Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Department of Water, Atmosphere and Environment
Institute of Sanitary Engineering and Water Pollution Control

Ceská zemedelská univerzita v Praze
Czech University of Life Sciences, Prague

Faculty of Agrobiology, Food and Natural Resources
Department of Water Resources

Design of a Sustainable Operation and Maintenance Concept of the Water Supply System of Paroisse de Rwaza (Rwanda)

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Lehner Susanne

Supervisor: Priv.-Doz. Dipl.-Ing. Dr.nat.techn. Günter Langergraber
Co-Supervisor: Professor Dr. Svatopluk Matula

Student number 0605239

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Table of Contents

I. Abstract

Adequate access to safe drinking water and sanitation is essential to health and represents a fundamental human right. The core task of drinking water suppliers is to provide drinking water that complies with governmental regulations. Especially small rural community water supplies are often subject to restricting frame conditions and tend to lack capacities for ensuring the desired product of safe drinking water. These preconditions create a particular need to support operators of small water supply facilities, in order to guarantee sufficient water quality. The *Water Safety Plan* (WSP) concept developed by the WHO detects, assesses and manages risks along the whole water supply chain, from catchment to consumer, and aims to prevent the whole system from contamination. The application of this preventive management approach shall help operators, to ensure long-term and proper functioning of the system and to provide a safe product.

This master thesis has the objective to contribute to the long-term sustainable operation of the water supply system of Paroisse de Rwaza and the system extension to the non-governmental organisation *Future for Kids*, and therefore to a secured water supply with safe drinking water in the area. In this study the water supply system of concern is examined, a quantitative and qualitative water examination is performed and a risk analysis according to the WSP approach is conducted. Based on that, Operation and Maintenance (O&M) check lists, timetables and work instructions for a sustainable O&M of the network are developed.

It was found, that the water quantity provided by the springs should be sufficient for the supplied consumers. However, the water quality does not meet health based quality standards and should therefore not be used for human consumption without prior treatment. Finally, the findings of this study recommend the elimination of the 70 determined risks through the application of the identified O&M activities.

II. Kurzfassung

Zugang zu sauberem Trinkwasser und sanitären Einrichtungen stellt ein fundamentales Menschenrecht und eine Voraussetzung für Gesundheit dar. Die zentrale Aufgabe eines Trinkwasserversorgers besteht darin, der Gesetzeslage entsprechendes Trinkwasser zur Verfügung zu stellen. Vor allem kleine, ländliche Wasserversorger sind bei der Sicherstellung von sauberem Trinkwasser oft mit hinderlichen Rahmenbedingungen und knappen Ressourcen konfrontiert. Dadurch besteht die Notwendigkeit zur Unterstützung der Betreiber kleiner Anlagen um eine angemessene Wasserqualität zu garantieren. Das von der WHO entwickelte *Water Safety Plan* (WSP) Konzept erkennt, bewertet und managt Risiken entlang des gesamten Wasserversorgungssystems und zielt darauf ab eine Kontaminierung zu vermeiden. Die Anwendung dieses präventiven Tools soll Betreibern helfen eine einwandfreie Funktion des Systems zu gewährleisten und sauberes Trinkwasser bereitzustellen.

Das Ziel dieser Masterarbeit besteht darin zu einem nachhaltigen Betrieb des Wasserversorgungssystems von Paroisse de Rwaza und dessen Anbindung zur Nicht-Regierungsorganisation *Future for Kids* beizutragen, und dadurch eine sichere Wasserversorgung mit sauberem Trinkwasser in der Region zu unterstützen. Dabei wird das betreffende System untersucht, eine quantitative und qualitative Wasseruntersuchung durchgeführt und eine Risikoanalyse gemäß des WSP Ansatzes vorgenommen. Darauf aufbauend werden Betriebs- und Wartungs- (O&M) Checklisten, Zeitpläne und Arbeitsanweisungen für eine nachhaltige Bedienung des Wassersystems entwickelt.

Es zeigt sich, dass die von den Quellen bereitgestellte Wassermenge für die VerbraucherInnen ausreichend ist. Jedoch wird die Qualität des Wassers gesundheitlichen Standards nicht gerecht, wodurch das bereitgestellte Wasser nicht ohne entsprechender Aufbereitung konsumiert werden sollte. Zusammenfassend wird empfohlen die 70 identifizierten Risiken durch die Anwendung der ausgearbeiteten O&M Aktivitäten zu reduzieren.

III. Abbreviations

AMCOW	African Minister’s Council on Water
DWO	Drinking Water Ordinance
EDPRS	Economic Development and Poverty Reduction Strategy
EICV	Integrated Household Living Conditions Survey
EWSA	Energy, Water and Sanitation Authority
ICTR	United Nations International Criminal Tribunal for Rwanda
JMP	Joint Monitoring Programme
L/(cap*d)	Litres per capita and day
L/d	Litres per day
L/s	Litres per second
MDG	Millennium Development Goal
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MININFRA	Ministry of Infrastructure
MINISANTE	Ministry of Health
MIS	Management Information System
MVK	Kigali Town Municipality
NGO	Non-Governmental Organisation
NISR	National Institute of Statistics of Rwanda
NTU	Nephelometric Turbidity Units
O&M	Operation and Maintenance
RBS	Rwanda Bureau of Standards
REMA	Rwanda Environmental Management Agency
RURA	Rwanda Utilities Regulatory Authority
UNICEF	United Nations International Children’s Emergency Fund
WCED	World Commission on Environment and Development
WHO	World Health Organization
WSP	Water Safety Plan

