



The Sanitary Situation in Bulyaheke, Sengerema District, Tanzania

A Study of Problems Linked to Lacking Sanitation in Rural
Tanzania and Possible Solutions

Master's thesis in the Master's Programme Infrastructure and Environmental
Engineering

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Cover:

The existing toilet facility for the students at Bulyaheke and Mandela Primary school.

Department of Architecture and Civil Engineering

Göteborg, Sweden 2020

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ABSTRACT

In developing countries, such as Tanzania, lacking sanitation is strictly linked to waterborne diseases with death as a potential outcome. Sufficient sanitation is therefore considered a human right and is addressed in both the Millennium Development Goals and the Sustainable Development Goals. In this study, the aim was to identify the reasons behind the lacking sanitary situation in the village Bulyaheke, rural Tanzania, but also to evaluate possible solutions to improve the situation when it comes to both toilet- and water access facilities. This was accomplished using qualitative research where interviews were combined with observations in the field and a literature study. The data gathered was later analysed using thematic analysis and the findings revealed that the situation was particularly bad at the two schools, as they had a low number of toilets together with limited access to water for hygiene purposes. To increase the standards for the students, different toilet- and water access facilities were evaluated and compared, resulting in the Ecological Sanitation facility, Fossa Alterna, and Rainwater Harvesting being the most appropriate solutions for the specific conditions. Furthermore, the implementation of such solutions would have to be through the Tanzanian Government in collaboration with external funders. This, as representatives from the government stated that they cannot provide funding for local projects. They did however express that in the long-term they want to be independent, and the money invested should therefore be used to 'help them, to help themselves'. A way to achieve this is therefore to implement pilot projects at the two schools where improvements are most needed, and thereby inspire the inhabitants to adopt the technologies at their homes.

Keywords: Ecological Sanitation, Rainwater Harvesting (RWH), Sanitation, Sanitation facilities, Self-help, Toilet facilities, Water Access facilities

Den Sanitära Situation i Bulyaheke, Sengeremadistriktet, Tanzania

En Studie av Problem till Följd av den Bristande Sanitära Situationen på Tanzanias Landsbygd
och Möjliga Lösningar

Examensarbete inom mastersprogrammet Infrastruktur och Miljöteknik

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SAMMANFATTNING

I utvecklingsländer är bristande sanitet starkt kopplat till vattenburna sjukdomar, vilket också är fallet för Tanzania, där en dödlig utgång inte är helt ovanligt. Att ha tillgång till väl fungerande sanitetslösningar anses därför vara en mänsklig rättighet, och ämnet är också inkluderat i Milleniemålen och i de globala målen för hållbar utveckling. Syftet med denna studie har varit att identifiera de bakomliggande orsakerna för den bristande sanitära situationen i byn Bulyaheke, på Tanzanias landsbygd, men även att utvärdera möjliga lösningar för att förbättra situationen, både när det kommer till toalettlösningar och vattentillgångsanläggningar. Detta gjordes genom en kvalitativ studie, där intervjuer kombinerades med observationer ute i fält, samt en litteraturstudie, där data sedan analyserades med hjälp av tematisk analys. Det framkom under studien att den sanitära situationen i byn var ohållbar, men framförallt i de två skolorna på grund av det låga antalet toaletter i kombination med en begränsad tillgång till vatten för hygiensyften. För att öka standarden för studenterna har olika toalettlösningar och vattentillgångsanläggningar utvärderats och jämförts, vilket resulterade i att Fossa Alterna, en ekologisk sanitetslösning, tillsammans med regnvattenuppsamling var mest lämpliga för de specifika förhållandena. Implementeringen av dessa lösningar bör genomföras i samarbete mellan den tanzaniska regeringen och utomstående finansiärer, detta då representanter från regeringen förmedlade att de inte har kapacitet att själva finansiera lokala projekt. Trots det, så uttryckte dem en önskan om att i framtiden kunna vara självständiga och oberoende av bidrag för landets utveckling, vilket har lett fram till en strategi med fokus på att 'hjälpa befolkningen, att hjälpa sig själva'. Ett sätt att uppnå detta är därför att initiera ett pilotprojekt på de två skolorna, där behoven är som störst, och därigenom inspirera andra i byn att tillämpa liknande lösningar hemma.

Nyckelord: Ekologisk Sanitet, Regnvattenuppsamling, Sanitet, Sanitetsfaciliteter, Självhjälp, Toalettlösningar, Vattentillgångsanläggningar

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PREFACE

The outcome of this study would not have been possible without the involvement from several parties. First, we want to thank Engineers Without Borders Sweden for the initiation of the project and their support along the way. We also want to thank the members of Fishers Union Organisation in Tanzania for their support with practicalities, translation and logistics during the field trip to Bulyaheke. The achievements would not have been the same without their support and guidance. Also, the contribution from the inhabitants of Bulyaheke was of great importance for the outcome of the study. Furthermore, we want to thank the District Water Engineer in Sengerema District for the valuable information provided and the time invested. Our thanks also go to the NGO commissioner office in Mwanza for their interest in, and kind words about the project.

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Elin Augustsson & Angelica Nylund, Gothenburg, May 2020

ABBREVIATIONS

CDC - Centers for Disease Control and Prevention
CUoT - Chalmers University of Technology
DWE - District Water Engineer
EcoSan - Ecological Sanitation
EWB-SWE - Engineers Without Borders Sweden
FUO - Fishers Union Organisation
MDGs - Millennium Development Goals
NGO - Non-Governmental Organisation
PE - Principal Economist
RCDO - Regional Community Development Officer
RUWASA - Rural Water Supply and Sanitation Agency
RWH - Rainwater Harvesting
SDGs - Sustainable Development Goals
SWASH - School Water, Sanitation and Hygiene
UN - United Nations
VIDP Latrine - Ventilated Improved Double Pit Latrine
VIP Latrine - Ventilated Improved Pit Latrine
WASH - Water, Sanitation and Hygiene
WHO - World Health Organisation
WSP - Water and Sanitation Program

DEFINITIONS

Excreta - Urine and faeces
Faeces - Not mixed with urine or flush water
Hazard - Event/object that can cause harm
Risk - The chance that any hazard will cause harm
Defecation - Discharge of faeces from humans
Open defecation - Practising defecation in the nature (field, open waters, bushes, etc.)

1. INTRODUCTION

Sanitation is an important global issue that was first addressed, internationally, in the early 1980s when a joint effort was incorporated to improve the global water and sanitary situation in the world (Institute of Medicine (US) Roundtable on Environmental Health Sciences, Research, and Medicine, 2009). This was later followed by other initiatives and included in the UN's Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs). One of the UNs (2015) MDGs, goal number seven, was to “*Ensure environmental sustainability*” (p.52). It was divided into several targets, one being “*Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation*” (p.58). This was however not fully achieved, even though the combined effort managed to accomplish great improvements globally. The number of people that gained access to improved sanitation during the period of the MDGs (2000-2015) reached 2.1 billion, and when comparing to 1990, the open defecation almost decreased by half. However, in 2017, the number of people still practising open defecation was 701 million (UN, 2019) and 62 per cent of the population (~3 billion people) in developing countries did not have access to handwashing facilities at their homes.

Furthermore, the importance of hygiene was not included in the sanitation concept in the MDGs, but it was later incorporated in the SDGs (UN, 2019), where goal number six was to ensure availability and sustainable management of water and sanitation worldwide. This after being highlighted by the WASH initiative (UNICEF, 2016a), which aims to teach basic sanitation and hygiene in developing countries (UN, n.d.). The SDGs also points out that in 2016, there was a lack of water, sanitation and hygiene services at one-third of all primary schools (UN, 2019). This is especially affecting the female students during menstruation. Furthermore, a lack of sanitation and hygiene facilities constitutes a hazard by potential spreading of waterborne diseases, and it has been estimated that two million individuals, where the majority are children, die each year of diarrheal diseases (UNICEF, 2016a). A large proportion of these is due to the lack of access to safe water and sanitation. Identifying the risk objects and the exposure pathways linked to such a hazard could help reduce the spreading and thereby increase the human health.

1.1 PROBLEM STATEMENT

One of the contributing factors to lacking water quality and spreading of waterborne diseases is poor sanitation, originating from insufficient wastewater- and hygiene facilities (World Health Organization, 2019). Lacking sanitation can also lead to contamination of surrounding soil and groundwater, affecting communities and activities that requires water.

Water quality issues have been reported in Bulyaheke, a village in rural Tanzania. A previous study performed by Fransson and Werner in 2019 (*Feasibility of SODIS as a Household Water Treatment Method in Rural Tanzania*) found that the water was insufficient and below existing standards for drinking water quality (2019). If contaminated water is used for e.g. personal hygiene, cleaning or irrigation, further spreading and exposure of the contaminants are risked (Centers for Disease Control and Prevention, 2018). In addition, there was a cholera outbreak in Bulyaheke in 2016 where almost one-third of the population was affected, leading to 260 deaths (personal communication with EWB-SWE, 18th of June 2019). This, in combination

with the above mentioned factors, makes the sanitary situation in Bulyaheke an important issue to address as the previous study did not investigate the origin of the drinking water quality problem.

1.2 AIM

The aim of this study is to investigate the origin of the sanitary problems in Bulyaheke. To reach this aim, a risk analysis will be performed in conjunction with a field study. Furthermore, possible solutions that can be implemented to improve the situation will be evaluated, focusing on toilet- and water access facilities. The purpose is also to evaluate what type of solution that provides the best outcome regarding its technical requirements, suitability, availability, need of maintenance, implementation efforts and investment cost. Furthermore, the study and its findings will hopefully work as a guiding document for future projects and implementation of solutions in Bulyaheke. Finally, the report could also be used as a supportive document for Fishers Union Organisation (FUO), the local organisation, when applying for funding and future recruiting of volunteers and companies.

1.3 RESEARCH QUESTIONS

To fulfil the aim of this study and to further contribute to the development of the village Bulyaheke, the following research questions have been specified:

- What are the main reasons for the lacking sanitation in the area?
- What does the open defecation situation look like, are there any toilets and are they being used?
- On what level is the locals' knowledge about sanitation and its connection to diseases?
- Based on the outcome of the previous questions, how can the sanitary situation be improved in a sustainable way in order to reduce the spreading of diseases?
- How can the maintenance of the found solution(s) be secured?
- Who is responsible for the sanitation situation in the area and how can the construction of the found solution(s) be implemented?

1.4 LIMITATIONS

The study is limited to only cover the mapping of sanitation issues, which originates from the lack of water- and wastewater infrastructure, and to evaluate possible solutions to these problems. It will therefore not include physical construction. Moreover, the limitations are also connected to the feasibility of the study. In order to reduce the uncertainties regarding the completion of the study, an identification of possible risks affecting the outcome has been performed and an action plan has been established, see *Appendix I*. Another limitation is the location of the village, being in the rural parts of Tanzania, making the accessibility an important factor.

2. BACKGROUND

2.1 TANZANIA

Tanzania mainland, previously called Tanganyika, and Zanzibar island got independence from Great Britain in 1961 respectively 1963 (BBC, 2018). The following year, 1964, Zanzibar and Tanganyika became The Republic of Tanzania, making it a relatively young country. While the economic growth has been steady, Tanzania remains one of the poorest countries in the world (Globalis, 2018).

Tanzania is a Sub-Saharan country located in the south-east of Africa with borders to the Indian Ocean in the east and to Lake Victoria, one of the world's largest water bodies, in the north-west, see Figure 1. Moreover, it borders eight other African countries.



Figure 1. The African continent, where the red arrow points out the location of Tanzania. This map is based on the United Nations map: Africa, Map No. 4045 Rev.8.1, July 2018, UNITED NATIONS (UN, 2018). Reprinted with permission and edited.

In the Sub-Saharan region, 48 out of 54 African countries included (World bank, 2019), the amount of people using improved sanitation facilities increased from 24 to 30 per cent between 1990 and 2015 (UN, 2015). To further continue the upward trend, significant investments together with technical solutions and political approval are required (Moe & Rheingans, 2006).

Moreover, it was estimated that to be able to reach the MDGs regarding sanitation in the Sub-Saharan region, 44 300 toilets had to be built each day during the time period between 2002 and 2015. The cost for this investment, assuming basic dry sanitation (i.e. no use of water for disposal of human excreta) was estimated to be \$4.4 million USD per day.

