2.00	3.00	**10.50**
NGO	2.00	2.00	1.00	3.00	**8.00**
Public service provider (WUC)	3.33	2.33	2.33	4.00	**12.00**
Private service providers	1.67	2.00	3.33	2.33	**9.33**
Sanitation technology providers	4.00	1.33	2.67	3.67	**11.67**
Farming sector	3.50	3.00	3.00	3.50	**13.00**

[a] excluding Department of Building and Engineering Services (no interviews conducted)

4.4.2 STEEPLED Analysis

Table 2 lists the relevant factors obtained in the STEEPLED analysis, based on the methodology used by Gendre (2012) and Larsen et al. (2010). The table gives an overview over the reported state and implications for technology selection. The full analysis of all factors is given in the Appendix (Section 8.2.3). Overall, 10 out of the 43 analysed factors were mentioned by half or more of the interviewees and therefore considered relevant.

Social aspects showed to be highly relevant. Interviewees mentioned a lack of awareness about water scarcity in the population. They highlighted the importance of information and education programmes as a key step to induce behaviour change. Any improved technology needs to be accompanied by vigorous awareness campaigns and programs in order to be implemented successfully (P. Odirile*). It was also stated that in Botswana, education needs a lot more effort than in industrialised countries (S. Ortwein*).

Looking at technological aspects, the analysis showed that operation and maintenance is often not done as designated. Reasons identified were a "lack of ownership by users" (B. Mathangwane*), people only calling the emptying service when their pit is already full (J. Banyatsang*), poorly maintained emptying vehicles (P. Gaamangwe*) and limited capacities of the public service provider (B. Bolaane*). Maintenance of future sanitation systems should therefore be low (S. Ortwein*) and easy (A. Kgomotso*), which means to design constructions as simple as possible, but still being progressive (C. Simon*; R. Velimir*). If the system is not serviced locally it is likely to fail due to lack of ownership, as shown in the Thamaga hospital treatment plant (T. Matladi*) and a project in Madiba School in Mahalapye (K. Mukokomani*). Another frequently mentioned problem was water availability. Water interruptions are mostly faced in areas depending on well fields such as Thamaga or Letlhakeng (B. Bolaane*). In these villages, water shortages are particularly encountered in more elevated areas where water pressure is lower (A. Kgomotso*).

A lot of interviewees highlighted the importance of economic aspects. Costs for construction, operation and maintenance were considered as important decision factors (S. Ortwein*; C. Simon*). However, this only applies if people are charged on a cost recovery basis. This conflicts with the traditional governmental policy to subsidize sanitation infrastructure

(C. Simon*) and people's expectation that this will continue to be the case (J. Banyatsang*). Recognizing that there are not enough means to provide everyone in Botswana with fully subsidized sewer networks, the government made efforts to establish cost recovery in waterborne sanitation (Bolaane & Ikgopoleng 2011a). However the country is still far from full cost recovery. At the moment, both the connection to sewerage and the emptying of pit latrines and septic tanks are still heavily subsidized. Given the rural poverty in the examined villages and the tradition of subsidizing sanitation, interviewees argued that ability or willingness to pay for sanitation might be very low.

A large number of interviewees recognized that there is still unused potential for reuse of water and nutrients from wastewater. There was no consensus whether the reuse should be organized centralized (K. Gaseitsiwe*) or on-site (S. Mabua*). Problems of water scarcity, one of the main reasons why this project had been set up, were highlighted as a general problem in Botswana (B. Kealotswe*; S. Ortwein*[5]). Suggestions to work on the water consumption side were much rarer than comments on re-use of wastewater. However, the government is currently evaluating the introduction of a water conservation fund which could be helpful to incentivize water-saving installations (B. Mathangwane*). The risk of groundwater pollution was not perceived that importantly and got only mentioned four times.

Many interviewees were concerned about the management capacity of public institutions. The current restructuring of the water sector is often used as an explanation for dissatisfactory service provision. A lack of efficiency (C. Simon*) and ownership (A. Kgomotso*), difficulties with the knowledge transfer (A. Kgomotso*) and personnel not fully qualified for their new position (B. Mathangwane*) are some of the issues that originated from the water sector reforms.

None of the analysed legal aspects was considered highly relevant. It is not very surprising that corruption only got mentioned twice as Botswana has been ranked the least corrupt African country for several years in a row (Transparency International 2012). However legal accountability and compliance with existing regulations still received considerable attention (8 mentions). People stated that the water restrictions government puts in place during extremely dry periods were barely enforced and therefore did not have a significant effect on people's behaviour (S. Mabua*). As water scarcity is a continuous problem in Botswana, many interviewees suggested to keep the restrictions in place all year around and not only during severe drought events.

No ethical or demographic aspects were considered highly relevant. Still, eight interviewees mentioned the issue of cultural acceptability, particularly with water-less toilets (T. Matladi*; B. Mathangwane*) or the handling and reuse of urine and faeces (J. Banyatsang*; Mma Kgarubane*). The low relevance of demographic aspects might be due to the very low population density in the studied villages.

[5] References indicated with * are based on information gained in the interviews; a complete list of interviewees is provided in Section 8.2.2.

Table 2. Main state of relevant STEEPLED factors and implications for technology selection.

Relevant STEEPLED Factors [a]	Total [b]	Main State of Factors	Implications for Technology Selection
Social aspects			
Behavioural change	10	Low public awareness of water scarcity and the importance of sanitation topics for public health and prosperity	Induce behaviour change through information and education programs
Information and education programs	15	Education and information is crucial and needs more effort than in industrialized countries	Accompany technology implementation with extensive information and education effort
Technological aspects			
Water availability	11	Most houses have standpipe yard connections Parts of the village face regular water service interruptions	Use only technologies that remain functioning during water service interruptions
Operation and maintenance	13	Often not done as designated	Preference for low maintenance technologies
Economic aspects			
Capital and O&M costs	11	Misperception of costs due to heavily subsidized sewer networks and emptying of pits and septic tanks People expect government to subsidize sanitation	System costs must be competitive (either through removal of subsidies for conventional systems, introduction of subsidies for the proposed system or substantial additional benefits that justify higher costs)
Willingness / capacity to pay	10	Low due to high unemployment and tradition of subsidizing sanitation systems	Choose only technologies with low costs or enhance willingness to pay e.g. through income generation from reuse of wastewater and nutrients
Ecological aspects			
Water scarcity	14	Water resources are scarce, accentuated by climate change	Use only water-saving technologies
Potential for reuse of water	14	Potential is not used yet	Establish solutions that allow for the reuse of greywater
Potential for reuse of nutrients	11	Potential is not used yet	Establish solutions that allow for the reuse of nutrients from wastewater (in a culturally acceptable way)
Political aspects			
Management capacity of public institutions	11	Water Sector reforms result in currently dissatisfactory service provision (lack of efficiency, ownership and qualified personnel)	Consider outsourcing of system management to private operators and avoid management-intensive solutions

[a] All legal, ethical and demographic STEEPLED factors got less than ten mentions and were therefore not considered relevant.
[b] Total indicates the number of interviewees making a statement about the STEEPLED factor. A total of 20 interviews were analysed.

5 Discussion

5.1 Current sanitation conditions

5.1.1 Thamaga

The results from the investigations made in Thamaga are well in line with the findings from previous studies undertaken in Thamaga. Focus Group Discussions conducted in Thamaga for the development of the National Master Plan for Wastewater and Sanitation Plan already reported problems with the desludging of septic tanks and pit latrines and contamination of groundwater caused by pit latrines (GoB 2003, vol. 8, appendix 3). The observation that flush toilets are more common in Thamaga than in Letlhakeng is supported by the Botswana Integrated Water Resource Management (IWRM) Water Efficiency (WE) Plan (Centre for Applied Research 2012, p.76):

"Pit latrines are the dominant type of sanitation for income levels up to BWP5000/month and flush toilets are most common for higher incomes. The trends are similar in urban and rural areas, but flush toilets are more common in urban areas due to the higher income level."

The household survey showed that most households have access to private sanitation. This is supported by the community mapping exercise carried out during the village workshops, where only recently developed plots at the outskirts of the village were reported to be without sanitation. A comparison of the results from the household survey to the data from the 2001 census (taken from Loci 2012) indicates that the access to private sanitation has substantially increased (see Table 3). Whereas in the census conducted 10 years ago, conventional pit latrines were the dominant type of private sanitation, VIPs seem to be more common than conventional pits these days. This might be a reason for only little complaints in the household survey and previous enquiries (GoB 2003, vol.8, appendix 5) in Thamaga about the smell compared to earlier investigations in other villages in Botswana (GoB 2003, vol. 1, p. 27; Bolaane & Ikgopoleng 2011b). Bolaane and Ikgopoleng (2011b) indirectly support this argument by also explaining the numerous complaints regarding smell with the high ratio of simple pits to VIPs.

Table 3. Access to sanitation in Thamaga. Comparison of survey results to 2001 census data.

Toilet Facilities	2001 Census		2012 Household Survey	
	Households	%	Households	%
Flush (own)	267	7.3	2	12.5
VIP (own)	649	17.8	9	56.3
Pit latrine (own)	1756	48.1	4	25.0
Enviro-loo (own)	2	0.1	0	0.0
Neighbour's toilet	393	10.8	1	6.2
Communal toilet	387	10.6	0	0.0
None	192	5.3	0	0.0
Unknown	1	0.0	0	0.0
Total	**3647**	**100.0**	**16**	**100.0**

According to GoB (2003), most of the existing pit latrines were constructed in the 1990ies, either under own initiative or with government assistance from the National Rural Sanitation Programme (NRSP). The NRSP is the most recent in a series of governmental sanitation programmes in Botswana erecting 18695 pit latrine substructures preventing from groundwater pollution (Bolaane unknown). The aim was to provide a safe substructure, which households would then complement with a superstructure at their own expense. Own observations showed that still many of the pit latrines in the village resemble to those provided by the NRSP and one of the interviewed households stated that they received funding through the NRSP. Bolaane's (unknown) research agrees with our observations that not all users were able to finish the superstructure.

Regarding institutional facilities, both interviewees and participants in the household survey assigned highest priority to improving the situation at the hospital treatment plant. The only on-site wastewater treatment plant in either of the project villages is lacking proper maintenance and effluent monitoring. High costs and sludge quantities were additional issues mentioned in the village workshop. However it has to be stated that the absence of proper effluent monitoring has been identified as a problem in Botswana (GoB 2003; Centre for Applied Research 2012) and developing countries in general (Massoud et al. 2009) before and is not a particular problem of Thamaga.

Sanitation infrastructure in Thamaga's schools has been investigated by Loci (2012). The results show great variety, ranging from 13 students per toilet in Letlole JSS up to 57 students per toilet in Western Primary School. According to the minimum requirements set by the Botswana Building Control Regulations (reg. 68, 69(1)) which are similar to the WHO standards for schools in low cost settings (WHO 2009) one toilet should accommodate not more than 25 students. Looking at the situation in Thamaga, two schools are complying, four schools do not have enough toilets and four schools did not provide data. The Thamaga average is a number of 34 students per toilet, which is still below the Botswana average of 40 students per toilet (SACMEQ 2011). As also observed in other middle-income countries, one can expect the number of working toilets to be significantly lower, as particularly flush toilets are prone to clogging and water shortage or might be locked to prevent vandalism (Chatterley 2011).

5.1.2 Letlhakeng

Opposite to Thamaga, where most of the households do have access to private facilities, there is still a considerable amount of the population in Letlhakeng practising open defecation or depending on the neighbour's facility (see Table 4). This is well in line with the fact that sanitation access is better in urban than in rural areas (Unicef & WHO 2012). There is no specific census data about access to sanitation available for Letlhakeng; therefore the results from the survey can only be compared to the whole Kweneng West area (Table 4). Letlhakeng is the centre of the Kweneng West area and accounts for about two thirds of the population. Loci (2012) suggest one can expect sanitation access to be slightly better in Letlhakeng, which agrees with the findings from the household survey.

Table 4. Access to sanitation in Letlhakeng. Comparison of survey results to 2001 census data. Observe that the census data is for Kweneng West Area and not for Letlhakeng only.

Toilet Facilities	2001 Census [a]	2012 Household Survey	
	%	Households	%
Flush (own)	10.1	1	6.2
VIP (own)	14.1	6	37.5
Pit latrine (own)	7.8	3	18.8
Enviro-loo (own)	0.1	0	0.0
Neighbour's toilet	8.4	3	18.8
Communal toilet	5.6	0	0.0
None	53.1	2	12.5
Unknown	0.0	1	6.2
Total	**100.0**	**16**	**100.0**

[a] There is no specific data for Letlhakeng available. Shares for Kweneng West area taken instead.

A map prepared for the Letlhakeng Development Plan in 2005 (attached in the Appendix, Figure 23) underpins the finding from community mapping and the household survey that most of the plots without toilet facilities are situated on the outskirts of the village. Particularly in the Eastern and North-Eastern end where previous informal settlements are situated, plots often do not have sanitary facilities and open defecation is commonly practised.

It is hard to do an objective description of the conditions encountered in Letlhakeng's institutional facilities. At the clinic, only a small fraction of the flush toilets was functional, even in an extension building completed in 2009. Wastewater is fed into an overflowing septic tank which has potentially caused the shutdown of a nearby water supply borehole due to contamination (Loci 2012). At Letlhakeng Primary School, only eight pit latrines are working for the total of 948 students. This results in nearly 120 students per usable toilet, nearly five times more than the acceptable maximum of 25 students per toilet suggested by WHO (2009) and three times more than the Botswana average. At Mphuthe JSS, the number of working toilets is higher, but the wastewater pipes are leaking so heavily that no water is reaching the sewerage ponds. Considering the fact that this school has the highest water consumption of all the schools in Thamaga and Letlhakeng (978,000 litres per month; see data obtained by Loci 2012), the leaking infrastructure poses a substantial risk for groundwater contamination, although being built less than five years ago!

5.2 Current sanitation challenges

A recent progress report on drinking water and sanitation states that sanitation coverage in Botswana has improved above Sub-Sahara African average (Unicef & WHO 2012). Other sources state that the Millennium Development Goal target on access to improved sanitation for 2015 has already been achieved (UNDP 2010). Despite the progress made in the past, the obtained information suggests that sanitation in the study area is still facing a number of challenges that cannot be solved by sole provision of infrastructure. Summarizing the results, problems reported mainly refer to one of the following five categories:

- **Lack of awareness for water scarcity.** Botswana is situated in an arid climate zone with low and erratic rainfalls. Growing water demand through economic development and climate change are adding to the already pressing issue of water being a scarce resource (Ölund Wingqvist & Dahlberg 2008). As long as water scarcity is not evident ("the tap is still running"), people are not aware that it is likely to have negative impacts on their future development. Instead, the current thinking of many is that it is possible to solve all the problems through engineering (e.g. trough construction of new dams, deeper boreholes etc.; see Swatuk & Rahm 2004).