1. Introduction

In 1994 Rwanda suffered from a terrible genocide that killed around one million people (mostly Tutsi) in a time period of approximately 100 days which accounts for approximately 15 percent of Rwanda's inhabitants (Brehm et al., 2014; Human Rights Watch, 2006; World Bank, 2010). The genocide started on April 6th in 1994, after the plane carrying the Rwandan president Juvénal Habyarimana and the Burundian president Cyprien Ntaryamira was shot down while approaching to land at the airport of Kigali (Human Rights Watch, 2006; ICTR, n.d.). All passengers were killed immediately and within a matter of hours a targeted and planned killing of Tutsi and Hutu associated with them began. The organisers of the genocide had made use of ideology and propaganda in order to bring Hutu to fear and hate Tutsi. Furthermore, they used state institutions to transform the hate and fear into acts of raping, hunting and killing Tutsi, which amounted to the genocide (Brehm et al. 2014; Human Rights Watch, 2006; World Bank, 2010). More than one million perpetrators – priests, judges, doctors and nurses among them – participated in the genocide and slaughtered their fellow countrymen as an "act of self-defence" (Brehm et al. 2014).

This human tragedy not only killed hundreds of thousands of people, but was accompanied by the widespread destruction of the country's infrastructure. Due to the terrible events, the water supply and waste water infrastructure in the country was heavily destroyed. When it comes to water supply, a decline in improved water supply coverage of more than 20 percent compared to the reference year 1990 could be observed after 1994, and dropped from more than 60 to 39 percent. Since then, the country tries to reach a coverage rate of 100 percent with the commitment to several international programmes, but the way to reach these targets is still long and difficult. Especially in the rural water supply sector many investments and improvements still need to be done in order to supply Rwanda's inhabitants with safe drinking water (World Bank, 2010). Besides the construction of water supply systems, the training of operators and the set-up of proper Operation and Maintenance (O&M) systems form a crucial step to a secured and safe water supply, as proper O&M activities are indispensable for the improvement of the efficiency, effectiveness and sustainability of water supply systems (Brikke, 2000; World Bank, 2010).

The object of inquiry of the master thesis was the rural water supply system of "Paroisse Rwaza du Diocèse de Ruhengeri", that is located in the border triangle of Rwanda, Uganda and the Democratic Republic of the Congo. The parish is situated in the district Musanze, formerly named Ruhengeri, in the Sector Rwaza, which is approximately 90 kilometres Northwest of Kigali (Klar, 2013). Within the territory of the parish the Austrian non-governmental organisation *Future for Kids* is located. In 2007, the organisation took over the responsibility for 50 orphans that were at that time in care of a nun in the parish Rwaza. The so called *Mountain Gorilla Education Centre* which provides a home and ensures the education of the children was founded. Furthermore, the centre serves as a facility for adult education, where inter alia courses in hygiene, birth control, wildlife conservation, agriculture, sewing and English are offered to the local population. In 2008, the new orphanage buildings were constructed and in 2013 the connection to the existing water supply system of Paroisse de Rwaza was conducted (Future for Kids, 2014). In the course of the extension of the system, the old system was rehabilitated and necessary reparation works were done. In the process of the system renovation it was detected that the water quality of the system had actually never been checked. Furthermore it was found that several times per year the water consumers suffer from water shortages – even though according to water flow measurements there should be enough water available – and that parts of the system were broken and did not work. These problems result from an inappropriate O&M of the water supply system. In fact, there was no preventive maintenance system available at all and at that time people only reacted when problems with the water system occurred. The absence of a proper maintenance system can be explained by 1) a lack of money, which is reflected in a very low budget for spare parts and in the non-employment of permanent employees, 2) a lack of O&M instructions and routines, 3) a lack of clear responsibilities, and 4) the absence of on-site checks by governmental authorities as the system is privately owned by the church. Now that the rehabilitation works are completed, it is crucial that the repaired and extended water supply system is maintained and operated suitably, so that a continued future use can be ensured and the lifetime of the system can be expanded (Klar, 2014).

The aim of the master thesis was to contribute to the sustainable O&M of the water supply system of the target area and therefore to a secured supply with safe drinking water. This objective was to be achieved via the development of O&M check lists, timetables and work instructions. The design of the checklists was based on a quantitative and qualitative water examination, an on-site inspection of the water supply system and an identification of hazards and critical points within the system (according to the Water Safety Plan approach from the WHO). The on-site investigations and data collection were executed in the course of the field research that took place in Rwaza in August and the beginning of September 2014.

2. Objectives

Adequate access to safe drinking water and improved sanitation is essential to health and represents a fundamental human right. The improvement of the access to safe potable water and sanitation services can lead to clear benefits to public health and should therefore be an important health and development issue at a national, regional and local level (RURA, 2015a; WHO, 2011). The WHO promotes an integrated preventive management approach from catchment to consumer for the securing of drinking water quality in their "*Guidelines for Drinking-Water Quality*"(2011). The by the WHO developed Water Safety Plan (WSP) concept (2004) detects, assesses and manages risks along the whole water supply chain, from the catchment to the consumer, and aims to prevent the whole water supply system from contamination. The application of this tool shall help to ensure long-term and proper functioning of the system and to provide a safe product. In the underlying field research of this diploma thesis, the WSP approach has been applied in order to improve the situation of the local water supply system of the study site (UBA and TZW, 2014; WHO, 2012).

The main objective of the present master thesis was *to contribute to the long-term sustainable operation of the water supply system of Paroisse de Rwaza and the system extension to the non-governmental organisation Future for Kids and therefore to a secured water supply with safe drinking water in the area.* To achieve this target, a set of sub-objectives has been developed:

- Investigation of the local water quantity and quality
- Identification of the used rural water supply and sanitation technologies
- Identification of the specific Operation and Maintenance (O&M) requirements of the used technologies
- Review of the present O&M situation and its comparison to the requirements
- Identification of possible critical points in the system, hazards, risks and mitigation options via the application of the Water Safety Plan (WSP) approach

Finally the achievement of these sub-objectives led to the development of a sustainable management plan, O&M checklists and work instructions. This was done in cooperation with the local stakeholders in order to ensure efficient O&M activities. It was intended that with this approach a step towards a sustainable water supply in the area will be achieved.