The two largest cities in Tanzania are Dar es Salaam and Mwanza city, where the latter one is located by Lake Victoria. Despite this, the inhabitants in the rural parts of Mwanza region face challenges in their daily life; both when it comes to access to clean water, and consequently, also, sanitation (Scheren, Zantig & Lemmens, 2000; Fransson & Werner, 2019). The problem originates from the escalating contamination of the lake due to increased transportation, and the expanded industrial and agricultural activities along the lake. The increased contamination is a direct response to a growing population, making the water a potential hazard if not handled properly by the user (UNICEF, 2016a). Moreover, the rural parts of Tanzania do not have access to proper infrastructure providing drinking water, or any wastewater management, contributing to the challenges connected to sanitation (UNICEF, n.d.).

The Tanzanian Ministry of Education, Science and Technology states that children in school should have the right to feel safe and that the school is supposed to be a place where children are secure, to enable them to play, grow and develop (UNICEF, 2016b). Even though the Tanzanian Government's ambition is clear, less than 10 per cent of all schools have proper handwashing facilities for the children, and only 38 per cent meet the demand for the number of latrines that should be available in school. Furthermore, since females and males have different needs regarding personal hygiene (e.g. during menstruation), lacking WASH facilities might lead to unequal opportunities when it comes to learning. To address these issues, a national guideline for water, sanitation and hygiene for Tanzania schools (SWASH) has been developed in collaboration with international and national organisations and development partners. It includes e.g. minimum standards for SWASH-facilities and guidance for establishment and maintenance of technical solutions.

2.2 SANITATION

Sanitation has played an important part in the history of human development, and research show that the topic has been addressed since even before the Bronze Age, 3000 B.C. (Abellán, 2017). Today, sanitation is defined by UNICEF (2016b) as the following: “... *preventing human contact from the hazards of waste to promote health. It is generally used to refer to the provision of facilities and services for the safe disposal of human faeces and urine, but it can also be used to refer to the maintenance of hygienic conditions, through services such as garbage collection, including for menstrual hygiene protection materials, and wastewater disposal*” (p.ix). Furthermore, the Centers for Disease Control and Prevention (CDC) (n.d.) points out that in the long term, if improved sanitation is achieved, it consequently leads to improved human health.

The lacking sanitary situation in developing countries is often due to the complete lack of water infrastructure for e.g. toilet- and hygiene facilities, or as the maintenance of the existing infrastructure cannot keep up with its disrepair (Moe & Rheingans, 2006). This causes a threat to human health by e.g. spreading waterborne diseases (WHO, 2019), and it is therefore important to identify the sources of contamination. Also, the current pandemic of the Covid-19 virus further proves the importance of proper hand hygiene, as handwashing is one of the most communicated measures recommended by World Health Organization (WHO) and

UNICEF (n.d.). This means that an improved sanitation, including both toilet- and hygiene facilities, could result in more benefits, increasing human health.

2.3 TOILET FACILITIES AND PATHOGEN REMOVAL

Improved sanitation is important to minimise the contact between humans and human excreta, containing harmful pathogens, in order to reduce spreading of diseases (UNICEF, 2016a; Carr, 2001). Pathogen removal achieved through improved sanitation depends on several environmental factors such as storage time, temperature, dryness, pH, UV light and presence of other organisms (Winblad, 2004; WHO, n.d.a). The mentioned parameters accounts for water, soil, sewage, and crops. Moreover, inactivation of pathogens is also achieved in conditions where the alkalinity is high or when ammonia is added, as the presence of nutrients and oxygen create a harsh environment for bacteria to survive in. The pathways for spreading of diseases are mainly food, soil, water, flies and hands. To construct a functioning sanitation facility, it is therefore important with barriers to hinder contact between the faeces and these pathways. One barrier is for instance to have handwashing facilities in connection to the toilet facilities to reduce the faecal-oral pathway (Winblad, 2004).

Facilities that are considered for improved sanitation are e.g. Pit Latrines, Ventilated Improved Pit Latrines (VIP Latrines), Flush or Pour-Flush Latrines and Ecological Sanitation (EcoSan). When choosing which type of toilet solution that is suitable, special consideration needs to be taken to cultural and social preferences for optimising the actual usage of the facility (UNICEF, 2016b). In some areas, a certain type of toilet could be preferred by the people, as for the case in Cochabamba, a peri-urban area in Bolivia, where the Pour Flush Latrine was the only facility with social acceptance (Hellegren et. al., 2018). Moreover, another aspect that needs to be taken into account is for instance what type of material that is commonly used for cleansing after using the toilet. In Tanzania, cleaning with water have for a long time been the most common approach (Mara, n.d.), but other materials used are a variety of dry materials e.g. toilet paper and leaves.

A way to increase the success of establishing WASH facilities is to include the community in the planning and design stage (UNICEF, 2016a). It is also beneficial to select solutions that can be constructed using materials that are easily accessed, i.e. locally produced materials. This, since it increases the chance of proper maintenance due to e.g. spare parts being available.

2.3.1 PIT LATRINES

Pit Latrines are widely used in developing countries for disposal of human excreta and was implemented to reach the MDGs connected to sanitation (Graham & Polizzotto, 2013). There are several different types available where Unimproved Pit Latrines and Improved Pit Latrines are the most common ones due to the low cost and their availability. The latter one is the most basic toilet facility for improved sanitation where a single pit and a superstructure is constructed (Tilley et. al., n.d.). Moreover, there are different types of Pit Latrines; it can either be a latrine flushed with water (see *Section 2.3.1.2 Pour Flush Latrine*) or a dry solution (see *Section 2.3.1.1 Ventilated Improved Pit Latrine and 2.3.1.3 Ecological Sanitation*).

There are normally two problems with Pit Latrines, odour and insects (UNICEF, 2016b). To counteract this, a small amount of either soil, ash or sawdust should be added after using the toilet (WHO, n.d.a). Another general problem is that they do not always have any barrier between the human excreta and the surrounding soil (Graham & Polizzotto, 2013), causing a risk of contaminating the soil and groundwater. It is therefore vital to investigate the groundwater level since it limits the depth of the pit and hence also the dimensions (Tilley et. al., n.d.). If the groundwater level is high another approach is to build a so-called raised pit (WHO, n.d.a).

Pit Latrines are most suitable for rural areas where there is enough space for moving the pit after reaching its full capacity, or where it is possible to treat the waste (Tilley et. al., n.d.: WHO, n.d.a). The waste can be used for agricultural purposes acting as fertiliser, but not without being treated. Moreover, it is the cheapest toilet facility to construct in terms of capital cost, the maintenance is however more costly and depends on the size of the pit and how regularly it has to be moved or emptied.

2.3.1.1 VENTILATED IMPROVED PIT LATRINES

The difference between a regular Pit Latrine and a Ventilated Improved Pit Latrine (VIP Latrine) is that the latter one is constructed with a ventilation pipe equipped with a fly screen (UNICEF, 2016b), see Figure 2. This reduces odour by allowing for wind to flow through the construction. The ventilation can further be improved if the heat from the sun is used to heat the pipes, resulting in new air being sucked into the pit, reducing the smell even further. However, a study made by Mara and Ryan (1983) showed that the induced ventilation from solar heating was minor compared to the ventilation caused by wind speed and its direction. Also, if the design is dependent on heat from the sun instead of wind flow to reduce odour problems, smell may occur during the night and early morning. Another advantage with VIP Latrines is that the presence of disease transmitting insects such as flies decreases (UNICEF, 2016b), leading to a reduced risk of spreading pathogens. As flies are attracted to light, it is important that VIP Latrines are kept dark so that the flies are drawn to the light at the end of the pipe instead of staying in the superstructure. Due to the fly screen the flies cannot escape from the pipe and will die because of dehydration.

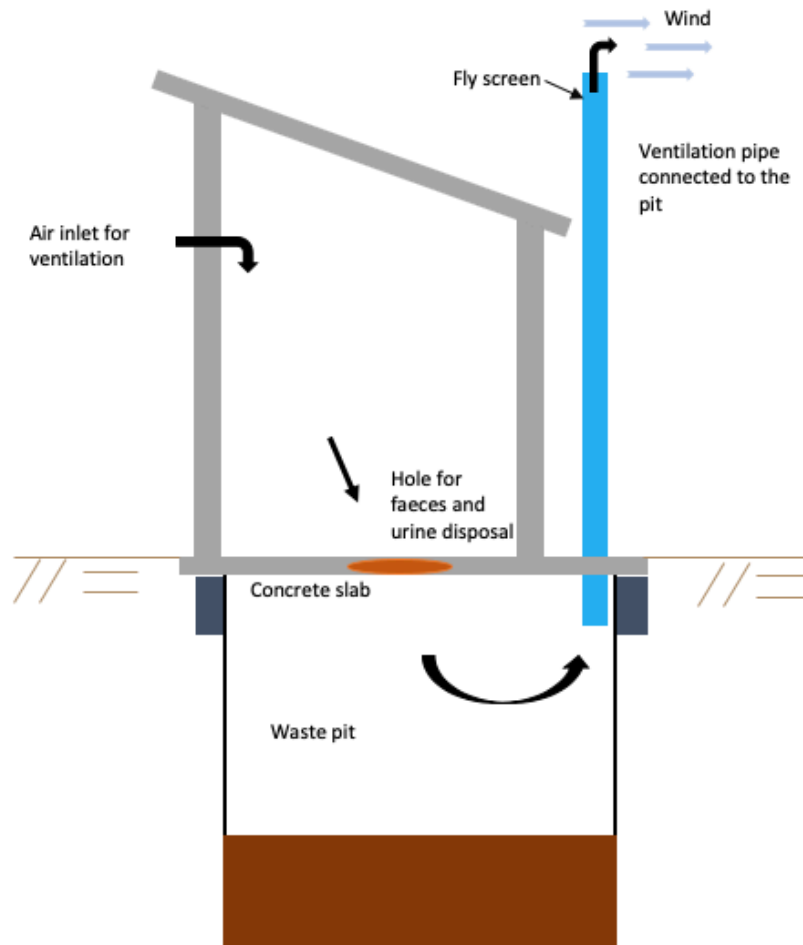


Figure 2. Principle illustration of a VIP Latrine (made by the authors).

It is preferred to construct the VIP Latrines with two pits i.e. a Ventilated Improved Double Pit Latrine (VIDPs), since it is a permanent structure, resulting in no need for relocation (Tilley et al., n.d.: WHO, n.d.b). By doing so, the usage will alternate between the two pits, allowing for one of the pits to rest and the excreta to degrade and become less harmful. It is later emptied manually and put into service when the second pit is full. This type of latrine does not require water for flushing and the water used for cleansing should be kept low.

Since the latrine has to be kept dark, people, and especially children, might feel uncomfortable using it (UNICEF, 2016b). Moreover, the construction cost is higher compared to the more traditional types and is estimated to be between 36-358 USD (ircWASHCost, 2012). The wide range depends on differences between countries, urban and rural areas, local conditions and the level of technology chosen.

According to the document *National guideline for Water, Sanitation and Hygiene for Tanzania schools* (UNICEF, 2016b) this type of toilet is applicable in both rural and urban areas, and where the water table is low. It is also favourable in areas with limited access to water and where the treated excreta can be used as a fertiliser (WHO, n.d.b). In the 1980s there was a project where 17 000 VIDPs were built in southern Tanzania (World Bank, 2005). This type of toilet was not socially accepted from the beginning, but after an individual accidentally dug into an old pit discovering that the excreta had turned into unarmful humus it changed. In

2005, 10 000 of these toilets were still being used, and a social survey showed that all households with access to this type of toilet used the treated excreta as fertiliser.

2.3.1.2 POUR FLUSH LATRINES

The Pour Flush Latrines are similar to the regular Pit Latrines, but it has a water seal that eliminates the odour and reduces the presence of insects and other animals attracted to human waste (UNICEF, 2016b: WHO, n.d.c), see Figure 3. With the most basic type of Pour Flush Latrines the human excreta are flushed into the pit with a small amount of water. The pit can be placed either directly below the latrine so-called 'direct' pit or slightly behind the latrine which is called an 'off-set' latrine (UNICEF, 2016b). The latter one is easier to maintain and to empty and therefore in most cases the preferred alternative (Mara, n.d.). It is also possible to connect this type of Pour Flush Latrine to a septic tank or a sewer system in the future.