- **Lack of collaboration and coordination between institutions.** Inter-agency disagreements about responsibilities are a typical institutional problem in developing countries (WHO 2000). The quality and efficiency of sanitation service provision in developing countries can be substantially increased by intensifying collaboration and coordination between institutions (Schouten 2010). The current reforms of the water sector in Botswana are supposed to allocate clear and rational responsibilities. However, they resulted in a temporary loss of knowledge, ownership and qualified personnel. Moreover, there are now three different entities providing services: WUC to households, the Council to primary schools and DBES to other public institutions (hospitals, police station, secondary schools). In our case, one way to improve collaboration would be giving WUC a mandate to service all institutional facilities (see Figure 13). Sharing of equipment has also been a suggestion made by Loci in their baseline study for the project (Loci 2012, p.84).

- **Lack of private initiatives.** In Botswana, more than 40% of the working population is employed in the public sector (CSO 2011a; Hammouya 1999). Service mentality is a barely encountered quality; the main motivation to work is to receive a payment at the end of the month. As this payment arrives regardless of the public servant's performance, there is no evident need to deliver an extraordinary service. People are used to getting directives top-down and everything being approved by the director. Instead of finding their own ways to solve problems on a local level, people expect the centralized government or their supervisor to take care of it. This is not a very enabling environment for private initiatives which could possibly bypass dissatisfactory public service provision.

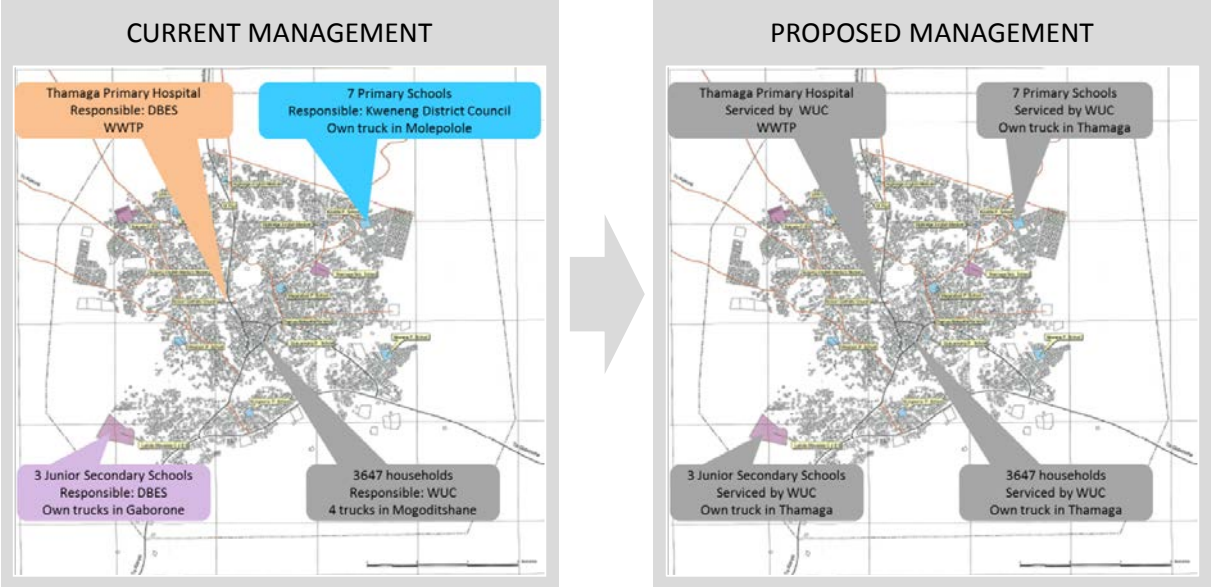


Figure 13. Lack of collaboration between institutions. Current situation (left): After the water sector reforms, three different entities are providing sanitation services in Thamaga. Suggested paradigm shift (right): If all emptying services were done by the same operator, the cumulated demand would allow for allocating one truck fully to Thamaga, thereby enhancing not only efficiency but also the level of service provision.
(Figure adapted to local situation from a presentation by Schouten 2010, maps from Thamaga Development Plan)

- **Lack of long-term commitment with financial and human resources.** Previous attempts to improve sanitary conditions in Botswana often failed due to a lack or loss of ownership during the process. An evaluation of a UDDT project in Paje after six years (SuSanA 2012) revealed that 40% of the constructed toilets had been abandoned. One of the reasons why toilets were abandoned was that the responsible person left the household. Also at institutional level, loss of ownership and knowledge is a common problem in Botswana, where national prevalence of HIV is a high 17.8% (UNDP 2010) and a handover of duties is usually not taking place. B. Bolaane* reported from a school project where the ownership is completely lost after several changes of the headmaster. Similarly, financial continuity can be a problem, when positions get forgotten or cancelled in the following year's budget (S. Ortwein*).

- **High dependence on imported goods and services.** Botswana imports a large part of their goods from neighbouring South Africa (including electricity, water and sanitation technology). This results in delays for repair of sanitation equipment, thereby causing service interruptions and delays in emptying service provision, as also experienced in similar context (Muller & Rijnsburger 1994).

All the above mentioned points result in serious operation and maintenance problems. The challenges observed in Thamaga and Letlhakeng are less due to inexistent infrastructure, but rather inexistent or malfunctioning maintenance procedures. Users are often not aware that every sanitation system requires regular maintenance to remain operative. Some users said in the household survey that they would even rather construct a new toilet instead of having the old one emptied. Those calling the emptying service do so only once their pit is completely filled up. Hence people get very impatient when it takes the council several weeks or months to empty the pits.

5.3 Requirements for improved sanitation systems

Based on the previously identified current conditions and challenges, improved sanitation systems have to fulfil a number of requirements in order to successfully match with the local conditions of Thamaga and Letlhakeng. In analogy to the findings from the stakeholder interviews, the requirements can be grouped into the different STEEPLED aspects:

- **Social requirements**

  Low population density and the fact that most of the households already dispose of a private toilet suggest that toilets should be **private**. Shared or communal toilets are unlikely to be of sustainable success.

  Furthermore, **project ownership** has to be created to keep operation and maintenance routines going and both to achieve and maintain a change in behaviour (Baye et al. 2012). This means that people have to understand the benefits of the proposed solutions. For awareness-raising purposes, it is essential to demonstrate the chosen technologies, to inform and to educate users.

- **Technical requirements**

  As seen in section 5.2, operation and maintenance have proved to be the bottleneck in Botswana's sanitation infrastructure. To reduce maintenance requirements, a system should therefore be of **low technical complexity**. Even simple technologies require regular maintenance and parts might need to be replaced after some time. Spare parts and appropriate maintenance skills must then be obtained without difficulty to avoid people putting the system out of operation (Thye et al. 2011). This can be achieved by selecting **locally producible and locally serviceable technology**.

- **Economic requirements**

  Given the rural poverty in the examined villages and the tradition of subsidizing sanitation, interviewees argued that ability or willingness to pay for sanitation will be very low. This contrasts with previous research undertaken (Bolaane & Ikgopoleng 2011b; GoB 2003, vol. 8). However, costs of an improved sanitation system have to be **(financially) competitive** with (subsidized) conventional solutions. This can be achieved through low-cost equipment or subsidies. But a far more sustainable way would be to enhance willingness and ability to pay. Box 3 discusses in more detail how this can be achieved.

- **Ecological requirements.**

  Scarcity of water resources and water interruptions claim for **water-saving** systems that are capable to remain operative for a certain period of time without water supply. Groundwater serves as a precious resource for drinking, both for cattle and human beings (Rahm et al. 2006). It is mainly therefore and not only to be compliant to legislation that future systems **should not pose a risk to groundwater pollution**. Especially in Thamaga, where the groundwater table is high, pit latrines or septic tanks that are not properly lined can cause contamination of aquifers resulting in shutdown

boreholes, as happened in the village of Ramotswa, 50 km South-East of Thamaga (Bolaane & Ikgopoleng 2011b).

An improved system should also include the reuse of nutrients and water. Looking at the National Policy (GoB 2003, vol. 7) and given the low acceptance of reuse for domestic purposes (Hambira et al. 2011), **reuse of effluent for agricultural purposes** seems to be the most appropriate option.

- **Political requirements**

  A considerable part of the sanitation problems encountered in Thamaga and Letlhakeng are related to the emptying of pit latrines and septic tanks. Hence to improve sanitation it is important to **provide an efficient, customer-oriented emptying service**. Despite being uncommon in Botswana at the moment, C. Simon* argued that outsourcing service provision to private companies might be more cost-effective. However, empirical evidence derived from a study by Castro (2010) does not support the claims that private sector participation can provide the solution to protracted public sector failures, especially in developing countries. Considering that also political acceptance for outsourcing (which implies a harsh tariff increase by ca. 600% due to sudden implementation of cost recovery and a loss of jobs) would be difficult to obtain, the option to outsource services is more than questionable. With the ongoing water sector reforms, responsibility for emptying service provision has been transferred from the district council to the parastatal Water Utilities Corporation. Experience from similar reforms in other developing countries has been positive (Schwartz 2008) and is therefore considered a better way to go than outsourcing to private sector operators.

- **Ethical requirements**

  Cultural acceptability of handling urine and faeces varies between cultures (Drangert 1998). Investigations in Thamaga showed that especially white-collar workers object to dealing with urine and faeces (A. Kgomotso*). Unless the waste is decomposed to a soil-like product that poses no longer offence to on-site handling by the households, it is therefore preferred to **appoint a service provider for conveyance and off-site treatment of excreta**.

Box 3. How to make people pay – strategies on how to establish competitive systems

Literature lists willingness to pay, ability to pay and willingness to charge as the economic factors that need to be considered when looking at future sanitation systems (Kvarnström & af Petersens 2004; Tayler 2007; Lüthi, Panesar, et al. 2011). Tradition of subsidizing sanitary infrastructure, high rates of unemployment and unsatisfactory service provision result in all three factors being low at the moment. But for long-term success of a sanitation system, users need to pay and be charged on a cost recovery basis (Lennartsson et al. 2009). Table 5 below proposes some strategies on how to achieve that.

Table 5. Actions suggested to create an enabling environment for new sanitation systems and corresponding literature references.

Action Suggested	Source (Literature)
Enhance willingness to pay	
Include users in planning process	Muellegger 2011
Offer a choice of different options based on user's preferences	Muellegger 2011
Offer a service guarantee to users	Wirtz 1998
Educate users about health effects of poor sanitation	Van Minh et al. 2012
Delegate operation and maintenance responsibility to (private) service provider	Muchiri et al. 2010
Generate income from excreta	Sijbesma 2011
Allow for payment in instalments	GoB 2003, vol. 8
Enhance ability to pay	
Use of free labour	Sijbesma 2011
Payment in instalments	Sijbesma 2011
Microcredits	Saywell 1999
Loans	Sijbesma 2011
Enhance willingness to charge	
Cost recovery as a condition for financial support from international donors	Evans et al. 2010
Shift from demand-oriented to supply oriented water policy	Swatuk & Rahm 2004
Establishing a community-managed social fund	Evans et al. 2009
Provide incentives for financially unattractive technologies like rainwater harvesting by establishing a Water Conservation Fund	Centre for Applied Research 2012
Cross subsidies from richer to poorer households, e.g. subsidizing pit emptying through surcharge on septic tank emptying	Evans et al. 2009
Cross subsidies from water bill to finance sanitation: add a sanitation levy on all water bills	Evans et al. 2009

5.4 Sanitation systems for households matching the local context

Needs, expectations and financial power differ among individual households. Therefore it is strongly recommended to always offer a various systems to users to give them a choice and to enhance their ownership (Muellegger 2011; Baye et al. 2012). Based on the determined conditions, challenges and requirements, various systems have been proposed, discussed within the Sweden project team and evaluated in the second village workshop (see Section 4.1). Finally, three systems which received mainly positive feedback in the evaluation and are targeting different groups of the population were proposed as a main result of this thesis. An overview of these systems is given in Table 6 below. Afterwards, system templates and a detailed discussion of each system are provided in Sections 5.4.1-5.4.3.

Table 6. Key facts and figures of the proposed sanitation systems for households.

	Basic dry system	Advanced dry system	Advanced wet system
Description	Single vault pit latrine	Fossa alterna (two pits used alternatingly)	Gendarme toilet connected to anaerobic filter
Greywater treatment	Basic system: tower garden	Basic system: tower garden	Advanced system: mulch filter
Faecal sludge emptier	Service provider	Household	Service provider
Target group	Low-income households with existing pit latrine infrastructure	Households without working pit latrine, interested in nutrient reuse and/or concerned about groundwater pollution	Households with higher income aiming for a wet system
Construction costs [a]	BWP 8,700	BWP 14,200	BWP 13,440
Costs in multiples of the poverty datum line [b]	9.9	16.2	15.3
Strengths	Locally proven sanitation technology Household is released from handling of excreta Easy upgrade from current pit latrine systems possible	Recovery of nutrients from faecal sludge Minimal risk of groundwater contamination No expenses for emptying	Locally produced system Household is released from handling of excreta Wet system independent from constant water supply Increased level of comfort through flush
Weaknesses	Regular expenses for emptying of pit Only greywater reuse Inappropriate use may cause groundwater pollution	Higher costs for construction (2 pits instead of 1) Household is responsible for emptying Inappropriate use may ruin compost	High costs for construction and regular expenses for desludging tanks No reuse of nutrients
Suitability for Thamaga	***	**	***
Suitability for Letlhakeng	***	***	**

[a] incl. 12% VAT, price of Gendarme system see www.gendarme-systems.com, costs for pit systems from Loci (2012). Construction costs of greywater systems are not included as they depend on the amount of greywater to be treated.
[b] National poverty datum line: 878.87 BWP/month (CSO 2011b).

All three sanitation systems include greywater treatment technologies. Tower gardens and mulch bed filters are the two different options proposed for greywater treatment. Sections 5.4.4 and 5.4.5 discuss them in more detail.

All systems match with the requirements defined in Section 5.3. They can therefore be expected to match the context of Thamaga and Letlhakeng. It must be emphasized that conditions, challenges and preferences are likely to be different in other villages and therefore other

systems might be more appropriate in other areas of Botswana. Moreover, there is no point in saying one of the systems is better than the other. Households should select according to their preferences and financial situation (Muellegger 2011).

5.4.1 Basic dry system

The first system is the most basic one and therefore applies most to low-income households. As income is lower in rural areas, it might be the most attractive option for many households in Letlhakeng.