This master thesis is structured as follows: After the introduction chapter and the description of the thesis objectives, chapter three deals with the fundamentals of the thesis. This chapter describes Rwanda's water sector with special emphasis on the rural water sector. In the course of this chapter, a short historical outline of the developments in and the organisation of the sector are described. Furthermore, chapter three is dealing with challenges of small community water supplies, it gives an introduction to the WSP approach and illuminates the importance of proper O&M systems. Beyond that, the water supply system of the study-site in Rwaza is presented.

Chapter four illustrates the used research methods. In the course of that, the applied methods of the water quantity measurement and of the microbiological and chemical water quality analyses are described. Furthermore, the tool of the WSP approach is presented in more detail. Thereby its six tasks "Engage the community and assemble a WSP team", "Describe the community water supply", "Identify and assess hazards, hazardous events, risks and existing control measures", "Develop and implement an incremental improvement plan", "Monitor control measures and verify the effectiveness of the WSP" and "Document, review and improve all aspects of WSP implementation" are described. After the theoretical explanation of the management tool, its realisation in the field is depicted.

Chapter five is devoted to the description, analysis and discussion of the results of the fieldwork. The first part of this chapter deals with the outcomes of the conducted water quantity measurements and their comparison to reference values of the WHO. Afterwards, the results of the microbiological and chemical water quality investigations are described and compared to governmental drinking water limit- and indicator values. Moreover, the output of the implementation of the WSP is presented. Thereby the WSP team is introduced, the water supply system is described and hazards, hazardous events, risks and existing control measures are depicted. Developed control measures and an incremental improvement plan as well as the established monitoring activities and documentation processes are delineated and in the end challenges that arose during the fieldwork are described.

The sixth chapter consists of a summary of the findings of this thesis. In the seventh and last chapter – conclusion and outlook – the achievement of the objectives of the present thesis is evaluated and an outlook for possible further research is given.

3. Fundamentals

For being able to understand the characteristics of the object of the investigation – the water supply system of the parish Rwaza – a description of the bigger picture that the study site is embedded within, seems to be indispensable. Therefore, an overview of the history and the organisation of Rwanda's rural water sector as well as present developments of theoretical approaches and practical tools in the field of sustainable management of rural water services are provided. In addition, the local water supply system of the parish Rwaza is described.

3.1 Historical Outline of Rwanda's Rural Water Sector

Rwanda still suffers from its history and the aftermaths of the genocide in 1994. The human tragedy not only killed hundreds of thousands of people, but was also accompanied by a widespread destruction of (water) infrastructure and a loss of capacity. According to the African Ministers' Council on Water (AMCOW) (World Bank, 2010) after the genocide – compared to the reference year 1990 – a decline in improved water supply coverage of more than 20 percent could be observed and fell from previously 64 to 39 percent. Concerning the 1990 sanitation coverage level of 29 percent, there is no governmental data available for sanitation coverage in the years after the genocide. After the tragic incident and its destructive effects, a subsequent period of emergency programmes lead to low investment, neglected maintenance and an abandonment of cost recovery in the Rwandan water sector (World Bank, 2010).

Nevertheless, the country managed to make good progress in extending water supply and sanitation coverage throughout the nation in the last years and in 2009 the water supply coverage rate reached 72 percent, while improved sanitation coverage reached 45 percent (World Bank, 2010). According to the 2010/2011 Integrated Household Living Conditions Survey (EICV), in 2011 Rwanda could reach a water supply coverage rate of 74.2 percent and a rate of improved sanitation of 74.5 percent (NISR, 2012; WHO, 2014). These improvements were achieved through political will, a working institutional framework and clear and feasible policies and strategies. Rwanda's government recognizes that "access to safe drinking water and improved sanitation is a fundamental human right" (RURA, 2015a) and that "the quality of drinking water and sanitation services has a direct impact on public health and both are key components of social and economic development" (RURA, 2015a). Based on this acknowledgement, a development agenda that focuses on people and aims to provide basic needs to Rwanda's population has been established. In the course of this, the country made a clear political commitment to three international programmes and their sets of objectives: the *Economic Development and Poverty Reduction Strategy* 2012 (EDPRS), the *Millennium Development Goals* 2015 (MDG) and *Vision 2020* (Jain et al., 2010; Sano, 2012; World Bank, 2010). On the basis of the target sets of the mentioned programmes, Rwanda also established its own ambitious 2015 targets. Until 2015, the country aimed to reach a coverage rate of 85 percent for water supply, and a 65 percent rate for sanitation. These target values are aligned with the requirements of the EDPRS (80 percent water supply coverage and 47 percent for sanitation in 2012), the targets of Vision 2020 (100 percent coverage for both sectors water supply and sanitation in 2020) and the MDGs (to halve the proportion of people without access to safe drinking water and basic sanitation by 2015) (World Bank, 2010). To accelerate the achievement of the 2020 targets of 100 percent water supply and sanitation coverage rates, Rwanda established in 2010 a 7-year programme to achieve those ambitious aims already by 2017 (Sano, 2012).