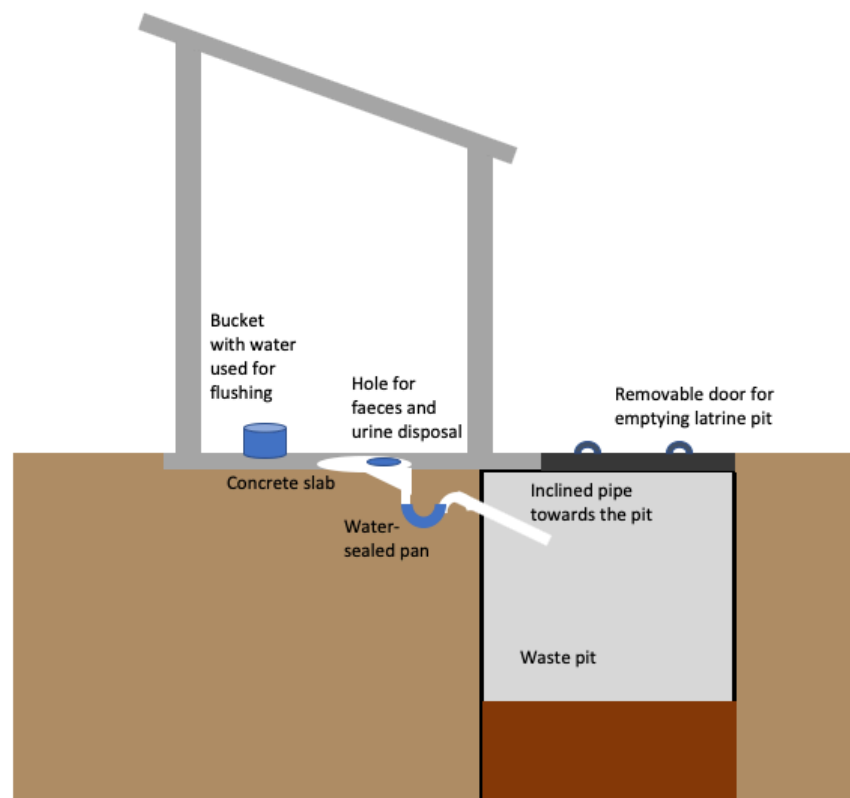


Figure 3. Principle illustration of an off-set Pour Flush Latrine with access to the waste pit from the outside (made by the authors).

The toilets can be designed as a single or double pit where the first one consists of one pit which after reaching its full capacity has to rest until the waste is safe to use (Mara, n.d.). For the second one, however, one of the pits can always be resting and the other one used. The faeces are treated in the pit under both aerobic and anaerobic conditions and after one to two years the pathogens will be removed due to biodegradation, temperature and time. The waste has turned into humus and is safe to use as fertiliser.

The water used for flushing and cleaning is together with other soluble products allowed to pass through the pit wall and enter the surrounding environment. However, dry cleansing

material could clog the pipes leading out from the water-sealed pan and result in impaired leachate (Tilley et. al., n.d.: WHO, n.d.c). An alternative is therefore, if dry cleansing material is to be used, to collect it separately.

Some of the advantages with Pour Flush Latrines are the acceptance among people living in developing countries; that the water needed for operations is about two to three litres (less than for water flushed toilets connected to a sewer system); that the cost is low; odour and presence of flies are low; it requires little maintenance; and that it is applicable for all ages (Mara, n.d.). Furthermore, the Pour Flush Latrine is suitable in rural areas (Tilley, et. al., n.d.), but the leachate from the pit has to be taken into account as it can infiltrate the surrounding soil and thereby could end up in groundwater aquifers.

This type of toilet is best applicable where there is no water scarcity (UNICEF, 2016b), because without water, neither cleaning nor flushing, is possible. The cost is estimated to be between 92-358 USD (ircWASHCost, 2012) and the wide range depends on differences between countries, urban and rural areas, local conditions and the level of technology chosen.

2.3.1.3 ECOLOGICAL SANITATION

The approach of Ecological Sanitation is based on a cycle where the human excreta are used as a resource instead of a waste product (Winblad, 2004; Water Engineering and Development Centre, 1999). To make this possible, viruses, bacteria and worm eggs have to be non-existent. The purpose of this type of toilet is also to free the urine and faeces from disease organisms on-site, in order to use the waste as fertiliser (Winblad, 2004). This could be favourable in areas where soil fertility is low (World Bank, 2005). If further treatment is necessary, the waste can be transported to a treatment facility. Out of the two components, urine and faeces, the latter one constitutes a higher risk of spreading diseases. To reduce the spreading, faeces are processed in a processing chamber or through storage in a pit. The urine, however, is most often safe to use for agricultural purposes after storage of approximately one month (Winblad, 2004). Furthermore, it can be used either undiluted or diluted with water, if diluted, the storage time is reduced (Water Engineering and Development Centre, 1999). Important to notice is that harvesting should not take place earlier than one month after the application of urine (Winblad, 2004).

The design of an EcoSan toilet can be performed in different ways, one way is to use it in a bathroom, where the processing chamber is located below the floor and accessed from outside (Winblad, 2004). For this approach, one can use a urine-diverting toilet, also called Skyloo (World Bank, 2005), see Figure 4. This type of toilet requires blending of the waste with ash or lime to create a dry, and preferable, alkaline condition for optimised pathogen destruction and to reduce breeding of flies. The waste then needs to be moved to a composting facility every 6-12 months, if only one pit is used, if instead two pits are used, this will not be needed. In areas where the groundwater level is high, or where other geological conditions can pose a risk of contaminating the groundwater, the Skyloo can be placed on a raised platform, with the storage tank situated underneath.

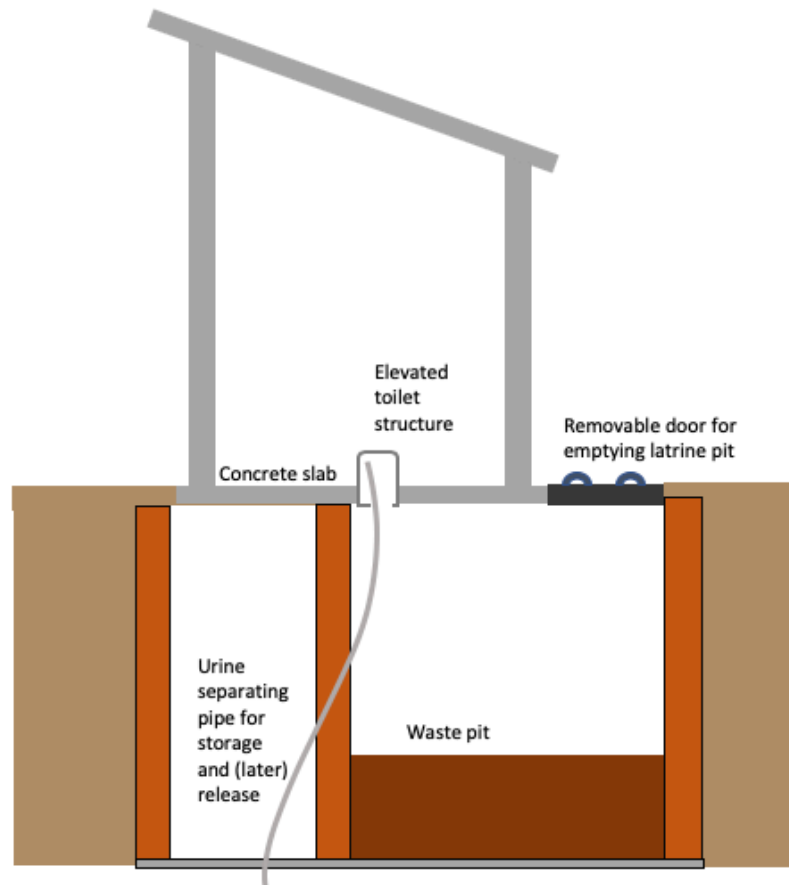


Figure 4. Principle illustration of the urine-diverting Skyloo, with access to the waste pit from the outside (made by the authors).

Another EcoSan toilet is the Fossa Alterna (World Bank, 2005), which instead of a chamber has two waste pits, allowing for the decomposition of the first one whilst the other one is in use. To optimise the degradation the waste is mixed with ash and soil to create a balanced compost. Another, more simple approach, is the Arborloo, which is a pit with a squatting facility above, the facility is relocated after one year, allowing for processing of the waste to take place (Winblad, 2004; World Bank, 2005). When the pit is full, a tree is planted on top to replace the facility.

There are two different methods used for treatment of the faeces, which kills pathogens and makes the waste unharmed; dehydration and decomposition (Winblad, 2004). Dehydration, also called drying of faeces is best practised if the excreta can be separated immediately from urine and water, this is e.g. obtained with the urine-diverting EcoSan facility, the Skyloo. These treatment methods are further divided into two processes; primary and secondary processing, for the removal of pathogens and making the waste safe to use. A reduction in weight and volume of faecal material is the main purpose of the primary processing, this to reduce the storage volume, and to facilitate transportation and further treatment. The primary processing takes place below the toilet's superstructure, in a chamber. The secondary process is implemented to make sure that the faeces are safe enough to use as fertiliser or to return to nature, the process can either be performed on-site or at an eco-station. The process involves further treatment, using high temperatures or increased pH, but the same effect can also be achieved by increasing the storage time.

A review of the implementation approaches of the EcoSan technology in east and southern Africa made by the World Bank (2005), as a part of the International Water and Sanitation Program (WSP), showed that in the year of 2005, the implementation of such technology was a slow process. However, there were some areas in Malawi and Mozambique that had shown great success in the implementation stage, indicating that there is potential if customised and introduced in a proper way. For this, the importance of ensuring that the locals are interested in such a solution is pointed out, and that the facility and technology is appropriate for the specific area and its economic situation. An EcoSan toilet can, dependent on the solution, construction materials and technology chosen, cost between 80-250 USD (World Bank, 2005). The wide range depends on differences between countries, urban and rural areas, local conditions and the level of technology chosen.

2.3.2 MAINTENANCE FOR TOILET FACILITIES

The work of maintaining toilets and other sanitation facilities is important to take into consideration since the expenditure for 20 years maintenance can be five to twenty times more expensive than the construction cost (ircWASHCost, 2012). Even though maintenance is important, the conditions for the sanitation workers are often below standards, resulting in daily exposure to hazards (World Bank, ILO, WaterAid, & WHO, 2019). Also, many sanitation workers do not have access to any type of protection such as gloves, boots or face masks, making their work a danger for their life and well-being.

VIP Latrines, Pour Flush Latrines and EcoSan toilets all need daily cleaning and maintenance of the waste pit. However, VIP Latrines also has the ventilation pipe with a fly screen that needs to be kept clean for the air to be able to flow uninterrupted (Mara et. al, 1983; WHO, n.d.b; WHO, n.d.c). Also, if the ventilation is dependent on heating of the pipe from the sun, it could be painted black to increase absorption of solar radiation, which then has to be maintained if worn.

An EcoSan toilet also has special requirements for maintenance to keep it operating sufficiently, and these demands vary depending on the type of toilet (Winblad, 2004). For instance, the condition in the waste pit or processing chambers needs to be dry, causing a need to regularly add ash, soil and lime to the waste pit (World Bank, 2005). This is also beneficial for avoiding transportation of the waste for further treatment, if using a single pit solution (Winblad, 2004). By adding these components, the condition in the pit can be controlled, and it increases the pH, decreasing the decomposition time. Additionally, if having a urine-diverting toilet, the tank for storage of urine needs to be emptied and maintained.

Finally, the everyday cleaning of the toilet facilities is of importance to reduce odours, contact with, and spreading of bacteria, this to improve the general toilet experience and reduce the risk of waterborne diseases.

2.4 FACILITIES FOR WATER ACCESS

The presence and location of groundwater aquifers are highly affected by the geology in an area. Not knowing where an aquifer is located and what its characteristics are could constitute a risk of contamination, resulting in spreading of waterborne diseases (Kamara et. al., 2017; Kashaigili, 2010). For instance, due to lacking sanitation facilities in rural areas, waste from toilet pits can leach out and be transported down to the groundwater. The uncertainties of where water can be accessed, and its quality, makes it important to investigate different types of water resources. This, since access to safe water is important not only for drinking, but also for hygiene purposes, to reduce spreading of diseases.

Furthermore, the minimum daily access of water in Tanzania should be, according to an estimation made by Globalis (n.d.), 20 litres per person and day. This amount of water should cover the need for drinking, cooking and cleaning. The intended usage of water access facilities in this study is for personal hygiene only, including washing of hands, cleansing and flushing of toilets.