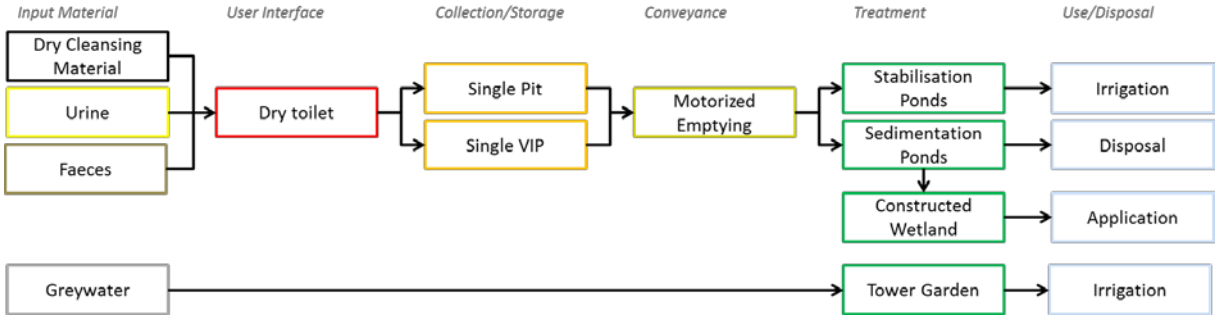


Figure 14. Basic dry system for households. (Functional groups and terms according to Tilley et al. 2008)

An illustration of the basic dry system is given in Figure 14. Urine, faeces and dry cleansing material are disposed in a dry toilet (see Tilley et al. 2008, pp.37–38) constructed above a single pit (see Morgan 2010; Tilley et al. 2008, pp.53–56). Both simple pits and VIPs are proven and working well in Botswana and therefore considered as the benchmark for dry on-site sanitation systems in the National Master Plan for Wastewater and Sanitation (GoB 2003, vol. 1). Once being filled, a motorized emptying vehicle is bringing the faecal sludge to a centralized treatment facility. As already reported by Boesch & Schertenleib (1985) for Gaborone, accessibility with emptying trucks is neither a problem in Thamaga nor in Letlhakeng. To provide an effective emptying service, WUC, which has recently taken over this responsibility, should either undergo intense capacity building or buy in capacity by contracting a private service operator. Compared to the council which was responsible before the sector reforms, WUC can be expected to maintain their truck fleets in a satisfactory manner, so that breakdowns and the thereby induced backlogs can be reduced. To reduce transport distances and thereby costs, it is important that a treatment facility and a truck are situated both within Thamaga and Letlhakeng. To approach full capacity, the same equipment should be used to empty and treat sludge from pits, previously constructed septic tanks and the proposed new gendarme toilets, both in institutional and private facilities. For Letlhakeng, it is recommended to discharge faecal sludge into the stabilisation ponds at Mphuthe JSS. In Thamaga, there is no such existing infrastructure and a new disposal site needs to be constructed unless all tankers are desludging at the existing WWTW in Molepolole (distance 35 km). An alternative to stabilisation ponds would be the construction of sedimentation ponds. Depending on the water content of the faecal sludge, a constructed wetland may be required to treat effluent from the sedimentation ponds. Low-income households, the main target group of this system, usually only dispose of an outdoor standpipe connection and have low water consumption. Hence only small quantities of greywater need to be treated. It is suggested to treat the greywater separately in a tower garden (see Section 5.4.4).

This system shows numerous advantages. The design allows for an easy upgrade for households already disposing of a pit latrine, requiring very little investment of both time and money. The household only needs to construct a tower garden and to refurbish broken or uncompleted parts of the existing pit. Besides the low technical complexity, the household is released from the handling of excreta.

However, there are cases in which other systems will be preferable. Households that do not dispose of any toilet yet, should consider the construction of a fossa alterna instead (advanced dry system proposed under 5.4.2). Financially stronger pit users considering the installation of a wet system should opt for the Gendarme toilet instead (advanced wet system proposed under 5.4.3). Another disadvantage of this system is that only greywater is reused.

In areas with shallow groundwater, the risk of groundwater contamination by pits is of special concern. For Letlhakeng, the risk of pollution is minimal as the groundwater table is very low (more than 150 metres deep) and separated from topsoil by impervious layers of mudstones and shales (Loci 2012). In Thamaga, groundwater can be within 3 metres from the surface. However, contamination can be avoided if the pit is not dug into the water table, properly lined and therefore not susceptible to flooding. The low population density (average plot size of 40 x 40 metres) further limits the release of pollutants. Another measure to minimize the risk is the proposed separate treatment of greywater. However, risk of groundwater contamination is even lower in the advanced dry system proposed below.

5.4.2 Advanced dry system

The advanced dry system is characterized by a lower risk of groundwater contamination and better re-use of nutrients on-site. It applies mainly to households that do not have a working pit latrine at the moment as it requires the construction of two new pits. Moreover, it is a suitable option for households concerned about groundwater contamination and households interested in on-site reuse of nutrients.

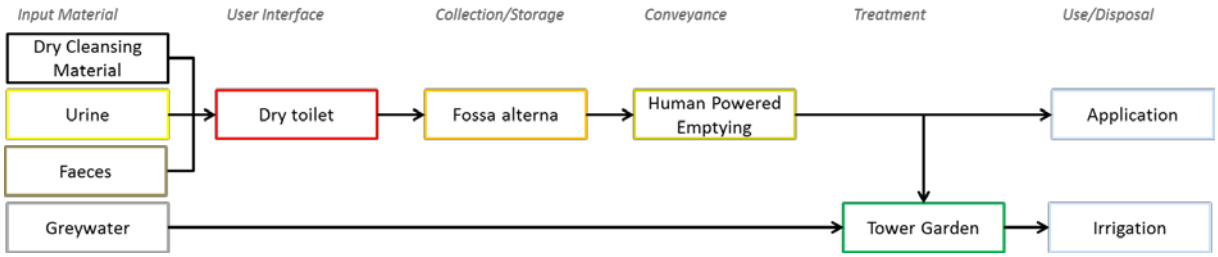


Figure 15. Advanced dry system for households. (Functional groups and terms according to Tilley et al. 2008)

An illustration of the advanced dry system is given in Figure 15. As for the basic dry system, a tower garden (see Section 5.4.4) is proposed to treat the greywater. Urine and faeces are disposed in a dry toilet (see Tilley et al. 2008, pp.37–38) constructed above a fossa alterna (see Morgan 2007). Fossa alterna compost toilets are a successfully proven concept in other Southern African countries like Mozambique, Malawi and Zimbabwe (Morgan 2010). The concept is to use two relatively shallow pits alternatingly. After each defecation soil, ash and/or leaves are added to enhance microbial degradation. Adding soil and ash, both commonly available, also reduce flies and odours. Further, the pit will fill up slower due to accelerated degradation. Dry cleansing material, if carbonaceous (e.g. toilet paper, newspaper), can also be

disposed into the pit, as this may enhance degradation and airflow (Tilley et al. 2008, p.19).The emptying of the compost out of the pit is easy in comparison to conventional pit emptying. This can be proved through demonstration units. Households can empty the pits themselves and therefore do not have to rely on an external emptying service. If the full pit is sealed for one year, the resulting material is safer and easier to handle, even though proper care should be taken when handling the product. The handling of the dry, earth-like product should pose substantially less objections than the handling of untreated urine and faeces. It can then be used as a soil conditioner on-site, for instance in the greywater tower garden on the plot.

Without demonstration and education on how to use this system, it is likely to fail. A crucial point is that no garbage can be put into the pit as this will make the compost unusable. The same holds for greywater which should be fully disposed in the tower garden and not into the fossa alterna. Another delicate part is that the pits need to be used alternatingly. Households have to understand that although there are *two* pits in their garden, they do only have *one* toilet. If users have not done it before, they might have objections to emptying a fossa alterna.

However, if used appropriately, this system offers a number of benefits. By adding soil and ash, excreta are dried and microbial degradation is accelerated. This results in less odour emissions and slower filling up of the pit, meaning it can be dug less deeply. Another advantage of the drying is that no infiltration into the groundwater can take place unless the pit gets flooded. The system is low-tech and households do not have to rely on external service providers for emptying. This also results in reduced operational costs, which is, however, compensated by higher construction costs due to a larger superstructure and the fact that two pits need to be constructed instead of one. With the on-site use of the compost, the household itself can benefit from nutrient recovery and does not give away the nutrients in form of faecal sludge. Looking at these advantages, households without any sanitary facility or households whose pit latrine has collapsed should rather consider the construction of a fossa alterna instead of a new pit, assuming they are willing able to use the system in a proper way.

5.4.3 Advanced wet system

Households with larger income usually opt for a wet system (Centre for Applied Research 2012). Given that flush toilets rely on continuous water supply and use large amounts of water they do not meet the previously defined requirements of an improved sanitation system. Therefore, an alternative advanced wet system "made in Botswana" is proposed as an alternative for households that want to upgrade to a wet system.

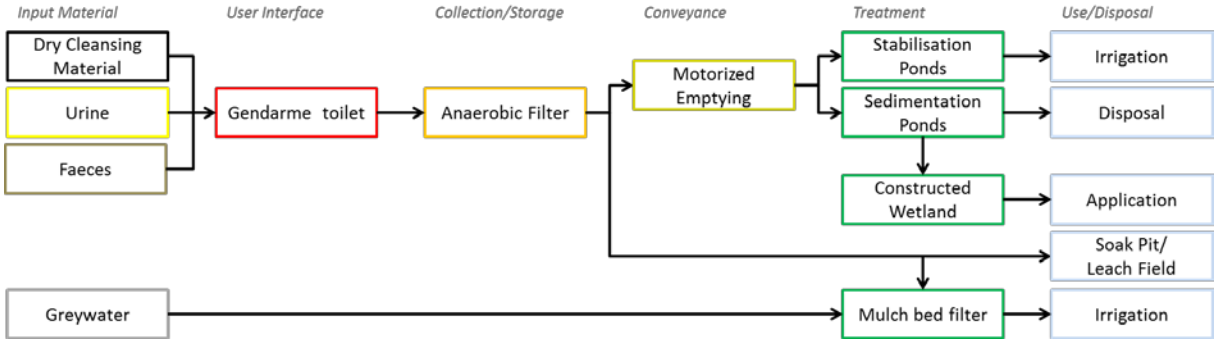


Figure 16. Advanced wet system for households. (Functional groups and terms according to Tilley et al. 2008)

The advanced wet system is illustrated in Figure 16. The system proposed to handle urine and faeces is called Gendarme system (see TAG 2007 and Figure 17 below). The user interface resembles to a standard cistern flush toilet. But opposite to a conventional flush toilet, this system is not relying on continuous water supply or needs a pit latrine as a backup. Instead, the toilet is flushed by using a hand pump situated next to the toilet. By using this pump, a vacuum is created which sucks the waste into a digestion tank situated underneath the toilet. The flush pressure breaks down the solids into small pieces and anaerobic digestion starts immediately (TAG 2007). Non-digestible solids will settle at the bottom of the tank, similar to an Aqua-privy (see Hoossein 2009). The effluent is then overflowing into a second tank with an anaerobic filter made out of polystyrene. From there the effluent will be released into a soak pit or leach field (see Tilley et al. 2008, pp.137–140). An alternative would be to release the effluent into the mulch filter which is set up for greywater treatment. The tank needs to be desludged from time to time, every 4-5 years depending on the number of users (TAG 2007). Conveyance, treatment and disposal of the sludge should be organized in the same manner as for the basic dry system (see Section 5.4.1).

The offering of a flush-like toilet system poses an increased level of comfort for the users. The use of the flush pump is also easily understandable to visitors and guests of the house and does not require special training. After construction, tanks are half-filled with water. Thereafter the system does not require the addition of any more water. This was the only flush-like toilet found that does not rely on continuous water supply, which is good both in terms of resource conservation and cost savings. Compared to pits, the Gendarme system has low odour emissions and does not attract flies. The system is manufactured in Botswana, using locally available materials. Laboratory analysis conducted for the DWMPC showed that the effluent from the anaerobic filter poses no risk to environmental or human health (TAG 2007).

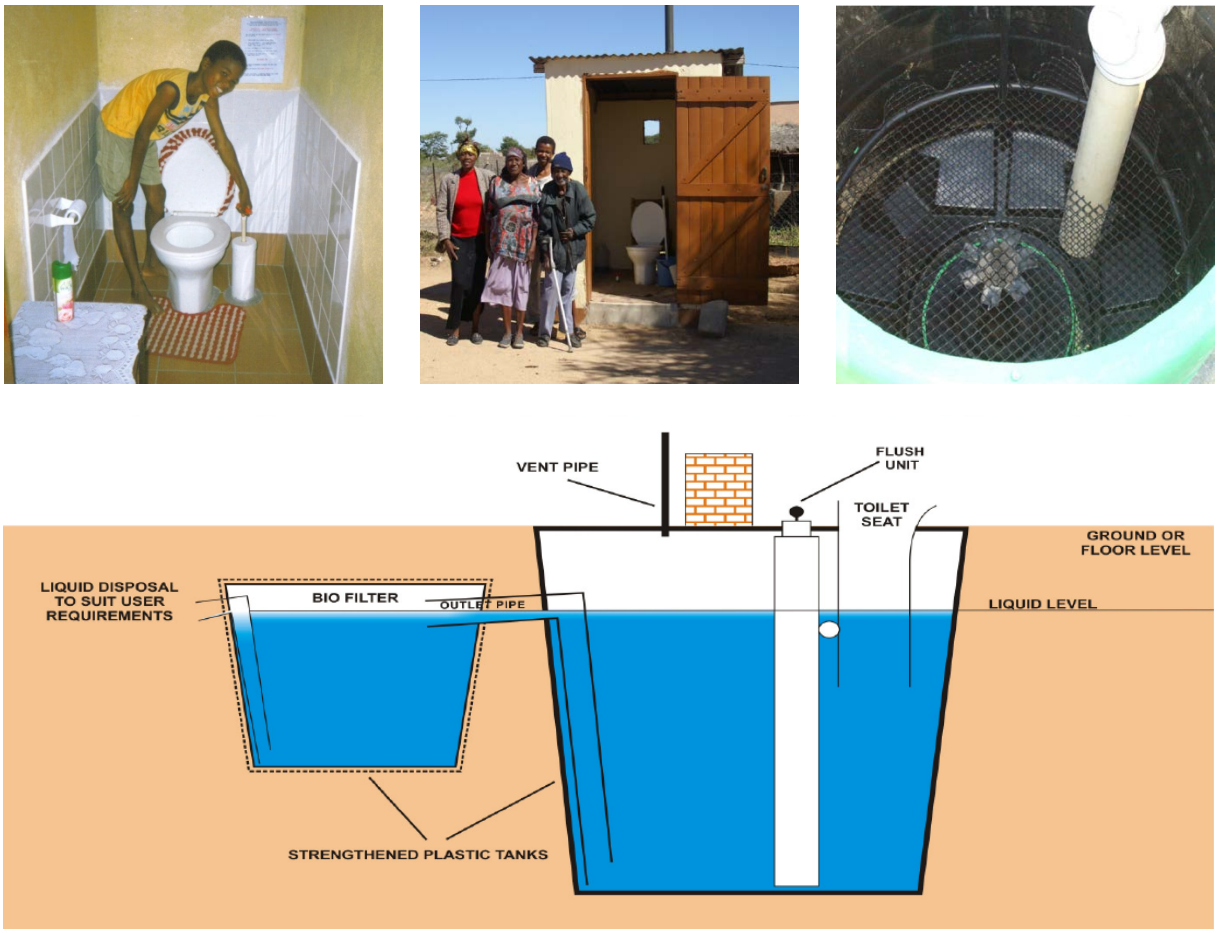


Figure 17. The Gendarme system. Upper part: The system can be installed both indoor like a conventional flush toilet (right) or outdoor like a conventional pit latrine (center). On the upper right is a picture of the inside of the plastic tank. Lower part: figure of the Gendarme system.(Pictures and figure from TAG 2007)

Given all these benefits, one wonders why the system has not taken off after being invented more than a decade ago. Albeit being very similar to conventional water flush systems, this system is not a conventional water flush system. Reluctance of people to try any alternative to conventional flush systems is a key factor hindering the successful rollout of this system so far (J. Hunter-Hardy*). Demonstration of the system would show whether users in Thamaga and Letlhakeng are open for this alternative or not. Another disadvantage is that the blackish anaerobic water is visible in the toilet and does have an odour. As with all systems, overuse can compromise the performance of the Gendarme toilet.