Due to the implementation of the mentioned measures, Rwanda is successively approaching its targets. For monitoring purposes, the Rwandan government established the so-called Management Information System (MIS). Furthermore, the WHO/UNICEF Joint Monitoring Programme (JMP) is observing Rwanda's progress in its target achievement. Due to differences in the used methodologies, discrepancies between JMP's and national MIS data can be found. According to the MIS, Rwanda is on track meeting its MDG target for drinking water. In contrast to that the JMP data state, that progress towards meeting the national MDGs is insufficient in the case of drinking water supply. In the field of sanitation JMP data suggests that even though Rwanda is not on track to meet the MDGs, the progress the country has made in the last two decades is noteworthy. The Water and Sanitation Programme of the World Bank has identified a considerable financing gap for Rwanda to achieve the MDGs for water and sanitation and estimates that the country needs to invest an additional 27 Million US$ per year in order to meet the targets (Sano, 2012). According to Water Aid and Development Finance International (Sano, 2012), the successful implementation of the strategy to meet 100 percent of water supply and sanitation coverage by 2017, will not be achieved unless this significant financing gap is closed. This can only be done through an increased budget prioritisation by Rwanda's government in combination with the accumulation of additional resources from development partners and NGOs (Sano, 2012).

In Rwanda the water service provision is divided into two main components: The rural and the urban water sector. They developed independently from each other and at various points in time. While the rural sector began to form in the 1960s, an urban utility was only created in 1976. Regarding the rural sector, in 1964 the issue of the countrywide rural water supply was delegated to an NGO, while the government of Rwanda took care of the financing of the sector (World Bank, 2010). In 1978 the NGO introduced a participatory approach and in 1992 the first national sectoral policy – the *National Policy and Strategy for Water Supply and Sanitation Services* – was developed (Sano, 2012; World Bank, 2010). The overall objective of the policy is to "ensure sustainable and affordable access to safe water supply, sanitation and waste management services for all Rwandans, as a contribution to poverty reduction, public health, economic development and environmental protection" (Sano, 2012, p. 5). Since its establishment, it has been revised several times, in the course of which emerging issues such as community management and demand responsive approaches (in 1997) reinforced participation and decentralisation (in 2004) and public-private partnerships, national quality standards, sanitation and the environment (in 2010), have been included into the national policy. The National Water and Sanitation Policy is supported by the central authorities and also well known by various stakeholders (Sano, 2012; World Bank, 2010).

Like already mentioned, the genocide destroyed and nullified many achievements in the sector and the time period after the genocide was followed by a series of humanitarian and emergency programmes. At the end of the last century, Rwanda developed a new strategy for the rural water supply sector that is based on four key elements (Jain et al., 2010; World Bank, 2010):

- A demand-responsive approach was formulated, through which a preferred service level could be chosen by the communities that is based on their willingness to pay
- A decentralisation process fostering planning and management at the district level was introduced
- The private sector was supported and included
- The public sector was redeployed

In 2001, a multi-sectoral regulatory agency, the Rwanda Utilities Regulatory Authority (RURA) was created and in the year 2007 the *National Strategy on Sanitation and Promotion of Hygiene* was established. Furthermore in 2008 the Rwandan government participated in *AfricaSan II* and signed the *eThekwini Declaration* in the field of sanitation (Jain et al., 2010; Lazarte et al., 2011; Sano, 2012; World Bank, 2010). In 2010, the African Minister's Council on Water defined the following priority actions for Rwanda's rural water supply sector: To "continue advocacy for donors to join harmonised procedures and basket funds", to "publish a national inventory for RWS [rural water supply], including access rates and strategic ratios", to "develop technical assistance support for private operators" and to "closely monitor O&M performances by RWS operators, to ensure long-term sustainability of water services" (World Bank, 2010, p. 19). Some of these priority actions – the topics about private operators and O&M activities – form essential components of the present thesis and will be described in more detail later in this chapter.

3.2 Organisation of Rwanda's Rural Water Sector

Rwanda's water sector is split in a rural and an urban water supply and sanitation sector and they are both divided into various levels. The institutional roles and relationships for both sectors are illustrated in the following graph of the African Minister's Council on Water (Figure 1).

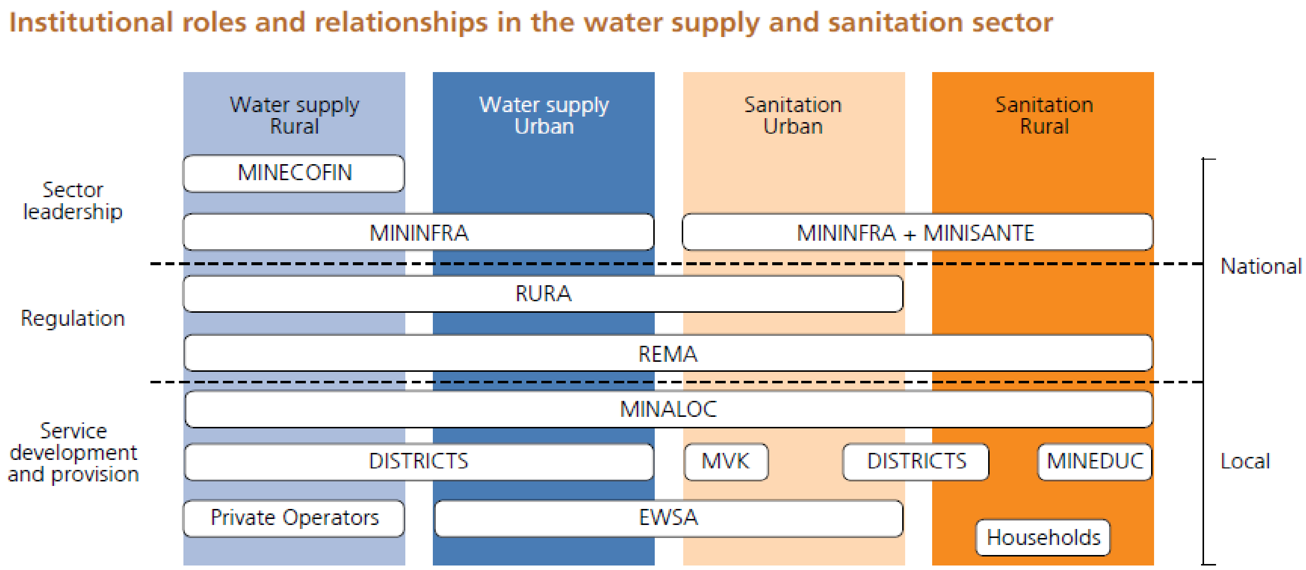

Figure 1: Institutional roles and relationships in the water supply and sanitation sector (World Bank, 2010, p. 14)