2.4.1 RAINWATER HARVESTING

Rainwater harvesting (RWH) is a method for collecting and distributing water and it has existed longer than the large-scale water systems we know today (Adeboye & Aladenola, 2009). It has the potential to complement the water supply in areas where water scarcity is a problem, but where rainfall is common. It is therefore not recommended as the only water source in areas with seasonal variations (UNICEF, 2016b). The collected water could be used as drinking water if treated, or for hygiene purposes and irrigation (Helmreich & Horn, 2008). Moreover, RWH is environmental-friendly when compared to modern water treatment facilities.

One approach of RWH is called Domestic RWH, which focuses on collecting water from rooftops, streets and run-off from courtyards close to the household (Helmreich & Horn, 2008; Mwenge Kahinda, Taigbenu, and Boroto, 2007). The water flows through gutters and pipes that can be made out of PVC, galvanised iron, wood or bamboo (UNICEF, 2016b). Roofs made out of sheet metal and tiles are especially suitable for RWH, other materials could give the water an unwanted taste and/or colour. After collection, the water is stored in tanks located close to the collection point, built underground or aboveground (Helmreich & Horn, 2008). Commonly used materials for constructing tanks used for storing small quantities of water are bricks, stabilized soil, rammed earth, plastic sheets and mortar jars. For larger quantities, it can be made out of pottery, ferrocement or polyethylene. Important to keep in mind is that the tank has to be sealed with a tight cover to prevent contamination. Otherwise, the water could be contaminated by humans, animals or other environmental factors, but also, algal growth or breeding of mosquitoes could occur. The investment needed for this method depends on the size, and the initial cost for construction is quite high, compared to the operational and maintenance cost. A project in South Africa, similar to the one in Bulyaheke, estimated that building a 30 m³ RWH tank including material, labour and introduction to the locals would be approximately 3000 USD (Mwenge Kahinda, Taigbenu, and Boroto, 2007).

If rainwater is to be used as drinking water, there are some considerations to take into account. First, the quality of rainwater is quite good in rural areas compared to rainwater in cities where atmospheric and industrial pollution is much higher (Helmreich & Horn, 2008). Despite this,

the presence of bacteria, viruses and protozoa originating from e.g. bird faeces and other animals may vary. The water should therefore not be used as drinking water unless disinfection is implemented or the water quality is constantly monitored (Kamara, et al., 2017). There are several methods available for this purpose where chlorination is the most common one for the deactivation of microorganisms. It is a cheap method, but the application of chlorine cannot be done in the storage tank because of the risk of it reacting with organic matter creating unwanted by-products.

Furthermore, solar radiation can be used for the treatment of drinking water for domestic use (Wegelin et. al., 1994; Fransson & Werner, 2019), as last year's study also showed, deactivating both microorganisms, bacteria and viruses. The efficiency of the method is good if the solar radiation is applied for about five hours, depending on its intensity. In Tanzania, the average yearly daylight is 12 hours (ClimaTemps, n.d.b), and the access of sunlight should therefore not be a problem. Moreover, the container material has an important role and should be transparent, and the turbidity should be kept low.

Another method to reduce the faecal presence is to cut off the so-called 'first flush' using a flush water diverter (Helmreich & Horn, 2008). This is a cheap method that operates automatically and is applicable to a variety of different tank sizes. Also, they are easy to install and maintain, but most importantly they reduce the risk of infectious diseases (UNICEF, 2016b).

General problems linked to RWH is a lack of successful implementation, acceptance and involvement among the users (Helmreich & Horn, 2008). However, a pilot study in Zambia, another African country, has shown good results (Handia, Tembo, and Mwiindwa, 2003). The water collected was drinkable, but only one test was performed. The conclusion drawn from this was that RWH has potential for collecting rainwater to be used as drinking water, but that more tests are needed. Handia et. al (2003) also pointed out that the residents in the area for the pilot study expressed an interest in harvesting rainwater.

2.4.2 DRILLING OF WELL

A successfully drilled groundwater well is a great contribution to the socio-economic standards in rural areas, as it decreases the risk connected to the usage of exposed surface waters (World Bank, 2006). Moreover, if located strategically, it reduces the time spent on catching water, allowing time to be spent on other activities and also, potentially increasing the attendance of children in school. However, regarding groundwater aquifers in Sub-Saharan Africa, there is a need for more in-depth information about recharge rates, extraction rates and water quality controls in order to sustainably withdraw water.

The estimated cost for drilling a 30 meters deep well is 6000 USD for handpumps and 12 000 USD for a mechanized system (Kashaigili, 2010). These prices include everything from the start until finalised and all the equipment needed. The price is dependent on the depth and estimated to be around 193 USD per meter for hard rocks.

3. METHODOLOGY

This study follows a qualitative method approach which includes interviews, observations and a literature study (Ochieng, 2009). In addition, this chapter is divided into five separate sections (*3.1 Background to Case Study, 3.2 Case Study Description, 3.3 Preparations, 3.4 Data Collection Strategy, and 3.5 Data Analysis*) to demonstrate the methodology. The first section describes the initiation of the project and the second the location of the area studied. The preparations made for the study are described in section three; starting with a desk study and communication with people involved in last year's study, to get familiarised with the area and its challenges. The fourth section aims to describe the information collection strategy both in the field and for the literature studied but also the topics addressed. Finally, the fifth section describes the work of processing the collected data and the evaluation of possible solutions. An overview of the work process is illustrated in Figure 5.

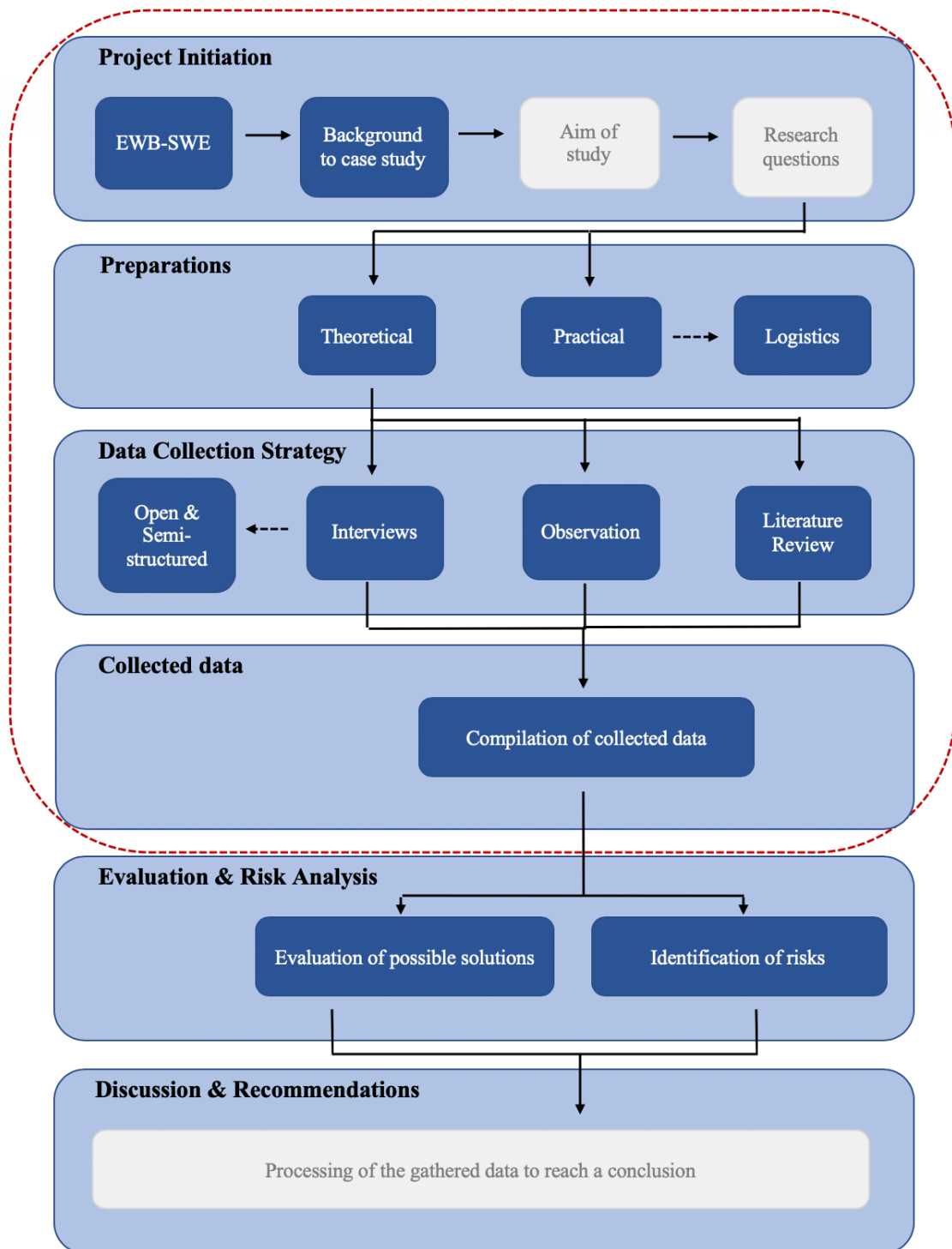


Figure 5. Schematic overview of the work process used for the study. The grey boxes are part of the process but are not necessarily explained in the methodology chapter. The solid arrows represent the workflow between the different steps (the boxes) and the dotted red line, indicates that the processes have been iterative. The dotted arrow shows a more detailed description of a step.

3.1 BACKGROUND TO CASE STUDY

The village Bulyaheke has historically experienced outbreaks of waterborne diseases related to lacking sanitation (Scheren, Zantig, and Lemmens, 2000; Fransson & Werner, 2019). This has been observed and communicated by the local Non-Governmental Organisation (NGO) FUI, which together with Engineers Without Borders Sweden (EWB-SWE) initiated a project in 2017 to improve the general situation in the village and mediate the needs of the population in Bulyaheke. As a result of this collaboration, a project in the villages Bulyaheke and Mbugani was initiated, followed by a study conducted by two master’s students from Chalmers University of Technology (CUoT) during the years 2018 and 2019. The focus of that study was to investigate the feasibility of using Solar Water Disinfection (SODIS) as a drinking water treatment method for households (Fransson & Werner, 2019). To further continue the cooperation between EWB-SWE and FUI, and also the work within the area, a second study has now been conducted in Bulyaheke. The study was initiated during the spring of 2019 by EWB-SWE, focusing on the sanitary situation; to decrease spreading of waterborne diseases which is closely linked to poor sanitation (Moe & Rheingans, 2006).

3.2 CASE STUDY DESCRIPTION

This case study was conducted in Bulyaheke, a village in Sengerema district with approximately 5000 inhabitants. Bulyaheke is a part of rural Tanzania, located in Mwanza region by the shore of Lake Victoria, see Figure 6.



Figure 6. Map over Tanzania with the boundaries of Sengerema district marked in red and the village Bulyaheke marked with a black arrow (Google maps, 2020. Edited by authors).

The region has a subtropical climate which is characterised by regular precipitation and high temperatures (Globalis, 2018). The yearly precipitation is 1119 mm (ClimaTemps, n.d.a), which is the same as 1119 l/m² per year. In Figure 7, an overview of the yearly precipitation can be seen.

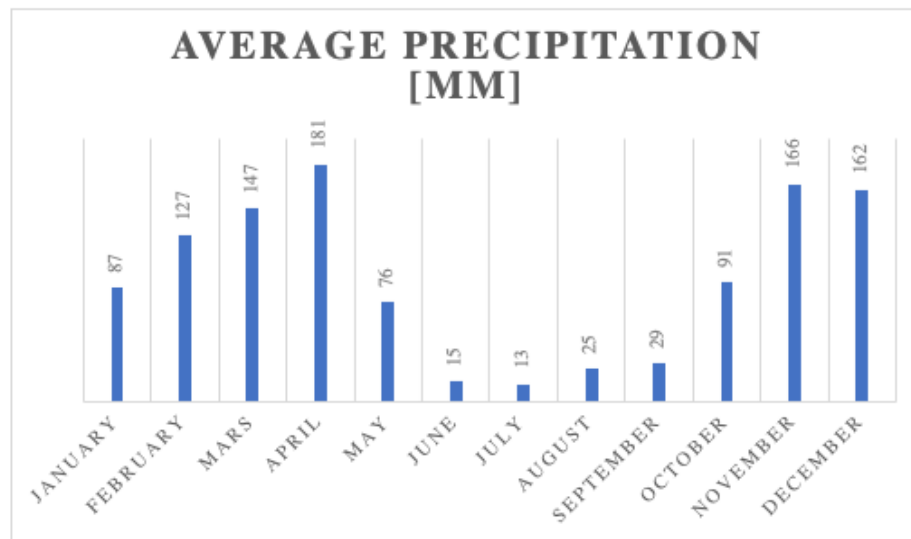


Figure 7. Yearly average precipitation in Mwanza region (ClimaTemps, n.d.a) (Authors own picture).