Households who can afford the high costs of a Gendarme system (13'400 BWP, approx. 1235 €) do probably have piped indoor water connection. Therefore the amount of greywater is substantially higher and cannot be treated in tower gardens anymore. Instead, a mulch bed filter is proposed for greywater treatment (see "advanced greywater treatment system", Section 5.4.5).

5.4.4 Simple greywater treatment system

This section proposes tower gardens as a simple greywater treatment system. Greywater towers provide a simple and low-cost method to treat and reuse greywater for gardening and food production. The only materials needed for the construction of a tower are wooden plots, flat stones, soil, manure, ash, a bucket with no bottom and shade cloth (Crosby 2004). All these materials are inexpensive and locally available.

Crosby (2004) provides a highly understandable manual on how to construct a tower garden out of these materials. Soil is piled up to a tower surrounding a column of fine stones with a bottomless bucket on top. Greywater is then poured into the bucket from where the flow is spread throughout the stone column, trickling more or less evenly distributed along the full tower height into the soil. The tower is stabilized by five wooden poles around which a shade cloth is wrapped. The side walls of the tower are then planted through holes in the shade net, e.g. with leafy crops like spinach. Additionally the garden can be planted on the top. Crosby (2004) advises to grow onions or garlic for the biological control of pests and diseases.

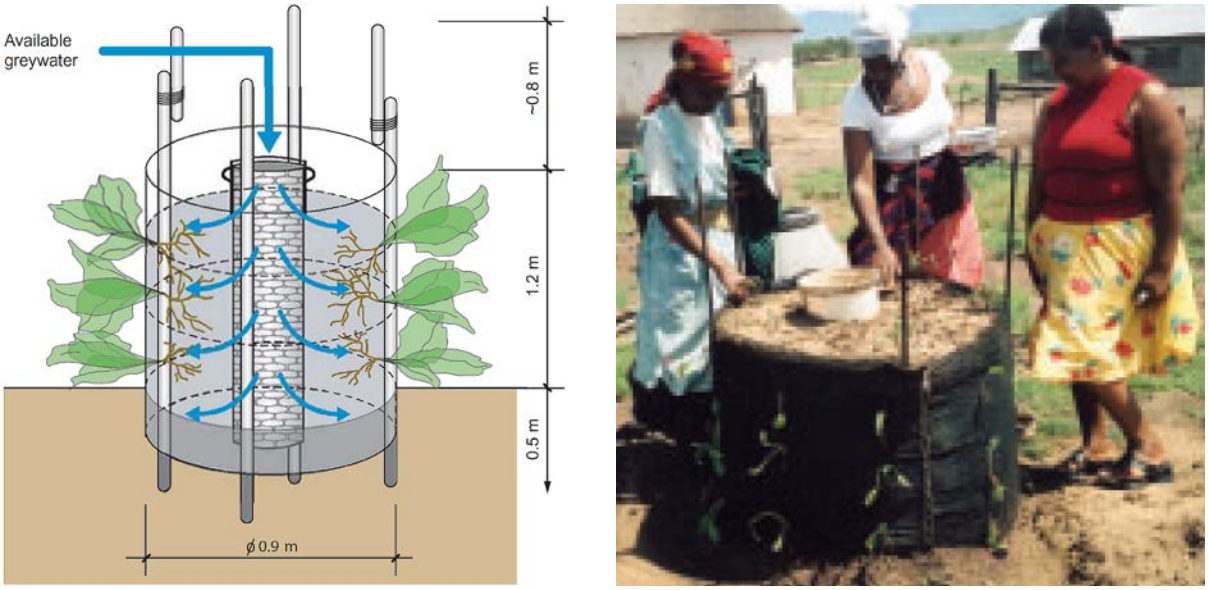


Figure 18. Tower garden. Schematic view (left) and newly finished construction in South Africa.
(Source: Morel & Diener 2006; Crosby 2004)

Once people have become familiar with the towers, little attention and labour is required. To prevent clogging of the system, Crosby (2004) advises to clean the system by pouring two buckets of fresh water each Saturday. To prevent toxic effects, household detergents should be selected carefully and the greywater should not be spilled directly over the plants. It is also advised to cook the harvested vegetables before consumption (Morel & Diener 2006).

Tower gardens are particularly recommended in water-scarce areas (Conradin et al. 2010). Experience in South Africa (Crosby 2004) has shown that in tower gardens, plants survived heat waves that proved too much for conventionally planted gardens. This might be due to the free air circulation, lower soil temperature or the better moisture status of the soil. An additional advantage in the local context of Thamaga and Letlhakeng might be that plants are less exposed to domestic poultry which is a big problem in gardens today.

Tower gardens have been successfully installed all over Africa, e.g. in Gauteng Province, South Africa (Morel & Diener 2006), Ethiopia (SuSanA 2012), Kenya (Pascal & Mwende 2009) and Uganda (Kulabako et al. 2009; SuSanA 2012). More information about applicability, advantages and disadvantages of greywater towers can be found in the SSWM toolbox (Conradin et al. 2010).

5.4.5 Advanced greywater treatment system

The simple treatment system presented above is only suitable to treat smaller quantities of greywater. With higher income, households in Letlhakeng and Thamaga usually can afford indoor connections and thereby water consumption increases (Swatuk & Rahm 2004). A simple system that can treat larger amounts of greywater is a mulch filter basin (Ludwig 2006).

Many projects presented in Morel & Diener (2006) are using grease traps for greywater pre-treatment. However personal enquiries (E. Narsi*; R. Velimir*; M. Palmér Rivera and P. Ridderstolpe, personal communication) have shown that grease traps pose major problems if not maintained correctly and on a regular basis. It is therefore considered more appropriate for smaller systems to lead greywater directly to the mulch bed (Ridderstolpe 2004). Where the design doesn't allow for that, a pipe system for distribution with a mulch tower for pre-treatment can be an adequate alternative. Both options are sketched out in Figure 19.

Figure 19. Greywater treatment with mulch. Direct single-source treatment in mulch basins (left); joint-source treatment in mulch tower and irrigation of respiration trench (right). (Sketches: Peter Ridderstolpe)

The proposed greywater treatment system does not require the installation of pumps. As pumps are costly and have a short life expectancy (R. Velimir*) they are not considered appropriate for installations in Thamaga and Letlhakeng. The trees growing in the mulch basins are aesthetically attractive and can generate fruits for subsistence. Greywater treatment with mulch has been successfully proved in South Africa, Sweden and the United States (Ridderstolpe 2007). The evaluation of a pilot project in Mexico showed that good care, commitment and understanding of the system is essential for success (Buenfil 2005). The major disadvantage of this option is the one that all greywater reuse solutions have in common: source control (Ridderstolpe 2004). This means that only environmentally friendly household chemicals should be used and sinks should be equipped with screens to prevent pipes from clogging.

5.5 Sanitation system for schools and institutions

Schools can provide an arena where sanitation can be shown at its best (World Bank 2013). Schools should therefore serve as a demonstration site for new technologies that are not yet accepted by the local population. To reduce the high water consumption of schools and the large problems faced with clogging and water interruptions, a dry system seems most adequate.

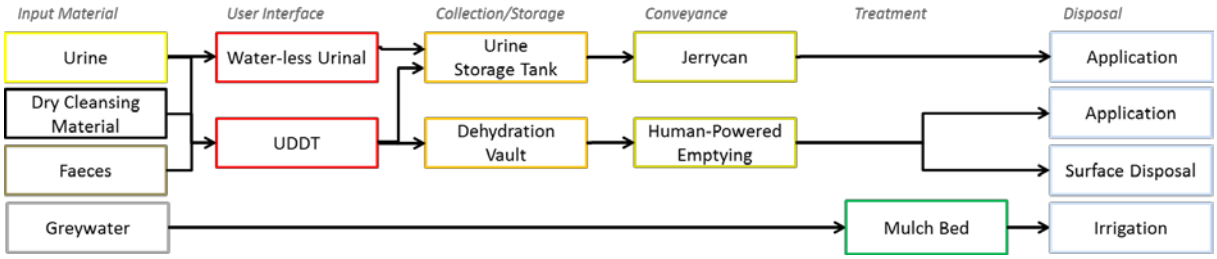


Figure 20. Dry system for schools and institutions. (Functional groups and terms according to Tilley et al. 2008)

Figure 20 provides an illustration of the proposed dry system. Urine is collected in urine-diverting dry toilets and water-less urinals (see Deegener et al. 2009) and transported to a storage container. Urine is normally sterile in the urine bladder but can get contaminated with pathogens in the lower parts of the urinary tract or exposed to faecal residues in a poorly cleaned pedestal (Schönning & Stenström 2004). When stored in a sealed container for a longer period of time, bacteria and viruses get inactivated (WHO 2006). The sanitized urine can then be applied as a valuable nitrogen fertilizer. Storage times between one and six months are suggested, depending climatic conditions and the intended use (Schönning & Stenström 2004). As done in a similar project in Burkina Faso (SuSanA 2012), it would be helpful to determine the corresponding values for Botswana's climate in a research project accompanying a demonstration facility. Faeces and dry cleansing material is collected separately. Multiple vaults are used alternatingly allow the faeces to dehydrate in one vault while the other vault fills (Tilley et al. 2008). Reed & Shaw (2008) provide useful guidelines on how to operate such multi-compartment pits in African primary schools. Depending on the composition of the dried material, it can either be applied as a soil conditioner or disposed on a solid waste landfill. Current experience from conventional pits showed that large amounts of waste are ending up in school toilets. Sometimes even whole mattresses were thrown into pits (B. Koosimile*). If this practice cannot be stopped, the disposal of the dried material on a landfill is the only viable option. Application of urine and dried faeces should be taking place in the school garden to teach students about the effectiveness of these fertilizers. Once students are convinced about the benefits, urine diversion could also be rolled out to private toilets. However, if capacity or interest at the schools does allow for on-site reuse, urine could be collected by a nearby farmer to be used on the fields. Storage could then either take place at the farm, at the institutional site or at the site of a private operator responsible for pick-up, storage and delivery of the urine. Greywater can be treated by mulch filters and be used for irrigation of the school garden or trees afterwards. Sub-surface drip-irrigation of the filtered greywater should be used to minimize crop or human exposure (Qadir et al. 2010).

Water reuse applications from institutional facilities were already recommended in the National Master Plan for Wastewater and Sanitation (GoB 2003, vol. 1). However, with the suggested

urine fertilization, reuse is brought to a new level. Therefore one can expect resistance from users new to this concept. Continuous information and education is needed to maintain project ownership by the school direction and the users. Positive experience with urine diversion in schools have been made in other African countries, namely Kenya (Gacheiya 2012; SuSanA 2012), Eastern Europe and Central Asia (Deegener et al. 2009). A previous project using UDDTs in Paje, Botswana on a household level did not lead to copying and many toilets were abandoned after some time (SuSanA 2012; Hanke 2004). Regarding urine diversion in Botswana, the following lessons can be learned to ensure successful operation of this system:

- It is not enough to create ownership but it also has to be maintained.
- Plastic pedestals provide a different level of comfort compared to the usual pit latrine concrete benches.
- Urine diverting pedestals have to be cleaned while cleaning is hardly necessary in some pit latrine designs

Compared to flush toilets, the proposed system substantially reduces water consumption and remains operative in case of water shortages. It is a robust, low-cost solution. However, various tasks need to be carried out on a regular basis by various people to keep the system operational: cleaners face more work compared to conventional pits, urine and faeces containers need to be emptied regularly, somebody has to make sure that the pits are alternated when full and finally the resulting sanitized fertilizer is useless unless applied somewhere.

5.6 Alternative solutions

Besides the above presented systems, a number of alternative technology options have been investigated. This section discusses alternative options considered.

Enviroloo (see Loci 2012, pp.52–53; GoB 2003, vol. 3, app. 4.5.1) and Jo Jo (see GoB 2003, vol. 3, app. 4.5.2) are pre-fabricated **dry composting systems** available from South Africa which have been investigated in the National Master Plan for Wastewater and Sanitation (GoB 2003 vol. 1, p.12):

"Dry composting has not performed adequately in Botswana based on the experience of the systems tried. At this time it should be discontinued unless significant changes occur to the designs. The systems in place will require a special recovery effort to fix them or convert them to adequate sanitation systems."

Nevertheless, the University of Botswana is currently involved in a UNDP project where Enviroloos are provided to two primary schools in Maun, Botswana (B. Bolaane*). Vigorous education and communication efforts are made to achieve stakeholder buy-in and sustainable reuse of faeces. Compared to the system for schools suggested in this thesis, an operation and maintenance of an Enviroloo is less intense, but urine is not reused and the technology is not produced locally. On a household level, the Gendarme system is preferred as it is less costly than an Enviroloo .

The solution with **double vault UDDT pits** on a household level received a lot of attention and achieved acceptable scores in the evaluation. However, management of such a system is more

demanding, as jerry cans to collect the urine have to be replaced on a regular basis. It is also questionable if a urine diverting toilet is easy to clean (see Gacheiya 2012), which was one of the criteria defined in the participatory workshops. Moreover personal inquiries have shown that there is currently no market or interest for application of large quantities of urine. It is therefore advisable to first implement urine diversion in schools with the proposed system to increase interest and acceptance. At a later stage, double vault UDDT pits might present an attractive alternative to the fossa alterna proposed in Section 5.4.2. In this case, a fossa alterna can easily be upgraded to a UDDT by adding urine diversion (Figure 21).