On the national level, the sector leadership in the rural water supply sector is taken over by the Ministry of Finance and Economic Planning (MINECOFIN) and the Ministry of Infrastructure (MININFRA). The institutions in charge of the regulation of the rural water supply are the Rwanda Utility Regulatory Agency (RURA) and the Rwanda Environmental Management Agency (REMA). On the local level, service development and provision in this sector are taken over by the Ministry of Local Government (MINALOC), the districts and private operators (World Bank, 2010). When it comes to private operators, water service provision is divided into different management models including schemes under public-private partnerships with contracts including companies, cooperatives and individuals, and those without management contracts like churches, water user committees, schools and tea and coffee factories (RURA, 2015b; World Bank, 2010). In the case of rural sanitation the sector leadership is shared by the MININFRA and the Ministry of Health (MINISANTE). The REMA is responsible for the regulation of the rural sanitation, and the service development and provision is implemented by the districts, the MINEDUC (Ministry of Education) and the households (World Bank, 2010).

Differences in the urban sector can be found in the sector leadership of the water supply that is only taken over by the MININFRA. On the other hand, the regulation of the urban sanitation sector is done by the RURA and the REMA. Concerning the service development and provision, the Energy, Water and Sanitation Authority (EWSA) and the Kigali Town Municipality (MVK) play an important role in the urban sector, while private operators and households are of no importance (World Bank, 2010).

In the course of the National Sectoral Policy revisions, decentralisation and the integration of private investors in the form of public-private partnerships started to play an important role in Rwanda's rural sector. The decentralisation process was intended to develop service delivery capacity on district-level in combination with staff reductions in the central government (Jain et al., 2010; Lazarte et al., 2011; World Bank, 2010). Although this process brought new opportunities, it also brought challenges due to the lack of capacity of local governments. Districts have still not received the required financial resources and skilled staff in order to work in an appropriate way and are struggling to obtain similar levels of operational capacity that were previously provided on national level. Furthermore, districts did not receive any training in managing, regulating and monitoring the newly established public-private partnerships. The shifting of traditional roles of institutions in the course of decentralisation processes requires the strengthening of local capacities, as without a capacity building on the local level, this development might lead even lead to a deterioration of the local situation (Brikke and Bredero, 2003; Jain et al., 2010; Lazarte et al., 2011; Sano, 2012; World Bank, 2010).

According to a study of the World Bank, half of the piped rural water supply systems in Rwanda were, due to poor management and poor cost coverage, not functioning in 2004. As a response to the problem, the Rwandan government started to promote the participation of the local private sector in the management of piped rural schemes in order to improve the performance of rural water supply systems. The authorities aimed to improve cost recovery in the sub-sector of rural water supply by switching from a central management model towards one of public-private partnership. The introduction of this management approach has been a success and has increased Rwandans' access to water supply. In 2010, already 30 percent of rural water systems were managed on a private basis and served approximately one million people. The types of operators vary in size and also in organisational structure. Most of the systems under public-private partnership contracts serve an average of 5,000 people and the majority of the supplied people are served by public water stations – only about five percent have household connections. These systems are owned and operated by private entrepreneurs, community-based associations or by private institutions such as parishes, dioceses, hospitals and factories – such as in the case of the present master thesis (Jain et al., 2010; Lazarte et al., 2011).

With the introduction of public-private partnerships in the management of water supply systems, the maintenance of existing infrastructures has been improving. Nevertheless, O&M activities executed by private operators need to be monitored and regulated at the district level and also collected fee rates require official regulation (Sano, 2012; World Bank, 2010). The RURA, which is in charge of the regulation of the rural water supply sector, still lacks capacity to regulate and monitor relations between districts, private operators and users. Since the process of decentralisation started, national surveys for rural water supply facilities have not regularly been updated and an accurate overview of local facilities and access rates is limited. Subsequently, evaluations of rehabilitation needs or assessments of the performance of the public-private partnership strategy are difficult to perform. Therefore, the RURA needs to be strengthened and an appropriate operating model needs to be established for being able to supervise the various districts and small-scale private operators (World Bank, 2010). According to Jain et al. Rwanda's government needs to "focus on ensuring the sustainability, reliability, and affordability" (Jain et al., 2010, p. 5) of the water supply services and on the management and protection of the country's water resources. Moreover, the authors state, "it is not so much a question of who manages the services, but how the service and the assets are managed and how long the service provider is technically and financially supported" (Jain et al., 2010, p. 5). Also Lazarte et al. (2011) write that the "private sector participation provides a promising solution to sustainable management of water services, but it is necessary to emphasize the two other Ps in 'PPP': public and partnership" (Lazarte et al., 2011, p. 4). This cooperation between water service providers and the public authorities is particularly significant in the case of small community water supplies, as they are due to several reasons that are explained in the following subchapter, more prone to problems with their water service provision.