The geology in the area allows for water storage in formations mainly made out of unconsolidated sand and gravel (Kashaigili, 2010), originating from the regions Plutonic-Metamorphic Gneiss rock (hard rock), creating isolated aquifer systems.

3.3 PREPARATIONS

The practical preparations needed for the study were made with help from EWB-SWE, one of the former students from last year's study, CUoT and FUU. It involved consultation with EWB-SWE and CUoT for administrative guidelines to assure that their policies were followed. Moreover, contact with FUU was established to ensure a continued collaboration and on-site logistics. Finally, the study was secured by granted scholarship applications to cover the financial practicalities.

Furthermore, the former student contributed with experience from last year's study on water quality in the village Bulyaheke. This, by providing interview material from their study and sharing personal impressions and thoughts. The information provided was used to get an increased understanding of the situation in the village and its challenges, before going out in field. The information was also used to be able to optimise the visit to the village and to formulate the interview questions in an expedient way. For this, literature of different interview methods was studied.

Also, the communication with the people in Bulyaheke had to be secured, since English is not the native language, nor widely practised. For this, FUU supported with translation from, and to, Swahili. The interview questions that had been prepared in advance were sent beforehand in order for FUU to prepare the translation, the follow up questions were however translated in field.

Meetings with the governmental authorities and district councils were also scheduled after arrival in Mwanza, in order to get approval of the project. This was necessary for the continuation of the study. Before leaving Mwanza, a follow-up meeting was scheduled with the Regional Community Development Officer (RCDO) for discussion about the project's progression and future. The representatives from FUIO acted as guides through these processes.

3.4 DATA COLLECTION STRATEGY

3.4.1 FIELD STUDY

During the three-day long field study interviews were held with inhabitants of the village Bulyaheke, especially students and teachers at the Bulyaheke and Mandela Primary School, to establish a dialogue with the people living and working in the area. To collect data of the sanitary situation the following topics were addressed; toilet facilities and habits of personal hygiene, knowledge about diseases linked to poor sanitation, together with preferences and opinions on potential improvements of the sanitary situation. Moreover, interviews were also held with employees working for the authorities; the RCDO and the Principal Economist (PE), both working at the NGO commissioner office. Also, the District Water Engineer (DWE) in Sengerema district was interviewed. During these sessions, the strategy and approach of the Tanzanian Government regarding sanitary issues were discussed, including; project initiations, construction, funding and future development plans. Altogether, the number of subjects interviewed, representing the different stakeholders, were; five teachers, eight students, three inhabitants of the village and three representatives from the Tanzanian governmental authorities. Furthermore, observations were continuously made during the stay in Bulyaheke as a complement to the interviews.

The interview subjects' approval of using the shared information was ensured in the beginning of each interview. For ethical reasons, it was made clear that if they felt uncomfortable answering any questions, they did not have to do so. Also, to ensure their anonymity, names of any participants are not shared, only their gender and occupation. These measures were specifically applied due to the young age of some of the interview subjects and because the topic addressed is sensitive, including private information about the subjects. Additionally, photographs with permission from the local chairman of FUIO and the headteachers from the two different schools were taken for documentation purposes.

3.4.1.1 INTERVIEWS

A method of open and semi-structured interviews, more like a dialogue (Ritchie, Burns and, Palmer, 2005) was used for collection of data, as it was found to be favourable to obtain the 'true' story from the interview subjects. Having an approach of using too structured questions could risk the interview subjects to leave out important details by asking the wrong, or leading, questions. Also, this method allows for follow-up questions to be asked by the interviewers if needed. Additionally, the answers were translated, transcribed and recorded to reduce the risk of information being omitted. Moreover, to get a wider perspective of the situation, it was

important to have dialogues with people representing different professions, age and genders. A list of the interview subjects can be found in *Appendix II*.

3.4.1.2 OBSERVATIONS

The addressed topic can be both intimate and sensitive to talk about, which is why complementary field observations of behaviour patterns and the condition of toilet- and water access facilities were included. This, to get an accurate picture of the reality. It was continuously performed and documented with photographs during the introduction walk through the village and during the interviews.

3.4.2 LITERATURE REVIEW

Literature concerning the regulation and development strategy of water and sanitation issues in Tanzania was studied; *Water, Sanitation and Hygiene situation in health care facilities in Tanzania mainland and way forward* (UNICEF, 2016a) and *National guideline for Water, Sanitation and Hygiene for Tanzania schools* (UNICEF, 2016b). These documents provided valid information about the Tanzanian Government's future plans for approaching issues for the specific topics, allowing for comparison with the prevailing conditions when out in field.

Moreover, literature about toilet- and water access facilities common in developing countries was studied in order to find suitable and appropriate solutions for the sanitary issues in Bulyaheke. This literature includes case studies relevant for the study, reports from e.g. WHO, the UN and UNICEF, together with relevant articles and data provided by governments.

3.5 DATA ANALYSIS

The collected data from the interviews and the observations were analysed using 'thematic analysis' and then compared to existing literature. This to compare the findings with similar, previous case studies and to see if methods used before could be applicable in Bulyaheke. Moreover, the knowledge of the people being interviewed was evaluated and their opinions on toilet solutions were noted. The information collected was later used to determine what type of solutions that could be favourable, and also most appropriate for the specified conditions, i.e. what type of toilet the population of Bulyaheke would approve of and be able to maintain together with the characteristics of the area (geology, hydrogeology and hydrology).

3.5.1 THEMATIC ANALYSIS

Thematic analysis is part of the general concept 'Content Analysis' which is a tool used to strategically analyse text when performing qualitative research (Vaismoradi, Turunen and Bondas, 2013). The purpose with this method is to identify trends and patterns of how words are used, how often they occur and the relationships between them in order to characterise the collected data or literature used.

To apply this method, code words were specified and used to easier locate and find information that answered the research questions in *Section 1.3*, but also to support the work of finding appropriate toilet- and water access facilities, evaluate their suitability in the area, and how an eventual implementation of such facilities could be arranged.

The used code words were the following: *Education, Hygiene, Implementation, Latrines, Maintenance, Pathogens, Rainwater Harvesting, Sanitation, Toilet, Waterborne diseases and Well*

3.5.2 RISK ANALYSIS

The observations together with the data from the interviews and the literature studied were analysed and used to identify hazards, risk objects and exposure pathways. Consequences related to these findings, and actions to be taken to avoid them, was then established and compiled in two tables, one for the village and one for the two schools. The result from the risk analysis was then used to find appropriate solutions for the circumstances present in the village.

3.5.3 EVALUATION OF POSSIBLE SOLUTIONS

An evaluation of the identified solutions was made to visualise the advantages and disadvantages of the different toilet- and water access facilities. The evaluation was based on the following criteria, which were chosen as they were considered important to secure a successful implementation:

- Technical requirements: *how advanced the technology for the facility is, including both construction and usage.*
- Suitability: *how adequate the solution is for the specific environment and area e.g. need of water, electricity and construction materials.*
- Availability: *the accessibility of the facility e.g. lighting, logistics and availability for disabled.*
- Need of maintenance: *the frequency of required maintenance and the required knowledge for operation.*
- Implementation: *need of education for usage and behavioural change together with availability of expertise and local workforce.*
- Cost: *the estimated cost for the facility.*

3.5.3.1 GRADING OF POSSIBLE SOLUTIONS

The different solutions were assigned with a score for each criterion described in the previous section, which then was summarised. The summarised score represents its suitability as a solution in relation to the current situation in Bulyaheke, e.g. in relation to the ground conditions and the need of educating the locals. The grading was based on the information found during the literature study together with the observations made during the field study and the interviews held. If the conditions in the area were favourable for the specific solution with respect to the specified criteria in the previous section, it was assigned with a low score. Respectively, if it would require a lot of effort for implementation and operation a high score, or another appropriate grade within the scoring scale, was assigned to the solution. The grading is defined as the following:

- 1 point: Low
- 2 points: Low-Medium
- 3 points: Medium
- 4 points: Medium-High
- 5 points: High

3.5.3.2 CALCULATIONS

The number of toilet facilities needed at the two schools was calculated using Tanzanian standards for schools. This to see the lacking number of toilets and how big of an investment that would be required to reach the standards. To calculate the number of toilets needed, ratios of required toilets per students presented in the *National guideline for Water, Sanitation and Hygiene for Tanzania schools* was used. Two different scenarios were analysed; one using different ratios for female students and male students, being 1:20 respectively 1:25, and one using a ratio of 1:40-50 for both genders, this to cover the most urgent demand. For this case, a mean value of 1:45 was used.

The cost for RWH depends on the number of tanks needed for the collected volume of rainwater. Therefore, calculations were made to estimate the collected water volume from the roofs of the two schools, this to be able to compare the two different water access facilities (RWH and drilling of well). The calculations made were the following:

$$\text{Number of student } [p] \times \text{daily water demand } \left[\frac{l}{p \times d} \right] = \text{Needed volume of water } \left[\frac{l}{d} \right]$$

Equation 1

$$\frac{\text{Needed water volume } \left[\frac{l}{d} \right]}{1000} = \text{Tank size (optimal coverage) } [m^3]$$

Equation 2

The water volume generated from the roofs of the two schools by the average daily precipitation, its coverage capacity in number of students and the RWH tank size needed was then calculated. An estimation of the daily demand of water for hygiene purposes was used based on the Swedish water consumption for personal hygiene, which is 65 per cent out of the total water consumption for one day, including showering, washing of hands and flushing of toilets (Sydvatten, n.d.). However, it was further estimated that the consumption of water for

personal hygiene in rural Tanzania is less than in Sweden, since the water access is more limited, therefore 50 per cent of the daily water usage is assumed to be used for hygiene purposes.

$$\text{Length [m]} \times \text{Width [m]} \times \text{Number of school buildings [-]} = \text{Total roof area [m}^2\text{]} \quad \text{Equation 3}$$

$$\text{Total roof area [m}^2\text{]} \times \text{Yearly precipitation} \left[\frac{\text{l}}{\text{m}^2} \right] = \text{Total volume of precipitation [l]} \quad \text{Equation 4}$$

$$\frac{\text{Total volume of precipitation [l]}}{365 [\text{d}]} = \text{Total volume of precipitation from the roofs} \left[\frac{\text{l}}{\text{d}} \right] \quad \text{Equation 5}$$

$$\frac{\text{Total volume of precipitation from the roofs} \left[\frac{\text{l}}{\text{d}} \right]}{\text{Daily water demand} \left[\frac{\text{l}}{\text{p}} \right]} = \text{Number of students covered} \left[\frac{\text{p}}{\text{d}} \right] \quad \text{Equation 6}$$

$$\frac{\text{Total volume of precipitation from the roofs} \left[\frac{\text{l}}{\text{d}} \right]}{1000} = \text{Tank size needed (actual coverage) [m}^3\text{]} \quad \text{Equation 7}$$

$$\frac{\text{Tank size needed (actual coverage)}}{\text{Tank size needed (optimal coverage)}} \times 100 = \text{Water demand coverage by RWH [\%]} \quad \text{Equation 8}$$

4. RESULTS

This chapter presents the findings of the study in terms of the current situation, the identified problems and an evaluation of possible solutions together with calculations to support the results. The data was collected in the village, at the two schools and during meetings with the authorities. Except from the data obtained during the stay in Tanzania, and the identified problems, a risk analysis based on these findings and a scoring of the possible solutions described in *Chapter 2* are presented.

4.1 COLLECTED INFORMATION

The results from the held interviews and observations are presented in this section, divided into different subsections, focusing on the different stakeholders. During the interviews it was noted that the sanitary situation at the two schools were more extensive than for the rest of the village. It was therefore decided during the field study to mainly focus on the two schools and the improvements needed there, resulting in a limited amount of people in the village being interviewed. Moreover, during the time spent in Bulyaheke, observations were made as a complement to the interviews.

4.1.1 VILLAGE

4.1.1.1 INTERVIEWS WITH INHABITANTS

When conducting the interviews in the village it was found that all interview subjects had access to some type of toilet at home and at work; Pit- or Pour Flush Latrines. However, it appeared that the Poor Flush Latrines were hard to keep clean due to the lack of sufficient amounts of water. Moreover, when talking to the people in the village about what type of toilet they prefer, the answer was a Poor Flush Latrine. However, when introducing the benefits with having a toilet facility that is in no need of water, or less need of water, most of the interview subjects were found to be positive to that type of solution.