Figure 21. Upgrade of existing pit to a UDDT by adding urine diversion.
(Source: Presentation by M. Palmér Rivera, Thamaga, 12 Nov 2012)

Vacuum sewer systems are gaining popularity as a cheaper alternative to conventional gravity sewerage (Loci 2012). Loci (2012, p. 47) explains the working principle of the system typically applied in Botswana:

"Sewage flows by gravity to a household collection chamber. When a pre-set level (approx. 20-30 litres) of liquid in the chamber is reached, the interface valve will open and draw the contents of the collection chamber into the vacuum system. The differential pressure between atmosphere and vacuum system (air), is the force that propels the liquid through the sewer pipes to the vacuum station. The interface valve requires no electrical connection for operation."

The collection chamber can store wastewater in case of shorter power cuts. But in a case of a pump breakdown for several days, the capacity of the collection chambers would be exceeded resulting in spillage of wastewater. Leaking drains would also undermine the concept (remember that all 978,000 litres of water are lost from the pipes at Mphuthe JSS on only a few hundred metres distance to the pump station!). Considering also the extensive water use of conventional flush toilets, this technology could not be a viable option for Thamaga or Letlhakeng.

Figure 22. Cisternlink Aquasaver (Source: OzAquasaver Pty Ltd, www.ozaquasaver.com)

For cistern flush toilets OzAquasaver Pty Ltd (see www.ozaquasaver.com) from Australia offers a greywater reuse solution **connecting the wash hand basin with flush cistern** (see Figure 22). Thereby, water used for hand wash can be reused afterwards to flush the toilet. The producer states that hand wash water will become unhygienic if stored for longer than 24 hours, which should not be a problem if the toilet is used regularly. The construction is simple and the material used should be locally available. Draining the wash basin to a cistern flush instead of a septic tank should not result in substantial additional costs and could be an interesting upgrade option for existing flush toilets.

Looking at the fact that gardening is not common in Thamaga and Letlhakeng, treated wastewater could also be used for different purposes. An interesting option might be the **reuse of treated wastewater for car wash** to generate jobs and income. This might also reduce the problem of cultural acceptability as the water is not entering the food chain.

To improve the **reuse of wastewater from the activated sludge plant** at Thamaga Primary Hospital, A. Kgomotso* suggested **to irrigate a nearby football field**[6]. Personal investigations have shown that the field is less than 200 metres from the wetland and a pipe could easily be installed to capture the effluent from the wetland and bring it to the football field. Mpho Mogwera, a local VDC member argued that the field is property of the hospital and could be used by them at any time for an extension project. However, this might be a simple option at low costs to improve quality of life in Thamaga.

[6] Photos of the football field are provided on the attached CD-ROM.

6 Conclusion

For this thesis, a set of four different participatory tools has been used to collect data about the current sanitation conditions in the two villages. Village workshops, school workshops, a household survey and stakeholder interviews proved to be a useful combination of participatory action research methods that allows for a meaningful evaluation of the local sanitation context.

It was found that most households in Thamaga have access to basic private sanitation. In Letlhakeng there is still a considerable part of the population using the neighbour's toilet or practising open defecation. The high access rate to sanitation can be associated with large scale projects that have been undertaken to build VIP latrines for unsewered communities. As observed in comparable context (see Buckley et al. 2008), inadequate planning and budgeting has been put in place to deal with the emptying, rebuilding or maintenance of full or damaged pit latrines, resulting in dissatisfying conditions.

To improve sanitation in Thamaga and Letlhakeng, cost-effective and sustainable sanitation systems that match with the local requirements were investigated. Two dry systems (single pit and fossa alterna) and one wet system (Gendarme toilet) were proposed that have the potential to provide improved sanitation services to Thamaga and Letlhakeng. All systems are characterised by low technical complexity, high financial competitiveness and a reduced risk of groundwater contamination. Furthermore all systems allow for the separate treatment and reuse of greywater, either in a tower garden or a mulch bed filter. To maximize private ownership, households should be offered the choice between these three systems based on their preferences and financial power.

An important finding was that the situation is worse and more pressing on institutional level, particularly in schools and hospitals. Resources (financial, human, technical, organizational) are available, but their mobilisation is a major challenge, a problem often experienced in similar contexts (OECD 2000). To address the specific needs of institutions, an additional dry urine-diverting system for schools and institutions was proposed. This system can be a valuable help to enhance functionality and to reduce water costs. Furthermore, schools pose a good opportunity to promote reuse of nutrients from urine and faeces, which is yet unknown and lacking acceptance in Thamaga and Letlhakeng.

It was found that for any system that is going to be implemented, the creation of public awareness and project ownership is essential. As many interview partners emphasized, continuous information and involvement of all the relevant stakeholders throughout the whole project is strongly recommended. Without the necessary awareness of the important implications improved sanitation has on health, school attendance and quality of life, people do not see a need to carry out their regular management duties and any system is likely to fail after some time.

A next step is now the testing and demonstration of the proposed systems. Once being successfully proven, accepted and adjusted according to the testers' feedback, the proposed systems are ready for broad implementation and have a high potential to sustainably improve sanitation in Thamaga and Letlhakeng.

7 References

Ali, M. (2010). *The Pitfalls of Questionnaire Surveys*, The Schumacher Centre for Technology and Development; Warwickshire, United Kingdom.

Batisani, N. & Yarnal, B. (2010). Rainfall variability and trends in semi-arid Botswana: Implications for climate change adaptation policy. *Applied Geography*, 30(4), pp. 483–489.

Baum, R., Luh, J. & Bartram, J. (2013). Sanitation: A Global Estimate of Sewerage Connections without Treatment and the Resulting Impact on MDG Progress. *Environmental Science & Technology*, Available at: http://www.ncbi.nlm.nih.gov/pubmed/23323809 [Accessed 31 Jan 2013].

Baye, S., Kloos, H., Mulat, W., et al. (2012). Assessment on the Approaches Used for Water and Sanitation Programs in Southern Ethiopia. *Water Resources Management*, 26(15), pp. 4295–4309.

Boesch, A. & Schertenleib, R (1985). *Emptying On-Site Excreta Disposal Systems: Field Tests with Mechanized Equipment in Gaborone (Botswana)*, Institutional Reference Centre for Waste Disposal (IRCWD); Dübendorf, Switzerland.

Boko, M., Niang, I., Nyong, A., et al. (2007). Africa. In M. L. Parry et al. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press; Cambridge, United Kingdom. pp. 433–467.

Bolaane, B. (unknown). Urbanization and Sanitation Nexus: The evolution of financing and cost recovery in Urban Village Sanitation Programmes in Botswana. (provided by the author).

Bolaane, B. & Ikgopoleng, H. (2011a). Cost recovery in waterborne sanitation: cases in Botswana. *Engineering Sustainability*, 164, pp. 275–286.

Bolaane, B. & Ikgopoleng, H. (2011b). Towards improved sanitation: Constraints and opportunities in accessing waterborne sewerage in major villages of Botswana. *Habitat International*, 35(3), pp. 486–493.

Buckley, C.A., Foxon, K.M., Nwaneri, C. & Balboni, E. (2008). *Scientific Support for the Design and Operation of Ventilated Improved Pit Latrines (VIPs) and the Efficacy of Pit Latrine Additives*, Water Research Commission; Gezina, South Africa.

Buenfil, J. (2005). *Evaluation of Greywater Treatment Systems in San Juan Tlacotenco*, TepozEco pilot project. Available at: http://www.bt.slu.se/eas/Projects2005/Prof_project/reports/HacintoFinal.pdf [Accessed 20 Feb 2013].

Castro, J.E. (2010). Private-Sector Participation in Water and Sanitation Services: The Answer to Public Sector Failures? In C. Ringler et al. (Eds.), *Global Change: Impacts on Water and Food Security*, Springer Berlin Heidelberg; Berlin, Heidelberg. pp. 169–193.

Centre for Applied Research (2012). *Botswana IWRM WE Plan. Volume 1: Main report*, Report prepared by the Centre of Applied Research for the Department of Water Affairs and the Kalahari Conservation Society.

Chatterley, C. (2011). *National Assessment of WASH in Schools - Belize*, Belize.

Chevalier, J.M. & Buckles, D.J. (2013). *Participatory Action Research. Theory and Methods for Engaged Inquiry*, Routledge, United Kingdom.

Conradin, K., Kropac, M. & Spuhler, D. (2010). *The SSWM Toolbox*, Available at: http://www.sswm.info [Accessed 21 Feb 2013].

Crosby, C. (2004). Food From Used Water. *The Water Wheel*, 3(4-5), pp. 26–29. Available at: http://www.wrc.org.za/Knowledge Hub Documents/Water Wheel/Magazine/WaterWheel_Archive_ww-jul-oct 04.pdf.

CSO (2011a). *Labour Statistics 2010*, Central Statistics Office (CSO); Gaborone, Botswana.

CSO (2011b). *Preliminary Results of the Botswana Core Welfare Indicators (Poverty) Survey 2009/10*, Central Statistics Office (CSO); Gaborone, Botswana. Available at: http://www.cso.gov.bw/templates/cso/file/File/BCWIS _Poverty_ Survey Statsbrief Nov 2011..pdf [Accessed 25 Feb 2013].

Dayal, R., Van Wijk, C. & Mukherjee, N. (2002). *Methodology for Participatory Assessments*, Water and Sanitation Program (WSP) and International Water and Sanitation Centre (IRC); Delft, The Netherlands.

Deegener, S., Wendland, C., Samwel, A. & Samwel, M. (2009). *Sustainable and Safe School Sanitation*, Women in Europe for a Common Future (WECF); The Netherlands/France/Germany.

Denscombe, M. (2010). *The Good Research Guide: For small-scale social research projects*, Open University Press; Maidenhead, United Kingdom.

Drangert, J.O. (1998). Fighting the urine blindness to provide more sanitation options. *Water SA*, 24(2), pp. 157–164.

Elliott, L. (2001). *How to integrate stakeholder analysis information into your project*, Available at: http://www.techrepublic.com/article/how-to-integrate-stakeholder-analysis-information-into-your-project/1039599 [Accessed 15 Feb 2013].

Evans, B., Trémolet, S. & Shaub-Jones, D. (2010). *Output-Based Aid for Sustainable Sanitation*, Global Partnership for Output-based Aid, World Bank; Washington, DC.

Evans, B., Van der Voorden, C. & Peal, A. (2009). *Public Funding for Sanitation. The many faces of sanitation subsidies*, Water Supply & Sanitation Collaborative Council (WSSCC); Geneva, Switzerland.

FAO/GIEWS (2013). *FAO/GIEWS Interpolated Estimated Dekadal Rainfall*, Available at: http://www.fao.org/giews/english/ierf/list.asp?code=35 [Accessed 31 Jan 2012].

Fink, A. (2012). *Report from School Workshops in Thamaga & Letlhakeng*, unpublished (attached on CD-ROM).

Gacheiya, R.M. (2012). *Status Report on the Operation and Management of the Existing UDDTs at the Learning Institutions 2012*, Capacity-Linked water supply and sanitation improvement for Africa's peri-urban and Rural Areas (CLARA); Kenya.

Gendre, J. (2012). A concept for providing a sanitary system to the urban poor of Kisalosalo in Kampala, Uganda. *Master Thesis*, Institute of Environmental Engineering, Swiss Federal Institute of Technology (ETH); Zurich, Switzerland.

GoB (2003). *Botswana National Master Plan for Wastewater and Sanitation*, Government of Botswana.

Griffiths, A. & Wall, S. (2004). *Economics for Business and Management. A Student Text.*, Pearson Books.

Groce, N., Bailey, N., Lang, R., et al. (2011). Water and sanitation issues for persons with disabilities in low- and middle-income countries: a literature review and discussion of implications for global health and international development. *Journal of Water and Health*, 9(4), pp. 617–627.

Günther, I., Niwagaba, C.B., Lüthi, C., et al. (2012). When is shared sanitation improved sanitation? *Research for Policy*, (2), pp. 1–4.

Hambira, W.L., Moalafhi, D.B. & Mulale, K. (2011). Water Demand Management in Botswana: Reflections on the latest review of Botswana National Water Master Plan. Available at: http://www.bscw.ihe.nl/pub/bscw.cgi/S4d043e0f/d2606897/Moalafhi-Hambira.pdf [Accessed 12 Feb 2013].

Hammouya, M. (1999). Statistics on Public Sector Employment: Methodology, Structures and Trends. Bureau of Statistics, International Labour Office (ILO); Geneva, Switzerland.

Hanke, T. (2004). *Experiencing Ecological Sanitation in Paje , Botswana CBNRM Missing Link project*, IUCN Botswana; Gaborone, Botswana.

Hoossein, S. (2009). The Development of Sustainability Criteriy to Facilityte the Selection of Sanitation Technologies Within the Buffalo City Municipality (Eastern Cape Province, South Africa). *Master Thesis*, Rhodes University; Grahamstown, South Africa.

Kanyemba, A. (2011). *Growing up growing at school. A guide to menstrual management for school girls*, Water Research Commission; Pretoria, South Africa.

Kulabako, R., Kinobe, J., Mujunga, J., et al. (2009). Greywater use in peri-urban households in Kitgum, Uganda. *Sustainable Sanitation Practice*, (1), pp. 16–24. Available at: www.ecosan.at/ssp/issue-01 [Accessed 22 Feb 2013].

Kvarnström, E. (2012a). *Workshop on the sanitation situation in Letlhakeng - Final report*, unpublished (attached on CD-ROM).

Kvarnström, E. (2012b). *Workshop on the sanitation situation in Thamaga - Final report*, unpublished (attached on CD-ROM).

Kvarnström, E. & af Petersens, E. (2004). *Open Planning of Sanitation Systems*, Stockholm Environment Institute, EcoSanRes Programme; Stockholm, Sweden.

Larsen, T.A., Maurer, M., Eggen, R.I.L., et al. (2010). Decision support in urban water management based on generic scenarios: the example of NoMix technology. *Journal of Environmental Management*, 91(12), pp. 2676–2687.

Lennartsson, M., Kvarnström, E., Lundberg, T., et al. (2009). *Comparing Sanitation Systems Using Sustainability Criteria*, Stockholm Environment Institute, EcoSanRes Programme; Stockholm, Sweden.

Loci (2012). *Baseline Sanitation Study - Final report*, Gaborone, Botswana.

Ludwig, A. (2006). *Create an Oasis with Greywater*, Oasis Design.

Lüthi, C., Morel, A., Tilley, E. & Ulrich, L. (2011). *Community-Led Urban Environmental Sanitation Planning (CLUES)*, Swiss Federal Institute of Aquatic Science and Technology (Eawag); Dübendorf, Switzerland.