3.3 Challenges of Small Community Water Supplies

According to the WHO "*Guidelines for Drinking-Water Quality*" (2011), drinking water suppliers are at any time responsible for the safety and quality of the water they produce. The core task of every drinking water supplier is to provide drinking water that complies with the applying international and national governmental regulations. Those regulations are valid for every central water supplier, regardless of the size of the provider and are therefore also valid for so called “small” community water supplies. There is no uniform definition of small community water supplies and different definitions are based on the number of people served, the quantity of water provided, the number of service connections or the type of used technology. The common denominator that sets small water supply schemes apart is the operating and management challenge they face. Especially small rural communities are often subject to restricting frame conditions and tend to lack personnel, financial, organisational and technical capacities for ensuring the desired product of clean and safe drinking water. Operators of small systems are often untrained, unpaid and may work only part time due to other community- or private responsibilities. They often face obstacles such as a lack of access to expert assistance, seasonal variations in water quality and quantity, limited support from governments and water user committees as well as limited financial resources for investments and reparations. Due to the listed circumstances, small community water supplies bear a greater risk of breakdown and contamination than large centralised schemes (UBA and TZW, 2014; WHO, 2011, 2012). According to the WHO (2012), the greatest risk to health in small community water supplies, is the potential for microbial contamination and outbreaks of related waterborne diseases. These conditions create a particular need to support providers and operators of small water supply facilities, in order to being able to guarantee a sufficient water quality by small community providers. Managing small community water supply systems represents a concern worldwide, as both in industrialised and in less developed countries a considerable number of people have to rely on small community water supplies – such as in the case of the small rural water supply system of the parish Rwaza. The concept of Water Safety Planning provides a reliable framework for small communities to focus on a cost-effective management and therefore boost their limited capacities (UBA and TZW, 2014; WHO, 2012). This concept is portrayed in the following subchapter.

3.4 Water Safety Plan Approach in a Nutshell

The so called Water Safety Plan (WSP) concept is a sector specific preventive risk management concept that was introduced with the Bonn Charta and the 3rd edition of the WHO “*Guidelines for Drinking-Water Quality*” in 2004 (NaWaTech, 2013). The aim of this systematic reflection and working process is to ensure and improve the security of drinking water supply. The WSP is a management tool that supports operators in identifying and subsequently controlling risks to their water supply system, and therefore helps to ensure long-term and proper functioning of the schemes (Asoka, 2010; Davison et al., 2005; NaWaTech, 2013; UBA and TZW, 2014; WHO 2012). This approach detects, assesses and manages risks along the whole water supply chain, from the catchment to the consumer before problems occur and therefore avoids “the limitations associated with relying on end-product testing as a means of water safety control” (Davison et al., 2005, p. 19). Although testing of water quality will always be an important component in verifying drinking water safety, an approach to better protect the consumers by lowering the risk of contaminants entering water supply systems in the first place, is to be favoured (Asoka, 2010; Davison et al., 2005; UBA and TZW, 2014; WHO 2012).

The document of the WSP itself records the process and the implemented practices of providing safe drinking water. This document is never “finished” in a narrow sense, but is continuously revised, changed and updated by the established WSP team. The application of the WSP approach is not a one-time undertaking, but an integral part of the every-day operation, management and maintenance of a water supply system. The development of a WSP implies several benefits for the operator. It strengthens the organisational safety, improves the understanding of the water supply system of the operating staff and puts the focus on possible weak points in the system. Furthermore, the concept helps the technical personnel to systematise operational processes, identifies required improvements and provides a basis for investment decisions. In addition, the implementation of a WSP fosters the knowledge about governmental regulations, encourages the communication between different stakeholders and serves to document specific knowledge (UBA and TZW, 2014; WHO, 2012).

A unique characteristic of Water Safety Planning is its adaptability to different socioeconomic structures and its capacity of being effectively applied at different scales. Furthermore, the concept can be employed not only for newly planned water supply systems, but also for already existing schemes. Therefore it is applicable to already existing small rural community based water supply schemes, which turns it into a suitable tool for the settings of the present master thesis (WHO, 2012). In the chapter *Material and methods*, the method of the WSP approach is described in more detail. In the course of the application of this method, O&M activities, which are described in the following, play an important role in order to ensure the proper functioning of water supply systems (UBA and TZW, 2014; WHO, 2012).

3.5 The Importance of Proper Operation and Maintenance Systems

Operation and Maintenance (O&M) is a term that is commonly used to identify all implemented activities in order to run and keep provided facilities in a good condition. According to the WHO, the aim of O&M programmes with regard to water services, is "to improve the efficiency, effectiveness and sustainability of water supply and sanitation services" (Brikke, 2000, p. V). The term o*peration* refers to "the actual running of a service" (Brikke, 2000, p. 42) and includes activities like the handling of pumps, the provision of fuel, the control of water collection points or the general mechanical procedures. The term m*aintenance* on the other hand describes activities "that keep the system in proper working condition" (Brikke, 2000, p. 42) such as cost recovery, management, repairs and preventive maintenance. Maintenance activities can be further subdivided in so called crisis- or reactive maintenance and in preventive maintenance. *Reactive maintenance* refers to actions that are only undertaken in response to system breakdowns, while *preventive maintenance* activities are executed according to prescheduled systematic inspection, repair and replacement plans. While in general the application of the first approach is leading to a poor service level, a faster equipment abrasion, higher O&M costs and users' dissatisfaction, the latter approach results in the continuity of the service level, an extension of the equipment's lifetime, a spreading of O&M costs over time and users' satisfaction and their willingness to pay for the received service (Brikke, 2000).

O&M activities encompass not only technical aspects, but cover also managerial, financial, social, community, gender, environmental, political and institutional issues and need to be focused on the elimination of the constraints that prevent the achievement of sustainability. Besides the improvements on a technical level, effective O&M activities also induce health and social benefits by sustaining water supplies in appropriate quality and quantity, by reducing the time needed for water collection chores and by providing income generating activities for the local population (Brikke, 2000; Brikke and Bredero, 2003; Jain et al., 2010; Lupu, 2010; Sano, 2012).