Another result from the interviews was that people with different backgrounds (occupation, age, and gender) had good or at least some knowledge about sanitation and its relation to diseases, they did however express a desire to learn more. Moreover, they thought that the lack of water to keep the toilets clean and for washing hands was the main reason for people getting sick in the village. The possibility of collecting rainwater in organised storage tanks for such uses was then presented to the interview subjects and everyone expressed that they would feel comfortable in using collected rainwater for washing of hands, irrigation and cleaning purposes.

4.1.1.2 OBSERVATIONS

First of all, it is important to mention that the roads during the trip to Bulyaheke were made out of compact soil, and in bad conditions due to the rain, affecting the accessibility to the village. Furthermore, during the introductory walk after arriving to the village it was observed that most of the buildings were made out of materials similar to concrete but also bricks; and that the roofs were made out of sheet metal.

Regarding the water supply in the area, one well was observed in the village (see *Appendix III, Figure i*); however, it was private, and the usage was controlled as a key was required, making it unavailable for other people. From this well, water could be bought at a cost of 50 TZS (~0.02 USD) for one bucket (15-20 l). Outside the village there was a spring (see *Appendix III, Figure ii*) with clear water which to a cost of 5000 TZS/month/family (~2.2 USD) allows people to use it. The income from this fee was used to pay for the security of the spring, which was surrounded by a fence. In this area, shoes were not allowed in order to minimise contamination.

Except for the organised water sources, temporary water pools and springs was observed. The water was seen to be used for washing of motorcycles and clothes, but one younger boy was also seen filling a water bottle at these temporary water sources. The usage of that water is however unknown.

4.1.2 SCHOOLS

4.1.2.1 INTERVIEWS WITH TEACHERS

Interviews were held at two different schools in the village, Bulyaheke Primary School and Mandela Primary School. The schools were situated in connection to one another, sharing schoolyard and toilets, see *Appendix IV*. Regarding the sanitary situation at the schools, it emerged during the interviews that they only had six toilets for the students, and two toilets for the teachers. They are maintained by the students together with the school staff each morning before school, for this, the students bring water from their homes. The water brought is also supposed to be enough for flushing the toilets and hygiene purposes during the day.

Moreover, it was also found when talking to the headteacher at Bulyaheke Primary School, that the number of students were 2323, where 1135 were males and 1188 were females. He also showed statistics of that they need 96 toilets for the number of students presented, resulting in a lack of 90 toilets. When calculating the number of toilets needed with the figures available in the *National guideline for Water, Sanitation and Hygiene for Tanzania schools* (UNICEF, 2016b), the toilet ratio being 1:20 for female students and 1:25 for male students, the number of toilets needed ends up at 105, if only taking Bulyaheke Primary School into account. The students at Mandela Primary School uses the same toilets and the school has 1778 students, 928 males and 850 females. If adding the students at both of the schools together, the number of toilets needed is instead 185. In *Table 1*, the number of toilets needed for the different schools are listed with regards to the ratios mentioned, but also with a ratio of 40-50 students per toilet, as this approach is accepted by the government to be able to alleviate urgent needs. For this case, a mean ratio of 1:45 was used.

Table 1. Number of toilets needed at Bulyaheke and Mandela Primary Schools.

	Bulyaheke PS			Mandela PS			Total	
	Number of students	Toilets needed with ratio 1:25/1:20	Toilets needed with ratio 1:45	Number of students	Toilets needed with ratio 1:25/1:20	Toilets needed with ratio 1:45	Toilets needed with ratio 1:25/1:20	Toilets needed with ratio 1:45
Males	1135	45.4	25.2	928	37.12	20.6	82.52	45.8
Females	1188	59.4	26.4	850	42.5	18.9	101.9	45.5
Total	2323	105	52	1778	80	40	185	92

When asking about construction costs for the number of toilets they had today (6 toilets), the head teacher said that it would cost approximately 3 000 000 TZS to construct the same type of facility. If this is applied for the number of toilets needed (92 toilets) it corresponds to an investment of 20 000 USD. Except for the number of toilets, the type of toilets was also discussed, and a dry toilet facility was presented. The advantage of being able to use the waste as fertiliser for the school crops was described to the headteachers which gave a positive response. They did however share their concerns about the technology needed to operate this type of facility. If the technology would be made available, they would be interested in using it, but they do not have the money to invest themselves.

Furthermore, when introducing the concept of RWH to the health teachers and the headteachers of the schools the response was positive as the water potentially could be used for irrigation of the school crops, increasing their income, but also for hygiene purposes. Only the health teacher at Bulyaheke Primary School expressed concerns about the roofs being dirty and that they could transmit bacteria into the collected water. If this could be prevented, he thought that the idea was good. During the interviews with the health teachers it was also found that education about hygiene and sanitation was included in the student curriculum and that lectures on this topic was held two times a week, 40 minutes per session at Bulyaheke Primary School and 20 minutes per session at Mandela Primary School.

4.1.2.2 INTERVIEWS WITH STUDENTS

When talking to the students it was revealed that they had knowledge about sanitation, and an interest in the sanitary situation at the schools. They also expressed concerns about the conditions, and the low number of existing toilets. Moreover, they also mentioned that every other week, one to two students experience problems with their stomach. When asking about the reason for this, they shared their thoughts and concerns about getting in contact with diseases due to the cleanliness of the toilets and the lack of handwashing facilities.

The female students also shared information about that they, during menstruation, had to go home in order to change pads and clean themselves. This, because the school toilets did not provide a sufficient amount of water for cleaning or garbage bins for disposal of the used pads. They also expressed an anxiety of using the school toilets due to the number of male teachers.

Finally, it was common that the students choose not to use the school toilets at all, and instead waited until they got home. A general desire was therefore to improve the overall toilet situation at the two schools.

4.1.2.3 OBSERVATIONS

The school toilets were separated from the main buildings and located behind Bulyaheke Primary School, on a hill about 50 meters away, see *Appendix IV* for an overview of the site. Moreover, the school buildings were estimated to be approximately 15x50 m² large, which is of interest when investigating the capacity for RWH.

The teachers had two Pour Flush Latrines, one for males and one for females, see *Appendix III, Figure iii*. It was a small shed built out of bricks and cement, and the roof was made out of sheet metal. The students had six toilets of the same type (see *Appendix III, Figure iv-vii*); the female students had three toilets, while the male students had three toilets and one urinal. In addition, there was a distinct odour from the toilets, which increased closer to the building. The stalls were dark, with uneven floors, allowing for the creation of water pools, but also urine. Some of them were missing doors and buckets with water for flushing, and in these stalls, human excreta were present. Another observation made was that there were no garbage bins available for used menstruation pads at the female toilets, and it was also noted that there were no toilets with access for students or teachers with disabilities. Also, neither the teachers nor the students had access to any type of hand washing facility, i.e. no water and soap, in connection to toilets. Furthermore, between the teacher's and the student's toilets, there was an open pit for general waste such as plastic bottles, toilet paper etc., see *Appendix III, Figure viii*. It was deep with no fence surrounding it, making it unsafe for young children to be around.

The area behind the school buildings was large and set aside for construction of toilet facilities in the future. Additionally, the schoolyard in front of the two schools were relatively big and flat, which is favourable for construction.

4.1.3 AUTHORITIES

In this section the results from the interviews held with the authorities are presented. The interview with the DWE was mainly held in Sengerema. Phone contact was established at a later stage in order to get answers to some complementary questions. The NGO Commissioner's Office where the interviews with the RCDO and the PE were held is located in Mwanza city centre.

4.1.3.1 INTERVIEW WITH DISTRICT WATER ENGINEER

When talking to the DWE it was found that, in comparison to the previous year, there was a newly established water agency called Rural Water Supply and Sanitation Agency (RUWASA), which operates under the Ministry of Water. This agency focuses on all implementation issues connected to rural water supply and sanitation; construction, maintenance and supervision of projects. Moreover, the agency works together with health departments with funding from the government.

Furthermore, when discussing last year's project about SODIS, the DWE said that the project had been of great success and that a pilot project in one of the rural villages would be the way to proceed in the implementation chain. He also pointed out that for the people to gain trust in projects like these, they need to see physical proof, e.g. pilot projects.

The issue of implementing dry toilets, as EcoSan toilets, was brought up and he was of the opinion that it would be possible if the locals were given enough knowledge about it. This would then, according to him, allow for water that is now being used for flushing to be used for other purposes, i.e. cleaning and personal hygiene. If such a structure is to be constructed, the government needs to be notified in advance for discussion about their involvement, and to see if they can provide any funding. Also, what needs to be considered with this solution is the collection of non-degradable materials as no organised collection of garbage is present in rural areas.

Furthermore, the idea of collecting rainwater for hygiene purposes and for cleaning toilet facilities was presented to the DWE who said that RUWASA already had plans on RWH due to the lack of piping systems. Collecting rainwater could then be combined with chlorination to increase the water quality.

Finally, during the discussion about construction, the DWE said that the agency included plans on construction of public toilets, but the ones in charge of the construction would be the health departments together with local funders. The toilets should be located by health centres or in the central parts of the village, and the best time for construction would be during the dry season which is between June and September. This, as it facilitates the transportation of materials that cannot be found in the village or local shops. Moreover, for private household toilets, it is the individual's responsibility to construct and maintain toilets. When asked about difficulties during construction and what the ground conditions look like, he said that normally there are no problems and that construction is performed according to the site requirements.

4.1.3.2 INTERVIEWS AT NGO COMMISSIONER OFFICE

At the Commissioner's office, meeting with the RCDO and the PE, the Mwanza region's development was discussed. They both mentioned an earlier collaboration with Sweden during the 1980s, which they were pleased with, expressing a desire for further collaborations. The previous collaboration was a project about health and water, funded by the Swedish Government during the period of 1985-2005. The RCDO further said that the project itself was successful, but that it had collapsed afterwards, due to people not practising what they had learnt. He therefore suggested the approach of 'self-help', meaning that during implementation, help and support will be provided for local engagement to 'help them, to help themselves'. In this way, the people become less dependent on the government, and it could therefore result in further initiatives without the government's involvement. Also, the acceptance for new developments and changed behaviour might increase.

During the conversation with the RCDO it became clear that the government do not provide any funding for individual projects, as construction of a toilet facility in Bulyaheke would be. The schools do however get 12 000 TZS (~5 USD) per student and year for operational costs which should include the maintenance of toilet facilities. Also, he pointed out that the government should have more strict rules for how the schools should spend that money, as that would help them to spend the money more wisely. He also expressed that a problem today is

that people do not show an interest in changing their behaviours, and therefore no further development is seen after completion of projects. Furthermore, for a successful implementation of sanitary facilities, he could contribute with knowledge since he has a degree in Civil Engineering.

Further on, the PE contributed with valuable information regarding the future of the region. He pointed out the importance of collaborating with the locals and to use local materials to support the country's economy. According to him it is not sustainable for them to take loans for development. He means that it has become a vicious cycle making them dependent on others. Instead he believes that involving the locals by using local companies and raw material from the region would result in an increase of their economy and a successful outcome. If other materials are used the maintenance can get complex because people do not know how to take care of it. Another positive outcome from this approach is increased acceptance from the locals and that they feel that the facilities belongs to them, which in other studies have been a problem.

4.2 RISK ANALYSIS

A risk analysis of the school area and the village resulted in the following identified hazards, risk objects and exposure pathways, see *Table 2 & 3*. With regards to these, potential consequences were identified, and suggested action plans are presented based on the information found during the interviews, observations and the literature study.