Lüthi, C., Panesar, A., Schütze, T., et al. (2011). *Sustainable Sanitation in Cities: A Framework for Action*, Sustainable Sanitation Alliance (SuSanA) & International Forum on Urbanism (IFoU), Papiroz Publishing House; Rijswijk, The Netherlands.

Massoud, M.A., Tarhini, A. & Nasr, J.A. (2009). Decentralized approaches to wastewater treatment and management: Applicability in developing countries. *Journal of Environmental Management*, 90(1), pp. 652–659.

McConville, J. (2008). Asessing Sustainable Approaches to Sanitation Planning and Implementation in West Africa. *Licentiate Thesis*, Department of Land and Water Resources Engineering, Royal Institute of Technology (KTH); Stockholm, Sweden.

McConville, J. (2010). Unpacking Sanitation Planning. Comparing Theory and Practice. *PhD Thesis*, Department of Architecture, Chalmers University of Technology; Gothenburg, Sweden.

Van Minh, H., Nguyen-Viet, H., Thanh, N.H. & Yang, J.-C. (2012). Assessing willingness to pay for improved sanitation in rural Vietnam. *Environmental Health and Preventive Medicine*,

Montgomery, M. & Elimelech, M. (2007). Water and sanitation in developing countries: including health in the equation. *Environmental Science & Technology*, 41(1), pp. 17–24.

Morel, A. & Diener, S. (2006). *Greywater Management in Low and Middle-Income Countries, Review of different treatment systems for households or neighbourhoods*, Swiss Federal Institute of Aquatic Science and Technology (Eawag); Dübendorf, Switzerland.

Morgan, P. (2010). *Ecological Toilets - Start simple and upgrade from Arborloo to VIP*, Harare, Zimbabwe.

Morgan, P. (2007). *Toilets That Make Compost: Low-cost, sanitary toilets that produce valuable compost for crops in an African context*, Stockholm Environment Institute, EcoSanRes Programme; Stockholm, Sweden.

Muchiri, E., Mutua, B. & Muellegger, E. (2010). Private sector involvement in operating a sanitation system with urine diversion dry toilets in Nakuru, Kenya. *Sustainable Sanitation Practice*, (2), pp. 21–25.

Muellegger, E. (2011). *Rapid needs assessment for low cost sanitation concept for Kyela Town*, GIZ, Water Sector Reform Programme; Tanzania. Available at: http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1559 [Accessed 21 Feb 2013].

Muller, M.S. & Rijnsburger, J. (1994). technology. *Waterlines*, 13(1), pp. 24–27.

OECD (2000). *Shaping the Urban Environment in the 21st Century: A Reference Manual on Urban Environmental Policy*, Paris, France.

Pascal, P. & Mwende, E. (2009). A Garden in a Sack: Experiences in Kibera, Nairobi. *Urban Agriculture Magazine*, (21), pp. 38–40.

Qadir, M., Wichelns, D., Raschid-Sally, L., et al. (2010). The challenges of wastewater irrigation in developing countries. *Agricultural Water Management*, 97(4), pp. 561–568.

Rahm, D., Swatuk, L. & Matheny, E. (2006). Water Resource Management in Botswana: Balancing Sustainability and Economic Development. *Environment, Development and Sustainability*, 8(1), pp. 157–183.

Reed, B. & Shaw, R. (2008). *Sanitation for Primary Schools in Africa*, Water, Engineering and Development Centre (WEDC), Loughborough University; Leicestershire, United Kingdom.

Ridderstolpe, P. (2004). *Introduction to Greywater Management*, Stockholm Environment Institute, EcoSanRes Programme; Stockholm, Sweden.

Ridderstolpe, P. (2007). *Mulch Filter and Resorption Trench for Onsite Greywater Managment. Report from a demo-facility built in Kimberly, South Africa*, EcoSanRes Programme; Stockholm, Sweden.

Ridderstolpe, P. & Palmér Rivera, M. (2007). What is Sustainable Sanitation and how do I plan for it? In I. Bodík & P. Ridderstolpe (Eds.), *Sustainable Sanitation in Central and Eastern Europe - addressing the needs of small and medium-size settlements*, Global Water Partnership Central and Eastern Europe; Bratislava, Slowak Republic. pp. 23–47. Available at: http://www.ccb.se/documents/SustainableSanitation_English.pdf [Accessed 12 Feb 2013].

Robinson, J.A. (2009). Botswana as a Role Model for Country Success. United Nations University. World Institute for Development Economics Research; Helsinki, Finland.

SACMEQ (2011). *Policy Brief - Progress in Gender Equality in Education: Botswana*, Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ).

Saywell, D. (1999). *Microcredit for Sanitation*, Available at: http://www.unep.or.jp/ietc/kms/data/1454.doc [Accessed 26 Feb 2013].

Schouten, T. (2010). Paradigm shift or business as usual? *Presentation*, The Hague, Netherlands. Available at: http://www.irc.nl/page/57942 [Accessed 22 Jan 2013].

Schwartz, K. (2008). The New Public Management: The future for reforms in the African water supply and sanitation sector? *Utilities Policy*, 16(1), pp. 49–58.

Schönning, C. & Stenström, T.A. (2004). *Guidelines on the safe use of urine and faeces in ecological sanitation systems*, Stockholm Environment Institute, EcoSanRes Programme; Stockholm, Sweden.

Sijbesma, C. (2011). Sanitation financing models for the urban poor. Available at: http://www.irc.nl/top25 [Accessed 12 Sep 2012].

SuSanA (2012). *Compilation of 25 case studies on sustainable sanitation projects from Africa*, Sustainable Sanitation Alliance (SuSanA) & Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); Eschborn, Germany.

Swatuk, L. & Rahm, D. (2004). Integrating policy, disintegrating practice: water resources management in Botswana. *Physics and Chemistry of the Earth, Parts A/B/C*, 29(15-18), pp. 1357–1364.

TAG (2007). *Gendarme Sanitation System. On-site sanitation technology evaluation report*, Technology Advisory Group, Department of Waste Management and Pollutant Control; Gaborone, Botswana.

Tayler, K. (2007). Principles of Town Water Supply and Sanitation. Part 2: Sanitation. *Water Working Notes*, The World Bank; Washington, DC. (14), Available at: http://water.worldbank.org/publications/principles-town-water-supply-and-sanitation-part-2-sanitation [Accessed 14 Jan 2013].

Tayler, K., Parkinson, J. & Colin, J. (2003). *Urban Sanitation. A Guide to Strategic Planning*, ITDG Publishing; London, United Kingdom.

Taylor-Powell, E. (1998). *Questionnaire Design: Asking questions with a purpose*, University of Wisconsin; Madison, WI.

Thye, Y.P., Templeton, M.R. & Ali, M. (2011). A Critical Review of Technologies for Pit Latrine Emptying in Developing Countries. *Critical Reviews in Environmental Science and Technology*, 41(20), pp. 1793–1819.

Tilley, E. (2013). Conceptualizing sanitation systems to account for new complexities in processing and management. In T. A. Larsen et al. (Eds.), *Source Separation and Decentralization for Wastewater Management*, IWA Publishing; London, United Kingdom. pp. 227–239.

Tilley, E., Lüthi, C., Morel, A., et al. (2008). *Compendium of Sanitation Systems and Technologies*, Swiss Federal Institute of Aquatic Science and Technology (Eawag); Dübendorf, Switzerland.

Transparency International (2012). *Corruption Perceptions Index*, Available at: http://cpi.transparency.org/cpi2012/ [Accessed 21 Jan 2013].

UN (2005). *Designing Household Survey Samples: Practical Guidelines*, United Nations; New York, USA.

UN (2003). *Indicators for Monitoring the Millenium Development Goals*, United Nations; New York, USA.

UNDP (2010). *Botswana Millennium Development Goals. Status Report 2010*, Government of Botswana, United Nations in Botswana; Gaborone, Botswana. Available at: http://www.undp.org/africa/documents/mdg/botswana_2010.pdf [Accessed 21 Feb 2013].

Unicef (1998). A Manual on School Sanitation and Hygiene. *Water, Environment and Sanitation Technical Guidelines Series*, United Nations Children's Fund (Unicef); New York, USA.

Unicef & WHO (2012). *Progress on Drinking Water and Sanitation. Update 2012*, United Nations Children's Fund (Unicef) and World Health Organization (WHO); New York, USA.

WHO (2011). *10 facts on sanitation*, Available at: http://www.who.int/features/factfiles/sanitation/facts/en/index.html [Accessed 31 Jan 2013].

WHO (2000). *Tools for assessing the O & M status of water supply and sanitation in developing countries*, World Health Organization (WHO); Geneva, Switzerland.

WHO (2009). *Water, Sanitation and Hygiene Standards for Schools in Low-cost Settings*, World Health Organization; Geneva, Switzerland.

WHO (2006). *WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume IV. Excreta and Greywater Use in Agriculture*, World Health Organization (WHO); Geneva, Switzerland.

Wirtz, J. (1998). Development of a service guarantee model. *Asia Pacific Journal of Management*, 15, pp. 51–75.

Wood, S., Sawyer, R. & Simpson-Hébert, M. (1998). *PHAST Step-by-Step Guide: A Participatory Approach for the Control of Diarrhoeal Disease*, World Health Organization (WHO); Geneva, Switzerland. Available at: http://www.who.int/water_sanitation_health/hygiene/envsan/phastep/en [Accessed 15 Feb 2013].

World Bank (2013). *School Sanitation , Hygiene and Wastewater resource guide*, Available at: http://water.worldbank.org/shw-resource-guide/promotion/school-sanitation-and-hygiene [Accessed 30 Jan 2013].

Ölund Wingqvist, G. & Dahlberg, E. (2008). *Botswana Environmental and Climate Change Analysis*, University of Gothenburg; Gothenburg, Sweden.

A. Introduction

Hello, my name is Phillip Mmilili Makwati and this is Andy Fink from Switzerland. We are students. We work for a project by the Botswana Ministry of Minerals, Energy and Water Resources in cooperation with Swedish government. For this project, we do a survey about the sanitary conditions and practices of Thamaga/Letlhakeng. Please tell us more about your problems and needs regarding sanitation and wastewater. This helps us to improve your situation. It will not take more than 30 minutes. Your answers will be treated confidential; we will not tell your name to anybody.

-----to be completed before interview start-----

A01 **Date** _____ A02 **Start time** _____ A03 **Ward** _____

A04 **How many households could not be interviewed before this household?** ____ households

B. Household characteristics

Thank you for your participation. First, we would like to learn more about the characteristics of this household.

B01a **What is your relation to the household head?**

1 ☐ I am the household head.
2 ☐ spouse
3 ☐ parent
4 ☐ brother/sister
5 ☐ son/daughter
6 ☐ other B01b **please specify:** _____

B02 **How long have you been living in this house?**

XX ___ years (since _____)
99 ☐ I have always lived here.
00 ☐ I don't know.

B03 **How many persons are currently living in this house (including children)?**

a ___ children (age 0-5) b ___ children (age 6-15)
c ___ men (age 16+) d ___ women (age 16+)

B04a **What is the main source of income of this household?**

1 ☐ farming
2 ☐ own business (e.g. shop owner, street vendor)
3 ☐ salary
4 ☐ family members living elsewhere/pension
5 ☐ other B04b **please specify:** _____

B05a **Does your household grow fruit or vegetables?**

1 ☐ Yes
2 ☐ No → ***skip C*** B05b **Why not?**
1 ☐ no land
2 ☐ no water
3 ☐ no fertilizer
4 ☐ no time
5 ☐ other: _____

C. Agriculture

You said you grow fruit or vegetables. We would like to learn more about this.

C01 **Do you sometimes sell the fruit or vegetables you are growing?**

1 ☐ Yes
2 ☐ No

C02 **Do you irrigate your plants?**

1 ☐ Yes
2 ☐ No

C03 **Where does the water for irrigation come from?**

_____

C04a **Would your household approve the use of greywater for irrigation?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

C04b **Would your neighbours approve if your household used greywater for irrigation?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

C05a **Would your household approve the use of blackwater for irrigation?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

C05b **Would your neighbours approve if your household used blackwater for irrigation?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

C06a **Do you use fertilizer?**

1 ☐ Yes C06b **What type?**
1 ☐ store bought (artificial)
2 ☐ manure
3 ☐ compost
4 ☐ contents of pits
2 ☐ No C06c **Why not?**
1 ☐ doesn't make a difference
2 ☐ too expensive
3 ☐ too far to go to get it
4 ☐ don't know what type/where to get
5 ☐ other: _____

C07a **Would your household approve the use of sewage sludge for fertilization?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

C07b **Would your neighbours approve if your household used sewage sludge for fertilization?**

1 ☐ Yes
2 ☐ No
3 ☐ Don't know

D. Access and use of toilet facilities

Now, we would like to learn more about the current situation in your household.

D01 **Does your household have electricity?**

1 ☐ Yes
2 ☐ No → ***D03***

D02a **How often are electricity service interruptions usually?**

1 ☐ multiple times a day
2 ☐ multiple times a week
3 ☐ multiple times a month
4 ☐ multiple times a year
5 ☐ once a year or less
9 ☐ do not know

D02b **How long are electricity service interruptions usually?**

1 ☐ 4 hours or less
2 ☐ 5 to 24 hours
3 ☐ 2 to 3 days
4 ☐ 4 days or more
9 ☐ do not know

D03 **What is the distance from the house to the next water tap (if inside house: =0, on own plot:=1)?**

____ minutes

D04a **How often are water service interruptions usually?**

1 ☐ multiple times a day
2 ☐ multiple times a week
3 ☐ multiple times a month
4 ☐ multiple times a year
5 ☐ once a year or less
9 ☐ do not know

D04b **How long are water service interruptions usually?**

1 ☐ 4 hours or less
2 ☐ 5 to 24 hours
3 ☐ 2 to 3 days
4 ☐ 4 days or more
9 ☐ do not know

D05a **What happens to the greywater used in the kitchen?**

_____

D05b **What happens to the greywater used for laundry and washing?**

_____

D06a **Is there a toilet on your plot (even if not working)?**

1 ☐ Yes
2 ☐ No → ***D10***

What type of toilet is it?