The importance of proper O&M activities has, especially in developing countries and in particular for small rural water supply and sanitation schemes, long been a neglected topic. This condition led to the non-functioning of 30 to 60 percent of existing rural water supply systems in developing countries (Brikke and Bredero, 2003). In the last few years though, the importance of O&M has gained more attention and nowadays O&M appear as keywords to improve the performance, efficiency and sustainability of rural water supply and sanitation services. Policy makers, project designers and local communities seem to be more aware of the direct connections between O&M practices and the sustainability of water supply and sanitation schemes. Also the significance of incorporating O&M in all phases of project development, from the planning- to the post-construction phases, has been recognised. For being able to fully benefit from an implementation of O&M programmes, the activities should be planned and organised at both national and local levels. Thereby, the creation of an enabling environment by the government plays a crucial role, as well as the management at community level and the support from local authorities and private stakeholders (Brikke, 2000; Brikke and Bredero, 2003; Jain et al., 2010; Lupu, 2010; Sano, 2012). Especially in cases where governments are shifting from service providers to facilitators of service provision in the course of decentralisation processes, it is important that the roles and responsibilities of the in the O&M activities involved actors are well defined (Brikke, 2000).

The most widely used definition of the term *sustainability* was published by the World Commission on Environment and Development (WCED) in the report "*Our Common Future*" – also known as the Brundtland report – in 1987. In this report *sustainable development* refers to "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED cited by Drexhage & Murphy, 2010, p. 6).

Derived from this definition of sustainable development, according to the WHO a service is said to be sustainable, when (Brikke, 2000, p. 45):

- It is functioning and being used
- It is able to deliver an appropriate level of benefits
- It continues over a prolonged period of time
- Its management is institutionalised
- Its operation, maintenance, administrative and replacement costs are covered at local level
- It can be operated and maintained at local level with limited but feasible external support
- It does not affect the environment negatively

Like already mentioned, the sustainability of water supply facilities depends to a high degree on efficient and effective O&M activities. Nevertheless, the contribution of O&M actions to the sustainability of supply schemes depends on several factors and processes that already have to be developed during the planning and construction phase of the system. In the literature several factors and processes which contribute to the effectiveness and sustainability of O&M activities and subsequently of a water supply system are described (Brikke, 2000; Lupu, 2010).

According to Brikke (2000, p. 45) there are four interrelated factors that affect sustainability:

- Technical factors
- Community factors
- Environmental factors and
- The legal and institutional framework in which the other factors evolve

Moreover, financial factors are a key element that is influencing all the other mentioned factors. Brikke (2000) also defines processes that influence the sustainability of O&M activities. For example the demand for an improved service, the responsiveness of support institutions and agencies, the participation of communities, the linkage of technology choice with O&M, the planning with a gender perspective, decentralisation processes, communication, public-private partnerships, co-responsibility between communities and municipalities and capacity-building at all levels.

Also the article "*Operation and maintenance of water and sanitation systems in northern Uganda*" (Lupu, 2010) defines factors or in this case challenges, that can severely affect the efficiency of O&M activities in rural East-African areas. According to Lupu (2010), they can be divided into technical, economic, social and managerial challenges and can be further subdivided according to the project phase in which they are most likely to occur (Lupu, 2010). As these defined categories were established for a comparable setting to the case study presented here, they are subsequently described in more detail.

In general, technical challenges are related to the physical construction of facilities. Therefore, it is crucial, that for each specific site appropriate technologies are selected and that poor quality materials are avoided in order to prevent frequent repairs. Lupu (2010) suggests the provision of handover manuals regarding the selected technologies, the construction techniques and the necessary O&M activities to all stakeholders (Lupu, 2010).

Economic challenges arise from the necessity of a correct calculation of the systems' costs, in order to guarantee the economic sustainability of the O&M activities. Therefore, both initial costs and current costs need to be taken into account. Furthermore, an income or revenue system that is appropriate for the specific site needs to be identified and implemented (Lupu, 2010). According to Jain et al. (2010) a key issue for the success of the public-private partnership approach is "to ensure financial viability by setting appropriate tariffs" (Jain et al., 2010, p. 5). The authors state, that cost recovery should be achieved while tariffs should still be affordable, so that the use of alternative and unsafe sources of water is not encouraged (Jain et al., 2010; Lupu, 2010).

In addition, challenges to O&M activities can also result from the social environment. To prevent difficulties in this field, implementing actors should gain knowledge about existing needs, cultural beliefs and attitudes related to water and sanitation and ethnical or religious divisions and should work participatory with the community (Lupu, 2010).

Furthermore, managerial difficulties can have an effect on O&M practices. In order to avoid them, several preventive measures should be considered. Firstly, the planning of O&M activities should be carried out before the construction of water supply facilities starts when it comes to the development of new schemes. Thereby it is important that existing policies can regulate O&M practices and that the local community is prepared to carry out managerial tasks. Secondly, it is important that agreements with local authorities and communities concerning management responsibilities, user's contribution and the use of the service are set in place. Once the planning phase is completed, management trainings for all involved stakeholders should be organised. As a last crucial step, the supervision and monitoring of the O&M activities – also after the facilities have been handed over – need to be performed (Lupu, 2010).

Based on the portrayed challenges, Lupu (2010, p. 31) provides recommendations for a successful implementation of O&M systems of water and sanitation systems in African rural areas:

- O&M should be selected, planned and implemented throughout the entire project and beyond
- Preventive rather than reactive O&M should be prioritised
- Communities and local authorities should participate in the selection of used technologies and O&M strategies
- Culturally sensitive facilities should be provided
- O&M managerial tasks and responsibilities should be selected in collaboration with local communities and authorities
- Local communities and authorities should be assisted in acquiring needed skills and in implementing appropriate managerial measures
- Local communities and authorities should be provided with hand over manuals and trainings on O&M procedures
- Assessments should be carried out for the selection and implementation of appropriate revenue systems
- Support and supervision should be guaranteed also after the end of a project

Nevertheless, for a successful implementation of sustainable O&M activities, site specific characteristics need to be taken into account (Lupu, 2010). Therefore, the water supply system of interest is described in the following.