4.2.1 VILLAGE

Table 2. *Risk analysis for the village.*

Hazard	Risk object	Exposure pathway	Consequence	Action
Poverty - lack of knowledge about the relation between sanitation, hygiene and diseases due to no school	Part of population that are missing out of school	Exposure due to unawareness: direct contact, dermal contact, hand-face exposure, ingestion of water and food, flies	People getting sick or potentially death if immune system is weak (e.g. elderly and infants), open defecation, transmitting bacteria	Public education about sanitation and hygiene, not only in school
Insufficient hygiene facilities	Population in Bulyaheke village	Ingestion of e.g. food with usage of hands or hands in direct contact with face	Spreading bacteria to others, people getting sick or potentially death if immune system is weak (e.g. elderly and infants)	Collecting rainwater in public tanks for increased access to water and increased water volumes or drilling a public well
Open defecation or poor handling of waste from toilets	Population in Bulyaheke village	Ingestion of drinking water and food, dermal contact (hands which then ends up in the face)	Groundwater contamination causing the population in the village getting sick or potentially death if immune system is weak (elderly and infants)	Increased numbers of toilets and organised cleaning, proper treatment of waste so that it does not leach out

4.2.2 SCHOOLS

Table 3. *Risk analysis of the school area.*

Hazard	Risk object	Exposure pathway	Consequence	Action
Insufficient maintenance of toilets	Students and teachers	Direct contact, hand-mouth exposure, flies	Students and teachers getting sick or potentially death if immune system is weak, non-usage of toilet, students wait to go to the toilet until they are home	Access to water for cleaning/flushing or having a toilet that does not need water, put someone in charge for cleaning
Insufficient hygiene facilities	Students and teachers	Ingestion of e.g. food with usage of hands or hands in direct contact with face	Students and teachers getting sick or potentially death if immune system is weak (e.g. elderly and infants), risk spreading the bacteria to other people, females missing out of school during menstruation	Collecting rainwater in tanks for increased water volumes or drilling a well
Open defecation or poor handling of waste from toilets	Population in Bulyaheke village	Ingestion of drinking water and food, dermal contact, hand-face exposure	Groundwater contamination causing the population in the village getting sick or potentially death if immune system is weak (e.g. elderly and infants)	Increased numbers of toilets and organised cleaning, proper treatment of waste so that it does not leach out
Open waste pits/ old toilet pits	Students and teachers at the two schools, but potentially also inhabitants in the village	Ingestion of soil, dermal contact, hand-face exposure, leaching/spreading to groundwater, flies	Students and teachers getting sick or potentially death if immune system is weak. Also, potential spreading to the village	Proper covering and storage of waste pits, build toilets with tanks that can be emptied so that toilets do not need to be moved

4.3 FEASIBILITY EVALUATION

To visualise the advantages and disadvantages of the different toilet- and water access facilities described in *Section 2.3 and 2.4*, two tables (*Table 4 & 5*) have been developed. The intention of these evaluations is to find the most appropriate facilities to reduce the identified risks in *Section 4.2*.

Also, the grading of the different criteria is accompanied by the cost of each solution, which was also presented in *Section 2.3 and 2.4*. This, as it facilitates the comparison between the solutions, both when it comes to the feasibility and the investment cost.

4.3.1 TOILET FACILITIES

The following table show the grading of the three different toilet facilities suggested to improve the toilet situation at the two schools. A low score is desirable, and as seen, the scoring is quite even, and especially between the Pour Flush Latrine and the EcoSan toilet. The latter one is however considered as the most appropriate solution since the water issue is a crucial factor, meaning that the category of suitability is weighted as more important. Moreover, as for the success of maintaining the facility in a good condition, there seems to be no, or little difference, in the need for maintenance.

Table 4. *Result from the scoring of the toilet solutions.*

Toilet facility	VIP Latrine	Pour Flush Latrine	EcoSan Toilet
Technical requirements	2	1	4
Suitability	5	5	1
Availability	4	2	1
Need of maintenance	3	4	3
Implementation	1	1	4
<i>SUM</i>	<i>15</i>	<i>13</i>	<i>13</i>
Cost	36-358 USD	92-358 USD	80-250 USD

4.3.2 FACILITIES FOR WATER ACCESS

The following table show the grading of the two different facilities suggested to improve the water access at the two schools, however, note that the usage of water is aimed for hygiene and cleaning purposes only. It can be seen that RWH got the lowest score, and it is therefore the most appropriate alternative according to this evaluation.

Table 5. Result from the scoring of the water access facilities.

Facility water access	RWH	Drilling of well (handpump)
Technical requirements	2	4
Suitability	2	3
Availability	1	2
Need of maintenance	3	3
Implementation	3	2
SUM	11	14
Cost	3000 USD (one tank of 30 m ³)	6000 USD

Moreover, the number of RWH tanks needed are based on the number of students at the schools, the yearly precipitation presented in *Section 3.2* and the assumption of water consumption made in *Section 2.4*, saying that the access of water should be 20 litres per person and day, and *Section 3.5.3.2*, assuming that the water usage for hygiene purposes is 50 per cent of the daily demand. To fulfil the need of 10 litres per person and day (50 per cent of 20 l/d), with 4101 students, a tank of 41 m³ is needed. Collecting this amount of water is however not possible at the schools due to the roof are available in combination with the yearly precipitation 1119 l/m². If taking the combined roof areas of the two school buildings, an area of 1500 m² is available for collection of precipitation, resulting in a tank size of approximately 5 m³. This tank would cover the water consumption of approximately 353 students (11 per cent of the total demand) per day if assuming a consumption of 10 litres per person and day. See *Appendix V* for calculations. The same calculations can be made for the whole village.

5. DISCUSSION AND RECOMMENDATIONS

It is important to keep in mind when evaluating the results and discussing potential solutions or improvements, that this study is qualitative, meaning that it only represents a selection of the population in Bulyaheke. The interview subjects were however chosen in order to represent different ages, genders and occupations, to get a wider perspective. Additionally, with respect to people's privacy and due to the sensitivity of the study's topic, a limitation is that one cannot expect that people will share personal information about their hygiene routines, and information can therefore have been left out.

5.1 VILLAGE

It was found that the lacking sanitation in the village partly depends on the absence of sufficient water volumes, as a result from the lack of infrastructure for water supply and sewerage systems. This since the interview subjects showed both basic knowledge about, and interest in, sanitation and its connection to diseases, but does not have the possibility to practise it due to the lack of water. The sanitation problem in Bulyaheke therefore seems to be more due to the lack of water and its inaccessibility, or to having inadequate toilets for the specific area, rather than having no toilets at all or lack of knowledge.

The Pour Flush Latrine is the most preferred toilet solution today and the reason could be due to its similarities to the water closet used in the western world. Also, it can be connected to a future sewer system which might be desirable for a lot of people. This will however most likely not happen in the near future and its need of water is therefore considered as a problem rather than an advantage at this moment. Unless the availability of water increases, alternative solutions to the preferred Pour Flush Latrines used today has to be considered. Unlike the case in Cochabamba, people in Bulyaheke seemed open for other alternatives, if introduced properly. This could be due to the difference in location and development, Cochabamba being a peri-urban area and thereby closer to the city compared to Bulyaheke, being a village in rural Tanzania. From the evaluation made in *Table 4, Chapter 4*, EcoSan is considered as an appropriate toilet solution. Moreover, by implementing an EcoSan toilet, water is made available and can be prioritised for other purposes. To free water is important since it is crucial for keeping a good hand hygiene and to be able to maintain the toilet facilities in proper conditions. Also, with the prevailing circumstances due to the spreading of the Covid-19 virus mentioned in *Section 2.2*; not having water for washing of hands, one of the most recommended measures by WHO and UNICEF, could result in severe consequences and spreading of similar viruses in the future. Therefore, approaches to improve the sanitary situation should aim to increase water access in the village.

The EcoSan toilets can be constructed so that they are emptied through access from outside, but the waste pits can also be covered up and the toilet later moved. An advantage of moving the toilet structure and establishing a new pit is that there are fewer risks for the maintenance workers to get in contact with the waste material, also, the waste has time to degrade into non-harmful substances. By instead having access to the waste pit creates an opportunity for emptying the pit and using the degraded waste as fertiliser. Also, this causes no need to move the toilet, which can be preferable in areas where the space is limited. There are also urine-

diverting EcoSan toilets, where the urine can be used for irrigation, acting as a fertiliser, already after one month of storage instead of waiting one year for the waste to degrade. This method is however more complicated and its applicability in Bulyaheke therefore has to be further evaluated. Moreover, a waste disposal system for non-degradable materials also needs to be available, e.g. for menstruation pads. This waste can then be incinerated, and the ash later used to optimise the decomposition rate.

As a complement, to further reduce the spreading of waterborne diseases and increase the water accessibility, two different methods were evaluated in *Section 4.3.2*. RWH received the lowest score and is therefore considered to be more advantageous compared to drilling of a new well. Moreover, unpredictable consequences due to the lack of knowledge about recharge- and extraction rates needed for a sustainable withdrawal from an aquifer makes the implementation of a new well more risky. If further comparing RWH with drilling of a well, the financial investment needed for a well is bigger, but the acceptance is most likely high among the inhabitants due to it being an already existing solution in the village. However, the pilot study made in Zambia, mentioned in *Section 2.4.1*, showed good results when implementing RWH and that an interest for the technology among the inhabitants existed. This interest was also seen in Bulyaheke. Another advantage with RWH is that it could help reduce temporary pools, causing a hazard if the water is used for the wrong purposes, e.g. as drinking water. This, given that one boy was seen collecting water from one of the larger temporary pools, using a water bottle. Moreover, as it rains regularly (8 months per year), and that the roofs in the village are made out of sheet metal, facilitates the collection of water. Also, bricks that can be used for building RWH tanks was observed in the village during the introductory walk. The preconditions for implementation of RWH can therefore be seen as advantageous. Moreover, RWH could be implemented and maintained rather easily by each household, and the investment cost is advantageous for the individual.

Furthermore, people continue to get sick despite the inhabitant's statement of that they have access to toilets both at home and at work, and that they also use them. This could be due to poor hand hygiene and inadequate cleaning of the toilets, or that open defecation occurs more frequently than shared, causing groundwater contamination. Another reason for groundwater contamination could be due to leachate from Pit Latrines with insufficient barriers, if located close to the groundwater recharge flow. It is known from the interviews that the groundwater is used for drinking without further treatment, collected both from the well and the spring. Also, one of the interview subjects thought that she got sick from drinking water from the village's well, but it was never confirmed or further investigated. A recommendation is therefore, if the problem remains, to further investigate the origin of the possible contamination of the groundwater, if not connected to deficient toilet- and hygiene facilities.

To enable a future implementation of the above recommended solutions (the EcoSan toilet and RWH), it would be favourable to use local materials and workforce. This, since the roads are in bad conditions during the rainy season, limiting the accessibility to the village. If materials can be purchased close to the construction site in combination with using local workforce, the construction, maintenance and operation of the facilities are secured, as the dependency on deliveries decreases.

5.2 SCHOOLS

The students at Bulyaheke- and Mandela Primary school are educated two times a week on the topic sanitation, despite this, more or less all students interviewed had experienced some kind of illness or stomach-ache that most likely was linked to lacking sanitation. This shows that knowledge by itself is not enough to stay healthy, and if the right facilities are not available, people will continue to get sick. The lack of water needed to be able to practise what is learnt is therefore considered to be the main reason behind the sanitary issues at the two schools.

Today, the number of toilets available at the two schools corresponds to less than 10 percent of the toilet demand required for the number of students, this according to the *National guideline for Water, Sanitation and Hygiene for Tanzania schools*. This is also confirmed as a national problem by the UNICEF as only 38 per cent of Tanzanian schools reach the demand. To fulfil the lowest demand, with a ratio of 1 toilet per 45 students, 92 toilets has to be built (as seen in *Table 1*), if accounting for the old toilets being replaced. However, to increase the number of toilets, without changing the technology, would lead to an increased water demand and the hygienic conditions will therefore remain poor; as the water brought by the students today is insufficient for the existing six toilets, the water will consequently not be enough for a total of 92 toilets.

The above mentioned facts indicate that the Pour Flush Latrine is inappropriate as a solution for the schools, even though it got one of the better scores in *Table 4, Section 4.3*. Instead, a dry solution as an EcoSan toilet could be favourable as it requires no water for flushing, freeing water for other purposes. It is also advantageous that the waste can be used as fertiliser for the school crops when decomposed. This could increase the income for the two schools, in addition to the funding from the government, allowing investments for e.g. sanitary improvements. Also, the EcoSan toilet does not have to be kept dark as the VIP Latrine, which is preferable for the user, and especially for children. Furthermore, as 92 toilets needs to be built at the two schools to reach the demands, space will most likely be a limiting factor. A permanent toilet structure is therefore favourable, such as the EcoSan solutions, Skyloo and the Fossa Alterna mentioned in *Section 2.3.1.3*. The latter one is however less complicated to construct and maintain due to lower technical requirements and it also has the advantage of double pits, allowing for alternating usage and thereby letting the waste in one of the pits degrade. Also, if implemented properly, the Fossa Alterna has historically been accepted, and as mentioned in *Section 2.3.1.3*, a study in Malawi and Mozambique was shown to be successful. Also, as the access by road is limited due to weather conditions during the rainy season, it is most suitable to construct a double pit latrine limiting the need of transporting waste and enabling on-site treatment. Keeping these aspects in mind, the Fossa Alterna is theoretically a suitable toilet facility for the schools in Bulyaheke but a pilot project is recommended for further evaluation.