D06b
1 ☐ flush
2 ☐ pour flush
3 ☐ no water

D06c
1 ☐ to sewer
2 ☐ to tank
3 ☐ to VIP (with vent)
4 ☐ to pit

D07a **Is the toilet on your plot working at the moment?**

1 ☐ Yes
2 ☐ No *D07b* **Why?** _____

D08a **Is there a second toilet on the plot (even if not used)?**

1 ☐ Yes

D08b
1 ☐ flush
2 ☐ pour flush
3 ☐ no water

D08c
1 ☐ to sewer
2 ☐ to tank
3 ☐ to VIP (with vent)
4 ☐ to pit

2 ☐ No → ***D10***

D09a **Is the second toilet on your plot working at the moment?**

1 ☐ Yes → ***D12***
2 ☐ No *D09b* **Why?** _____

D10a **What is the main reason why you do not have a (working) toilet on your plot?**

1 ☐ no need
2 ☐ no land
3 ☐ no money
4 ☐ other *D10b* **please specify:** _____

D11a **Does your household have access to a shared toilet/your neighbour's toilet (even if not used)?**

1 ☐ Yes *D11b* 1 ☐ flush 2 ☐ pour flush 3 ☐ no water *D11c* 1 ☐ to sewer 2 ☐ to tank 3 ☐ to VIP (with vent) 4 ☐ to pit

2 ☐ No

D12 **Where do most of the members of the household usually ease themselves (including yourself)?**

1 ☐ in own private toilet
2 ☐ in shared/neighbour's toilet
4 ☐ in the bush
9 ☐ prefer not to say

D13 **Do you use this toilet facility also at night?**

1 ☐ Yes
2 ☐ No

D14a **Where do children under age of 6 usually ease themselves?**

1 ☐ There are no children below 6 in this household.
2 ☐ same toilet as adults
3 ☐ drainage
4 ☐ in the bush
5 ☐ other *D14b* **please specify:** _____
9 ☐ prefer not to say

D15 **What is the distance from the household to the toilet the household uses?**
(if inside house: =0, on own plot:=1)

____ minutes

D16 **With how many households do you share the toilet?**

____ households / ____ stances = *xx* ____ households per toilet

E. Management capacity

E01 **How full is the toilet facility you are using?**

1 ☐ full (76 to 100%)
2 ☐ half filled (25 to 75 %)
3 ☐ empty (0 to 24%)
9 ☐ do not know

E02 **Was the facility ever emptied?**

1 ☐ Yes
2 ☐ No → ***F01***

E03a **Who emptied the facility?**

1 ☐ council
2 ☐ private contractor
3 ☐ emptied it ourselves
4 ☐ other *E03b* **please specify:** _____
9 ☐ do not know

E04 **How satisfied ("happy") were you with the emptying service?**

1 ☐ very satisfied → ***E06***
2 ☐ somewhat satisfied
3 ☐ somewhat dissatisfied
4 ☐ very dissatisfied

E05 **What would you suggest to improve the emptying service?**

_____

_____

_____

E06 **When told the tank was full, how long did it take for them to come to empty it?**

1 ☐ 0 to 7 days
2 ☐ 8 to 31 days
3 ☐ 2 to 3 months
4 ☐ 4 to 6 months
5 ☐ more than 6 months
6 ☐ they never came
9 ☐ do not know

E07 **Where was it emptied to?**

_____

F. Satisfaction with current toilet facility

Now, we would like ask a few questions about how happy you are with the current situation.

F01 **How satisfied ("happy") are you with the toilet facility you normally use?**

1 ☐ very satisfied
2 ☐ somewhat satisfied
3 ☐ somewhat dissatisfied
4 ☐ very dissatisfied

F02 **What do you think are the 3 major advantages of the toilet facility your household normally uses?**

1. _____
2. _____
3. _____

F03 **What do you think are the 3 major problems of the toilet facility your household normally uses?**

1. _____
2. _____
3. _____

F04 **5 years ago, the sanitary conditions were…?**

1 ☐ better
2 ☐ the same
3 ☐ worse

F05a **What products do you use to clean your toilet?**

1 ☐ detergent — *F05b* **brand if known:** _____
2 ☐ soap
3 ☐ water
4 ☐ other — *F05b* **please specify:** _____
5 ☐ none
9 ☐ do not know

F06a **What cleaning products do you use for laundry?**

1 ☐ detergent — *F06b* **brand if known:** _____
2 ☐ soap
3 ☐ water
4 ☐ other — *F06b* **please specify:** _____
5 ☐ none
9 ☐ do not know

G. Sanitation costs

Please let me ask a few questions about the costs for sanitation now.

G01 **Who paid for the <u>construction</u> of the toilet your household uses (multiple answers possible)**

1 ☐ landlord
2 ☐ our household
3 ☐ other sharing households
4 ☐ NGO/project
5 ☐ National Rural Sanitation Programme (NRSP)
6 ☐ other governmental programmes (e.g. presidential poverty eradication programme)
7 ☐ building loans (SHESP/SHAA/ESPP/turnkey)
9 ☐ do not know
0 ☐ We do not use a constructed toilet. ***→ G04***

G02 **Who pays for <u>repair/emptying</u> of the toilet your household uses (multiple answers possible)?**

1 ☐ landlord
2 ☐ our household
3 ☐ other sharing households
4 ☐ NGO/project
5 ☐ government
9 ☐ do not know

G03 *for users of private or shared toilet:*

If there was a <u>sewer network</u> installed, what would you be willing to contribute (multiple answers possible)?

1 ☐ one-time fee to connect my private toilet — max. BWP _____
2 ☐ monthly fee for usage of the sewer — max. BWP _____
3 ☐ cannot pay money, but would be willing to help constructing — max. ____ workdays
4 ☐ I would not pay anything or help constructing (government must pay).
9 ☐ do not know/prefer not to say

G04 *for users of shared or no toilet:*

If there was a <u>private</u> toilet facility for your household installed, what would you be willing to contribute (multiple answers possible)?

1 ☐ one-time fee to construct my private toilet — max. BWP _____
2 ☐ monthly fee for usage of my private toilet — max. BWP _____
3 ☐ cannot pay money, but would be willing to help constructing — max. ____ workdays
4 ☐ I would not pay anything or help constructing (government must pay).
9 ☐ do not know/prefer not to say

G05 *for users of no toilet:*

If your household got access to a shared toilet facility, what would you be willing to contribute (multiple answers possible)?

1 ☐ fee per use max. BWP _____
2 ☐ fee per month per household max. BWP _____
3 ☐ cannot pay money, but would be willing to help constructing max. ____ workdays
4 ☐ cannot pay money, but our household could help cleaning
5 ☐ I would not pay anything or help constructing (government must pay).
9 ☐ do not know/prefer not to say

G06 *for users of no toilet:*

What would be the maximum number of households you would accept to share with?

1 ☐ I would not use a shared toilet.
2 ☐ max. 1 household
3 ☐ max. 2 to 3 households
4 ☐ max. 4 to 5 households
5 ☐ max. 6 or more households

H. Sanitation service requirements

Skip section for housholds (i) with santiation today and (ii) happy with the system they have today

In the project, we are looking for new solutions to improve your satisfaction with the sanitation services. To design a toilet that satisfies you most, please answer our questions on how important the following properties are.

H01 **How important is it for you to have a private toilet?**

5 ☐ very important
4 ☐ rather important
3 ☐ neither important nor unimportant
2 ☐ rather unimportant
1 ☐ very unimportant

H02 **How important is it for you to have separate toilets for men and women?**

5 ☐ very important
4 ☐ rather important
3 ☐ neither important nor unimportant
2 ☐ rather unimportant
1 ☐ very unimportant

H03 **How important is it for you to have a toilet that does not smell badly?**

5 ☐ very important
4 ☐ rather important
3 ☐ neither important nor unimportant
2 ☐ rather unimportant
1 ☐ very unimportant

H04 **How important is it for you to have a clean toilet?**

5 ☐ very important
4 ☐ rather important
3 ☐ neither important nor unimportant
2 ☐ rather unimportant
1 ☐ very unimportant

H05 **How important is it for you to have an inexpensive toilet?**

5 ☐ very important
4 ☐ rather important
3 ☐ neither important nor unimportant
2 ☐ rather unimportant
1 ☐ very unimportant

H06 **How important is it for you that your toilet is close to your house?**

- *5* ☐ very important
- *4* ☐ rather important
- *3* ☐ neither important nor unimportant
- *2* ☐ rather unimportant
- *1* ☐ very unimportant

H07 **How important is it for you that you do not have to wait when using the toilet?**

- *5* ☐ very important
- *4* ☐ rather important
- *3* ☐ neither important nor unimportant
- *2* ☐ rather unimportant
- *1* ☐ very unimportant

H08 **How important is it for you that your toilet is rarely broken?**

- *5* ☐ very important
- *4* ☐ rather important
- *3* ☐ neither important nor unimportant
- *2* ☐ rather unimportant
- *1* ☐ very unimportant

H09 **How important is it for you that your toilet does not create any harm to nature or health?**

- *5* ☐ very important
- *4* ☐ rather important
- *3* ☐ neither important nor unimportant
- *2* ☐ rather unimportant
- *1* ☐ very unimportant

I. End of the survey

Thank you for answering all our questions. We will now analyse your comments and then we will propose improved systems based on your answers. Is there any other remark or comment you would like to make?

I01 **Comments/Remarks by the interviewee**

J. Observations by the interviewer

------to be completed after the interview ------

J01a **End time** _____ *J01b* **Duration** ____ minutes

J02 **Site**

- *1* ☐ Thamaga
- *2* ☐ Letlhakeng

J03 **What gender was the main interviewee?**

- *1* ☐ male
- *2* ☐ female

J04 **Were other persons present and listening during any time of the interview (multiple answers possible)?**

- *1X* ☐ Yes
  - *11* ☐ interpreter
  - *12* ☐ household members
  - *13* ☐ neighbour/others
- *20* ☐ No

J05 **Is this toilet accessible enough to be emptied with a vacuum truck?**

- *1* ☐ Yes
- *2* ☐ No
- *9* ☐ Cannot say

J06 **Is there any visible excreta around the household or in the direct neighbourhood?**

- *1* ☐ Yes
- *2* ☐ No

J07 **Were any pictures taken during the interview?**

- *1* ☐ Yes
- *2* ☐ No

J08 **Comments/Remarks by the interviewer**

8.2 Stakeholder interviews

8.2.1 Interview questionnaire

Example questionnaire from interview with Mrs B. Mathangwane:

Stakeholder interview questionnaire

Name:	Bogadi Mathangwane
Organisation:	Department of Water Affairs
Position within organisation:	Deputy Director
Date of interview:	18 December 2012, 9.00 - 9.45 a.m.

About me and my project

Myself: student from Switzerland, environmental sciences, age 22, in BW since September, for 3 months

My project: corporation between governments of Sweden and Botswana. Workshops, experts from Sweden and BW, two students writing MSc thesis about this project. Aim: to improve sanitation conditions in the villages of Thamaga and Letlhakeng. Before we come up with solutions, we want to understand the stakeholders' views on the situation – therefore this interview, many thanks again for your participation.

About you and your organisation

Yourself: background, how long have you been working for DWA?

DWA: What are the main challenges DWA is currently facing in Botswana? What are the main achievements made by DWA? What are DWAs expectations to the project? Where do you see the role of DWA in the project? Has DWA undertaken any initiatives to raise awareness for water scarcity? What is your opinion about the water restrictions that are currently in place? Do they work? Guidelines on greywater reuse – status, idea?

About the local context

Thamaga: Where do you see the challenges in the current sanitation conditions? How could we address these challenges? Do you have any experience from other projects in this village? Is there anything particular in your eyes we need to consider about Thamaga?

Letlhakeng: Where do you see the challenges in the current sanitation conditions? How could we address these challenges? Do you have any experience from other projects in this village? Is there anything particular in your eyes we need to consider about Letlhakeng?

Solutions for households

What expectations do households have with respect to such a project? How can we make sure to improve conditions sustainably and successfully?

What do you think would be an optimal system for households in Thamaga (peri-urban Botswana)?

What do you think would be an optimal system for households in Letlhakeng (rural Botswana)?

Solutions for institutions

What do you think would be an optimal system for institutions (e.g. schools and clinics)?

How could we address maintenance and vandalism issues in institutions? Who should take responsibility for the facilities?

Goals of this interview (check if achieved before going home):

- ☐ DWAs role and potential influence on the project
- ☐ DWAs understanding of the problems and challenges
- ☐ Status of greywater guidelines

Stakeholder assessment – levels of interest, influence, impact and support:																
Interest				**Influence**				**Impact**				**Support**				**Total**
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	

8.2.2 List of Interviewees

Table 7. List of interviewed stakeholders.

Name	Organisation	Position within organisation	Date of interview
Public authorities			
Bogadi Mathangwane	Department of Water Affairs	Deputy Director	18.12.2012
Audrey Kgomotso	Department of Waste Management and Pollution Control	Research and Development Division	02.11.2012
Tshimologo Matladi	Department of Waste Management and Pollution Control	Environmental Engineer	14.11.2012
Simon Basinyi	Department of Crop Production	Irrigation Engineer	20.11.2012
Phenyo Gaamangwe	Kweneng District Council	Environmental Health Officer	28.11.2012
Joseph Banyatsang	Kweneng District Council	Chief Public Health Officer	13.12.2012
Academic institutions			
Dr. Phillimon Odirile	University of Botswana	Lecturer	22.11.2012
Prof. Dr. Benjamin Bolaane	University of Botswana	Head of Department	27.11.2012
Non-governmental organizations			
Kutlwano Mukokomani	Kalahari Conservation Society	Project Administrator IWRM Botswana	26.11.2012
Wastewater service providers			
Bantou Kealotswe	Water Utilities Corporation	Water Quality Section	18.10.2012
Seabe Mabua	Water Utilities Corporation	Water Works Engineer	27.11.2012
Seanokeng Molomo	Water Utilities Corporation	Senior Risk Officer	29.11.2012
Chris Simon	SkipHire	General Manager	07.11.2012
Boikanyo Koosimile	Sani Care	Managing Director	28.11.2012
Emlyn D. Narsi	Multi Waste (Pty) Ltd.	General Manager	29.11.2012
Sanitation technology providers			
Stefan Ortwein	Gendarme Sanitation Systems (Pty) Ltd.	Marketing Director	01.11.2012
John Hunter-Hardy	Gendarme Sanitation Systems (Pty) Ltd.	Managing Director	19.12.2012
Radovic Velimir	PR Green Paradise (Pty) Ltd	General Manager	11.12.2012
Farming sector			
Mma Kgarubane		Farmer	19.11.2012
Kwenantle Gaseitsiwe	Farmer's Magazine Botswana	Publisher	22.11.2012

8.2.3 STEEPLED Analysis

Table 8. List of chosen STEEPLED factors and corresponding literature sources (amended from Gendre 2012). Relevant factors are indicated in bold.