Moreover, the maintenance of the toilet facilities is today handled by the students and the teachers. A solution where the pit has to be emptied must therefore have strict guidelines for how the waste should be handled, to minimise the risks connected to direct contact with faeces. Preferably, the schools should hire someone in charge of this work, but it cannot be assumed that the work of maintaining the toilets is performed by educated sanitation workers. This increases the need for proper tools and protective equipment together with close supervision during maintenance.

Like most Tanzanian schools (90 per cent of all schools), Bulyaheke and Mandela Primary School do not provide proper handwashing facilities at the schools, this due to the low access of water. To eliminate, or at least reduce the need for the students to bring water from their homes every morning RWH could be implemented at the schools. The collected rainwater could be stored in tanks strategically located at the schools (e.g. in connection to the school toilets). Depending on the usage of the water, i.e. drinking water, or only for hygiene, cleaning and irrigation, additional treatment of the water might be needed. The fact that the collected water is not drinkable if not treated has to be made clear to avoid infections and spreading of waterborne diseases. Different treatment methods suitable for RWH could be installation of a flush water diverter or using external self-treatment methods after collection as chlorination or solar radiation. To eliminate the risks connected to self-treatment, another approach is to put someone in charge of the RWH, who maintains the facilities and assures a good quality of the water. For a successful implementation, a pilot project is recommended to evaluate the feasibility of RWH, to find a suitable treatment method and to see what type of material for the tank that could be easily maintained and used within the area. Also, by performing a pilot project at the schools, one can inspire other people in the village to construct similar tanks for their own needs.

5.3 AUTHORITIES

The Tanzanian Governmental agency, RUWASA, with the responsibility of water and sanitation issues in the rural areas of Tanzania, promotes the approach of ‘self-help’ through pilot projects for rural development. It is therefore recommended that the help provided for this project’s continuation should aim to ‘help them, to help themselves’, which also was supported by the RCDO. Moreover, the EcoSan and RWH solutions were encouraged by the DWE as good alternatives to the Pour Flush Latrine, and as a way to increase the water access. This, even though the locals preferred Pour Flush Latrines, as they seemed open for other facilities if introduced properly.

For the construction phase, the recommendations are to; construct during the dry season (June-September); use local workforce and materials to support the local economy and to ensure the long-term operation and maintenance; involve the inhabitants to make them feel like they own the facility (which previously has been pointed out as a problem when the government arrange constructions); and finally to consult the authorities and NGOs for the implementation phase. By involving parties with high reliability, as the authorities and NGOs, in combination with local engagement the acceptance among the locals would most likely increase, securing a successful implementation. Moreover, if continuously monitoring the different implementation steps, one could avoid a collapse of the project caused by people going back to their old behaviour patterns, which was stated as a problem by the RCDO during the last collaboration in 1985.

Finally, governmental funding is not an option as RUWASA does not have the capacity to invest in local sanitary solutions. They are however open for future collaborations with other countries or organisations to bring the project forward, but external funders are required.

6. CONCLUSION

The combined results from the interviews and the observations show that the sanitary situation in Bulyaheke is inadequate, potentially causing spreading of waterborne diseases. The main issue was seen at the two schools in terms of; number of toilets, availability of water for cleaning the existing toilets, and availability of water for personal hygiene. Moreover, the fact that the existing toilets are moved when the waste pit is full requires large areas. This is not considered a problem today, but if Tanzanian standards for the number of toilets that should be available in schools are to be fulfilled, together with an increased number of handwashing facilities, mobile structures are not an option. Therefore, the recommended solutions for the two schools, and possibly also for the village in the future, are the Fossa Alterna and RWH. The Fossa Alterna is favourable since it does not require water for flushing, and thereby making water available for other purposes. Additionally, it can also be built as a permanent structure with double pits, enabling the waste to degrade into non-harmful substances and to be used as fertiliser. Moreover, since the roof constructions in the village are advantageous for collecting rainwater and that rain events are relatively consistent in the area, RWH is suitable as a measure to increase the availability of water.

To conclude, the possibility of organising a pilot project at the two schools has to be explored, with the purpose of evaluating the acceptance, the performance and the operational retention of the Fossa Alterna and RWH. If the project turns out to be successful, it could also inspire and create a desire among the inhabitants in Bulyaheke, making them adopt the technologies and construct similar facilities at their homes. For this to be possible and for the project to proceed, external funders are needed for the implementation stage together with support from the Tanzanian Government and NGOs. To recruit investors, this study could be used by e.g. EWB-SWE or FUI as an informative document, describing the situation and the current needs.

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APPENDIX

Appendix I

Identified risks and actions taken to secure the feasibility of the study.

Risk	Action plan
Finding interview subjects	<ul style="list-style-type: none"> • Contact FOU and DWE beforehand • Use contacts from the previous study 2018/2019
Bias	<ul style="list-style-type: none"> • Talk to people with different backgrounds (locals, teachers and students, Authorities, FOU) • Have in mind that all information might not be completely 'true' or accurate
Sensitive subject	<ul style="list-style-type: none"> • Complement interviews with an observation of people's behaviour
Time limit	<ul style="list-style-type: none"> • Schedule visits to the village together with FOU and the DWE at the first meeting to ensure interaction with interview subjects
Wi-fi, data connection and electricity	<ul style="list-style-type: none"> • Important literature will be printed beforehand • Data will be bought for the usage of mobile phones and computers to ensure communication both in Tanzania and with EWB-SWE. • Usage of power banks
Language barrier	<ul style="list-style-type: none"> • Use of a translator provided by the FOU • Transcribing and recording of interviews

Appendix II

The interviews performed in this study were made both with people in the village Bulyaheke and with representatives from the Tanzanian Government. The interview subjects are listed below:

- At the village:
 - Head teacher at Bulyaheke Primary School
 - Health teacher at Bulyaheke Primary School
 - Students at Bulyaheke Primary School; males and females
 - Head teacher at Mandela Primary School
 - Health teachers at Mandela Primary School
 - Inhabitants of the village Bulyaheke

- Government representatives in Mwanza region:
 - Regional Community Development Officer
 - Principal Economist at NGO commissioner registrar, Mwanza
 - District Water Engineer, Sengerema District

Appendix III

Pictures taken by the authors in field in February 2020 in Bulyaheke.



Figure i. Private well located in Bulyaheke.



Figure ii. Public spring which was located in the outskirts of the village.



Figure iii. The teacher toilets seen from outside.



Figure iv. The back of the student toilets showing ventilation pipes.



Figure v. The male toilets, missing doors and uneven floors.



Figure vi. Picture from inside one of the female toilets showing uneven floor, lack of light and water for flushing and cleaning.



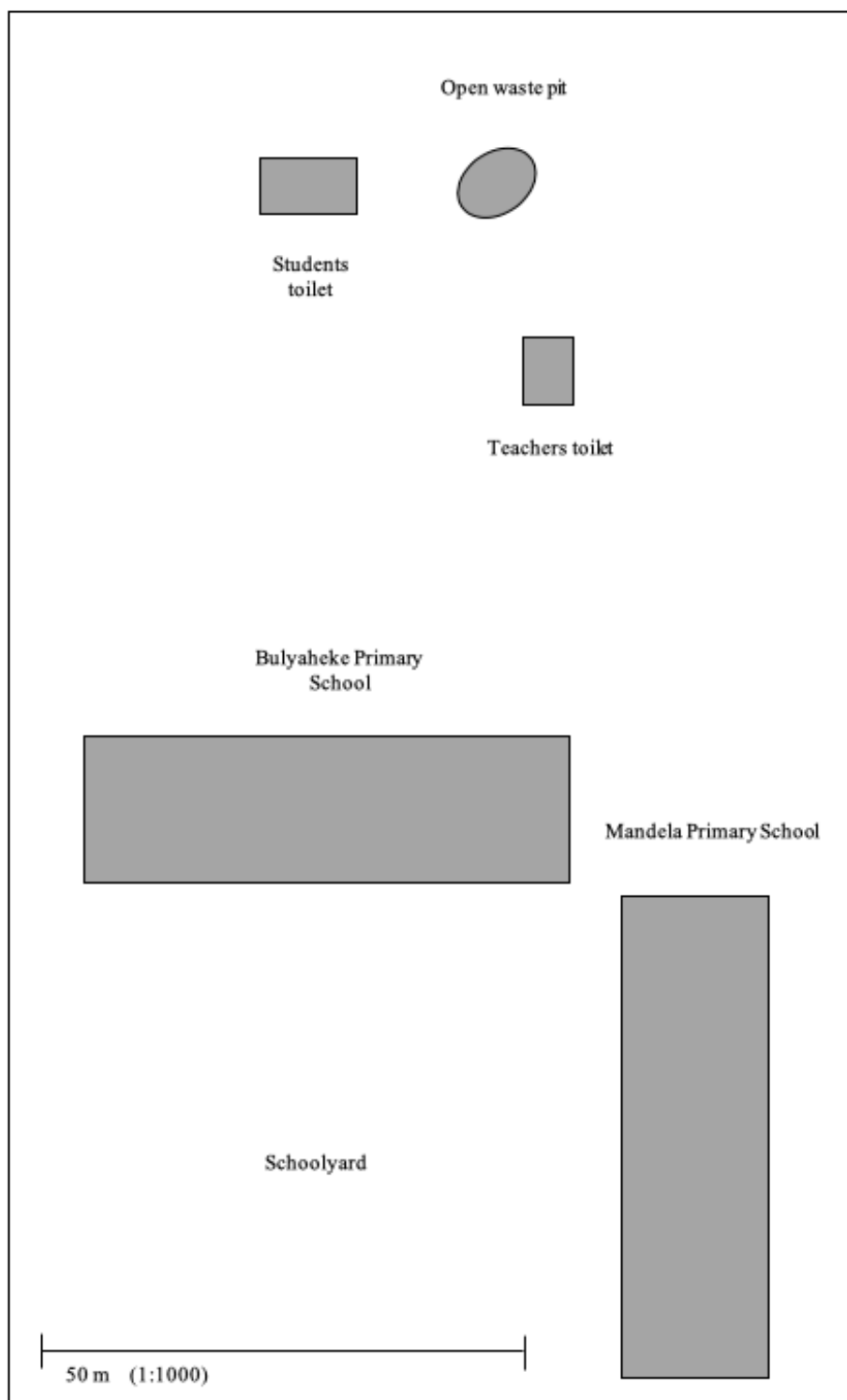
Figure vii. Outside the female toilets.



Figure viii. Open waste pit located between the teachers and student toilets.

Appendix IV

An overview of the school area in Bulyaheke seen from above:



Appendix V

Calculations for estimating the number of rainwater tanks needed and the coverage of the collected water in terms of number students.

Data	
Daily water demand	10 [l/d/p]
Roof area (1 building)	50x15 [m ²]
Yearly precipitation	1119 [l/m ²]
Number of students	4101 [p]

Needed water volume (including all students) and corresponding tank size

Needed water volume:

$$4\,101 [p] \times 10 \left[\frac{l}{p \times d} \right] = 41\,010 \left[\frac{l}{d} \right]$$

Equation 1

Tank size needed (optimal coverage):

$$\frac{41\,010 \left[\frac{l}{d} \right]}{1000} \sim 41 [m^3]$$

Equation 2

Water volume generated from the two school roofs and corresponding tank size

Total roof area:

$$50 [m] \times 15 [m] \times 2 [-] = 1\,500 [m^2]$$

Equation 3

Total volume of precipitation collected from the roofs during one year:

$$1\,500 [m^2] \times 1119 \left[\frac{l}{m^2} \right] = 1\,678\,500 [l]$$

Equation 4

Total volume of precipitation collected from the roofs during one day (average):

$$\frac{1\,678\,500 [l]}{365 [d]} = 4\,594 \left[\frac{l}{d} \right]$$

Equation 5

Number of students covered by the collected water when assuming 10 litres per person and day:

$$\frac{4\,594 \left[\frac{l}{d}\right]}{10 \left[\frac{l}{p}\right]} \sim 459 \left[\frac{p}{d}\right]$$

Equation 6

Tank size needed (actual coverage):

$$\frac{4\,594 \left[\frac{l}{d}\right]}{1000} \sim 4.6 [m^3]$$

Equation 7

Water demand covered by RWH:

$$\frac{4.6 [m^3]}{41[m^3]} \times 100 \sim 11\%$$

Equation 8



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