STEEPLED Factors	Source (Literature)
Social aspects	
Hygiene and public health: risk of infection for household and/or environment	Lennartsson et al. 2009; Lüthi, Panesar, et al. 2011
Defecation practices	McConville 2008
Safety	Lennartsson et al. 2009
Private, shared, public	Günther et al. 2012
Convenience for user	Lennartsson et al. 2009
Religion	Lüthi, Panesar, et al. 2011
Gender	Lüthi, Panesar, et al. 2011; WHO 2006
Behavioural change	McConville 2010; McConville 2008; WHO 2006
Information and education programs	WHO 2006
Technological aspects	
Water availability	Tilley et al. 2008
Wastewater infrastructure	Larsen et al. 2010
Type of housing and setting	Larsen et al. 2010
Adapt existing infrastructure	Lüthi, Panesar, et al. 2011
System robustness (vulnerability to power cuts, water shortages etc.)	McConville 2010; Lüthi, Panesar, et al. 2011
Operation and maintenance	McConville 2008; Tilley et al. 2008
Complexity of construction	Lennartsson et al. 2009
Availability of construction material	Tilley et al. 2008
Local serviceability	McConville 2008
Economic aspects	
National resources for sanitation	Larsen et al. 2010
Capital and O&M costs	Lennartsson et al. 2009; Tilley et al. 2008
Market for sanitized products, Energy (biogas)	Lüthi, Panesar, et al. 2011
Cost recovery	McConville 2008
Willingness / capacity to pay	McConville 2008
Ecological aspects	
Water scarcity	Larsen et al. 2010
Resource consumption and conservation	McConville 2010
Groundwater contamination	McConville 2010
Potential for reuse of water	Lennartsson et al. 2009
Potential for reuse of nutrients	Lennartsson et al. 2009

Political aspects	
Time frame of politicians	Larsen et al. 2010
National Strategies and policies	WHO 2006; Swatuk & Rahm 2004
Involvement of key leaders	McConville 2008
Management capacity of public institutions	McConville 2010
Institutional roles and responsibilities	WHO 2006; Swatuk & Rahm 2004

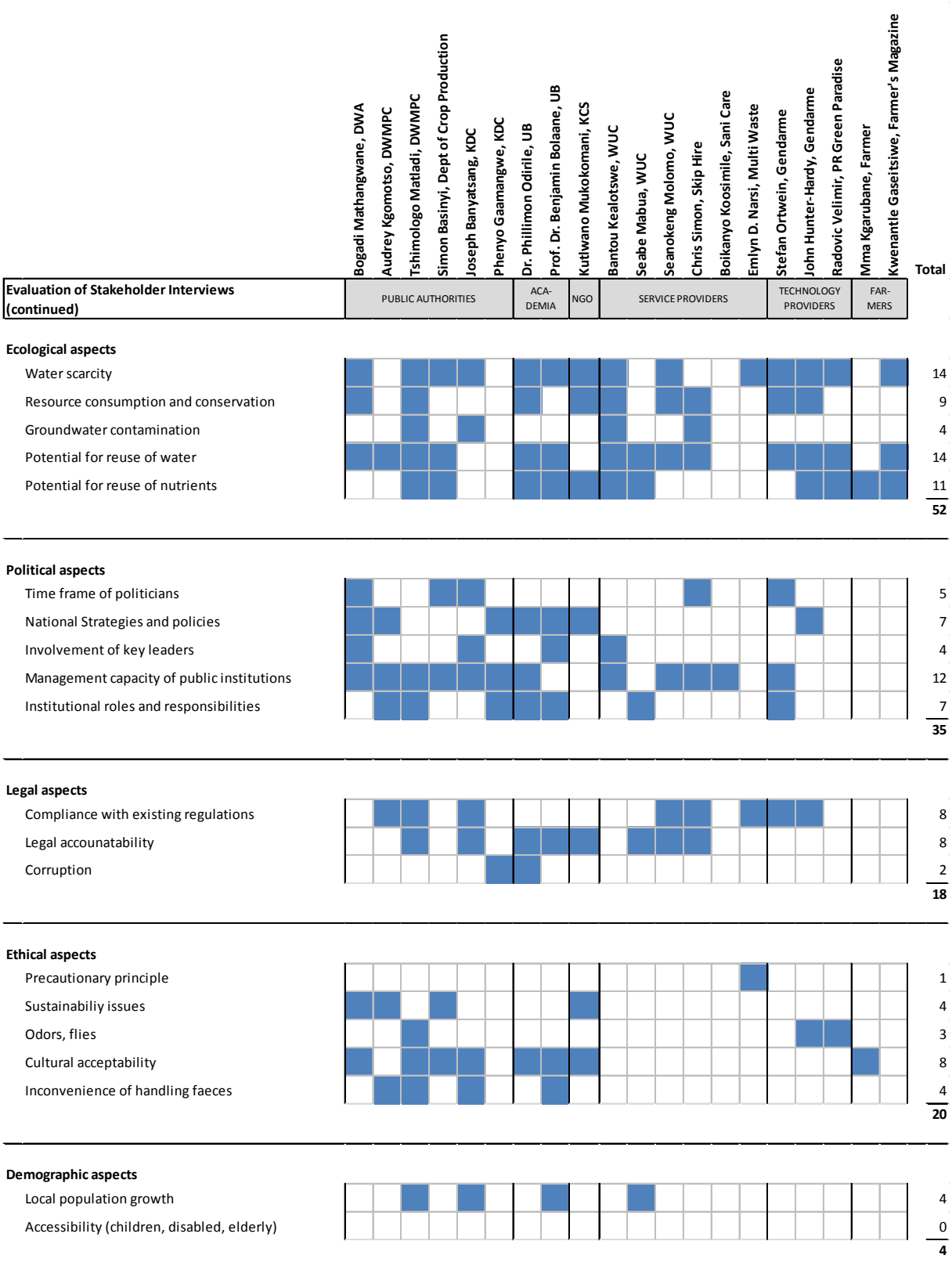
Legal aspects	
Compliance with existing regulations	Lüthi, Panesar, et al. 2011
Legal accountability	Swatuk & Rahm 2004
Corruption	Lüthi, Morel, et al. 2011

Ethical aspects	
Precautionary principle	Larsen et al. 2010
Sustainability issues	Larsen et al. 2010
Odours, flies	Lennartsson et al. 2009; Tilley et al. 2008
Cultural acceptability	McConville 2008
Inconvenience of handling faeces	WHO 2006

Demographic aspects	
Local population growth	Larsen et al. 2010
Accessibility (children, disabled, elderly)	Groce et al. 2011

Table 9. STEEPLED Evaluation of stakeholder interviews. Blue highlighted fields represent statements made by the interviewee which match to the corresponding STEEPLED factor. The last column shows the total number of interviewees with statements related to the STEEPLED factors.

Evaluation of Stakeholder Interviews	Bogadi Mathangwane, DWA (PUBLIC AUTHORITIES)	Audrey Kgomotso, DWMPC (PUBLIC AUTHORITIES)	Tshimologo Matladi, DWMPC (PUBLIC AUTHORITIES)	Simon Basinyi, Dept of Crop Production (PUBLIC AUTHORITIES)	Joseph Banyatsang, KDC (PUBLIC AUTHORITIES)	Phenyo Gaamangwe, KDC (PUBLIC AUTHORITIES)	Dr. Phillimon Odirile, UB (ACA-DEMIA)	Prof. Dr. Benjamin Bolaane, UB (ACA-DEMIA)	Kutlwano Mukokomani, KCS (NGO)	Bantou Kealotswe, WUC (SERVICE PROVIDERS)	Seabe Mabua, WUC (SERVICE PROVIDERS)	Seanokeng Molomo, WUC (SERVICE PROVIDERS)	Chris Simon, Skip Hire (SERVICE PROVIDERS)	Boikanyo Koosimile, Sani Care (SERVICE PROVIDERS)	Emlyn D. Narsi, Multi Waste (SERVICE PROVIDERS)	Stefan Ortwein, Gendarme (TECHNOLOGY PROVIDERS)	John Hunter-Hardy, Gendarme (TECHNOLOGY PROVIDERS)	Radovic Velimir, PR Green Paradise (TECHNOLOGY PROVIDERS)	Mma Kgarubane, Farmer (FAR-MERS)	Kwenantle Gaseitsiwe, Farmer's Magazine (FAR-MERS)	Total
Social aspects																					
Hygiene and public health: risk of infection for household and/or environment			■		■		■	■								■	■	■	■		8
Defacation practices													■								1
Safety																					0
Private, shared, public																					0
Convenience for user					■		■	■				■				■					5
Religion																					0
Gender									■												1
Behavioral change	■	■	■	■	■		■	■	■			■								■	10
Information and education programs	■	■	■	■	■		■	■	■	■	■			■	■	■		■		■	15
																					40
Technological aspects																					
Water availability		■	■	■	■	■	■	■	■		■	■					■				11
Wastewater infrastructure		■			■		■			■			■								5
Type of housing and setting				■			■					■									3
Adapt existing infrastructure		■									■									■	3
System robustness (vulnerability to power cuts, water shortages etc)								■	■				■	■				■			5
Operation and maintenance	■	■	■		■	■	■	■		■			■		■	■	■	■			13
Complexity of construction		■											■					■			3
Availability of construction material		■		■			■								■						4
Local serviceability		■	■						■	■	■						■				6
																					53
Economic aspects																					
National resources for sanitation	■	■	■			■	■				■		■	■		■					9
Capital and O&M costs			■			■		■	■	■		■	■	■		■	■	■			11
Market for sanitized products, Energy (biogas)		■																			1
Cost recovery		■			■			■	■	■	■	■	■								8
Willingness / capacity to pay			■		■	■	■	■		■	■	■	■			■					10
																					39


Bogadi Mathangwane, DWA
Audrey Kgomotso, DWMPC
Tshimologo Matladi, DWMPC
Simon Basinyi, Dept of Crop Production
Joseph Banyatsang, KDC
Phenyo Gaamangwe, KDC
Dr. Phillimon Odirile, UB
Prof. Dr. Benjamin Bolaane, UB
Kutlwano Mukokomani, KCS
Bantou Kealotswe, WUC
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Seanokeng Molomo, WUC
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Emlyn D. Narsi, Multi Waste
Stefan Ortwein, Gendarme
John Hunter-Hardy, Gendarme
Radovic Velimir, PR Green Paradise
Mma Kgarubane, Farmer
Kwenantle Gaseitsiwe, Farmer's Magazine
Total
Evaluation of Stakeholder Interviews (continued)
PUBLIC AUTHORITIES
ACA-DEMIA
NGO
SERVICE PROVIDERS
TECHNOLOGY PROVIDERS
FAR-MERS
Ecological aspects
Water scarcity 14
Resource consumption and conservation 9
Groundwater contamination 4
Potential for reuse of water 14
Potential for reuse of nutrients 11
52
Political aspects
Time frame of politicians 5
National Strategies and policies 7
Involvement of key leaders 4
Management capacity of public institutions 12
Institutional roles and responsibilities 7
35
Legal aspects
Compliance with existing regulations 8
Legal accounatability 8
Corruption 2
18
Ethical aspects
Precautionary principle 1
Sustainabiliy issues 4
Odors, flies 3
Cultural acceptability 8
Inconvenience of handling faeces 4
20
Demographic aspects
Local population growth 4
Accessibility (children, disabled, elderly) 0
4

8.3 Maps

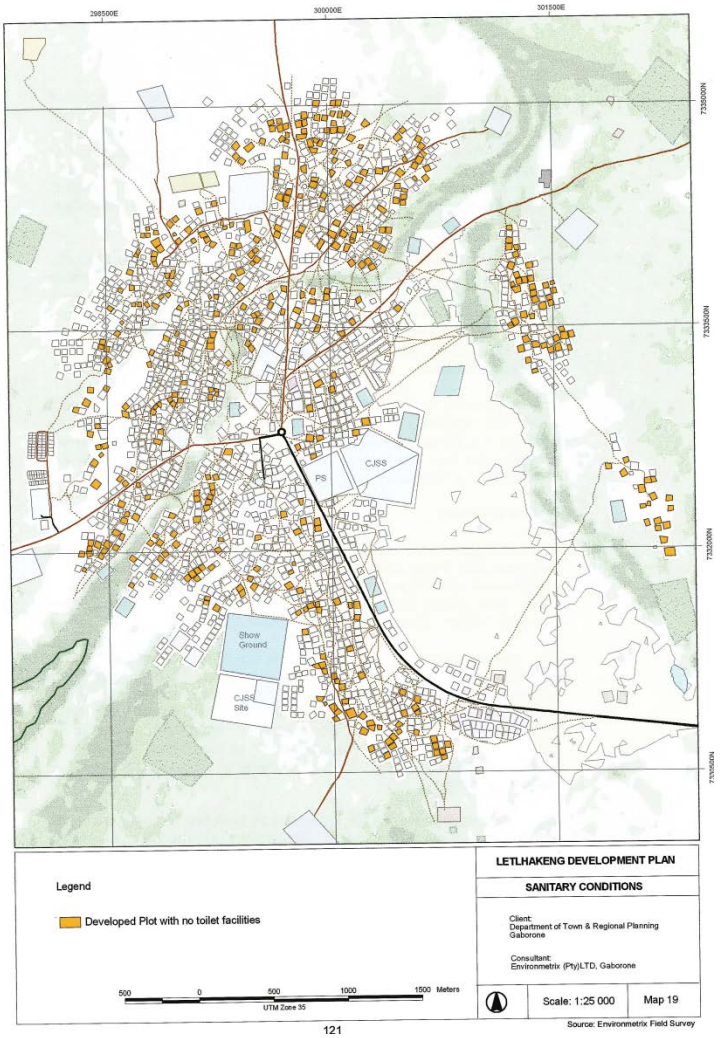

Figure 23. Sanitary conditions in Letlhakeng. Developed plots with no toilet facilities are indicated in orange.(Map prepared for the Letlhakeng development plan; Source: Loci 2012)

8.4 Attached CD-ROM

There is a CD-ROM with additional material attached to this thesis. All the materials on the CD-ROM can also be accessed online at: https://www.dropbox.com/sh/kzmm5ap1tnug64l/UafGxATQOL?m.

1. Thesis
    A. Final version in PDF Format
    B. Editable version of own illustrations
2. Presentations
    A. 08 Nov 2012| Presentation of survey results to Sweden project team
    B. 10 Jan 2013 | Presentation for mid-term meeting with supervisor
    C. 25 Feb 2013 | Final presentation of thesis to Sandec group and supervisors
3. Research Proposal
4. Village Workshops
    A. Minutes Workshop 1
    B. Participants Lists Workshop 1
    C. Reports Workshop 1 *(Kvarnström 2012a; Kvarnström 2012b)*
    D. Minutes Workshop 2
    E. Participants Lists Workshop 2
    F. Technology Evaluation results Workshop 2 *(prepared by E. Kvarnström)*
5. School Workshops
    A. Report from School Workshops *(Fink 2012)*
    B. Further Documentation
6. Household Survey
    A. Questionnaires from Other Projects
    B. Survey Questionnaire
    C. Raw Data Excel File
    D. Raw Data SPSS File
    E. Analyzed Data
7. Stakeholder Interviews
    A. Questionnaires
    B. Answers
    C. List of Interviewees Including Contact Data
    D. Analysis of Interviews (Relevance & STEEPLED)
8. Photos