3.6 The Water Supply System of Paroisse de Rwaza

The present master thesis dealt with the local rural water supply system of the parish in Rwaza. The sector Rwaza is situated in the district Musanze – formerly called Ruhengeri – in the Northern Province of Rwanda, approximately 90 kilometres in the northwest of the capital Kigali. The water supply system is privately owned by the parish in Rwaza and the superordinate diocese in Musanze, and there is no public involvement. The scheme was built in the late 1950s in order to serve the local parish “Paroisse de Rwaza du Diocèse de Ruhengeri” and its facilities. These facilities include the parish itself, two primary schools, a health centre, the village Igiturushiya where teachers of the schools and the staff of the health centre are housed and only occasionally also the secondary school sisters of the area. Also the local population is supplied via two public water stations. In total, the system supplies approximately 750 people and is roughly four kilometres long. The whole water supply system is gravity-fed and no additional pumps are needed. The original distribution network is made out of drawn steel pipes. Broken pipes are replaced by polyethylene pipes (Klar, 2013, 2014).

The water supply system of the parish Rwaza consists of the following components (Figure 5 in chapter 5.3): The system is served by four springs, one source from the valley Mukono and three sources from the valley Mikamo. All four springs are protected in brickwork structures that are closed with steel covers. The three springs from Mikamo are united in a collection chamber from where the water is conveyed via a washout to a second collection chamber. In this chamber the three sources from Mikamo are merged with the water that comes from the source Mukono. Next to the second collection chamber, there is a public water station located (public water station Mikamo), which consists of a small storage tank, a washout and a public tap. From the second collection chamber another pipe transports the water to a pressure reduction and air release chamber. In this system point, a second public water station (public water station Bukara) is located. From the first pressure reduction chamber the water is transported via a washout to a second pressure reduction and air release chamber. At this point in the system the storage tank of the local sisters is connected to the water supply system of the parish. However, this tank is not really a part of the system, as it is only very rarely supplied, because the nuns are normally provided via another water source. Therefore, this tank is not considered in the following. From the second pressure reduction chamber a pipe transports the water to the main storage tank of the parish. The main storage tank is made of steel and has a volume of 24,000 litres. It stands elevated on columns and at its bottom the pipes that supply the health centre, the two primary schools, the tank of the village Igiturushiya and the parish Rwaza, that are all equipped with taps, are attached. For a more detailed technical description of the water supply system of Paroisse de Rwaza, see the “*Operation and maintenance manual*” written by Werner Klar in 2013 (Klar, 2013, 2014).

In 2013, the existing water supply system was extended and the orphanage buildings of the Austrian non-governmental organisation *Future for Kids* were connected to the old system. In the course of the system extension, the whole system was examined by the German water engineer Werner Klar of the Senior Experten Service. In the course of that, the status-quo of the system was recorded and necessary repairs were ordered and performed. Furthermore, the extension to the orphanage was planned and later implemented by a local construction company. When Werner Klar investigated the system in August 2013, he came to the conclusion that the system itself was in a quite good condition for its age, but parts of the system had not been maintained for ten or more years. Some of the valves had not been in use for that time period and could not be operated anymore, and also some of the washout chambers were covered with a 30 centimetres soil layer and had to be excavated. Water losses of approximately 30 percent were detected in the distribution network. In the process of the system renovation it was detected that the chemical and microbiological water quality of the system has actually never been checked. The encountered status-quo of the water supply system can be explained with the circumstance that there has not been a proper O&M system in place. The parish – as the owner and operator of the system – did not have enough economic resources in order to set up a preventive O&M system and to employ workers on a regular basis. Instead, a reactive maintenance was applied and broken parts were only repaired in case of system breakdowns. Furthermore, the tool room of the parish was more or less empty and even small system repairs were associated with hurdles. After the successful rehabilitation of the system, it is crucial that the repaired and extended water supply system is maintained and operated suitably, in order to ensure a continued future use and the expansion of the system’s lifetime. In the course of his work at the site, Werner Klar developed an “*Operation and* *maintenance manual*" (Klar, 2013), which describes the required measures for operating the system in a sustainable way. It consists on the one hand of a list of actions that should be done immediately in autumn 2013, in order to repair broken parts of the system, and on the other hand of a manual that describes which operation and preventive maintenance activities have to be carried out in which part of the system and in which periodicity. This O&M manual was used as a point of entry of the present master thesis, as it was the basic source of information upon which the in the course of the fieldwork developed O&M checklists were built on (Klar, 2013, 2014).

4. Material and Methods

The data were acquired via literature review, semi-structured interviews and in the course of the fieldwork during the three-week stay on the site in Rwaza. In total, four semi-structured interviews were conducted. Two expert interviews with the water engineer Werner Klar in the course of the preparation of the fieldwork, and one with the manager of the NGO *Future for Kids* Justin Rurangirwa as well as with the head priest of the parish Rwaza Father Narcisse during the field research. Apart from that, several informal conversations with the two helping students and the manager of the orphanage were held. During the fieldwork the water quantity was assessed, the chemical and microbiological water quality was examined and the tool of the WSP was applied. In the following, the used methods are described in more detail.

4.1 Water Quantity

Water flow measurements in different parts of the system were performed in order to detect whether the system provides an adequate quantity of water for the supplied water consumers. Therefore, the "*Timed Volume Method*" also called "*Bucket Method*" was used. This method can be used for the estimation of flow from pipes and from streams with low flow volumes running over an edge. It is an easy method to estimate discharge and only requires a container or bucket of known volume, a stopwatch, paper and pencil. The container needs to be placed under the pipe capturing all the discharge. In addition, the time until the container is filled needs to be recorded with the stopwatch. This procedure needs to be repeated three times in order to obtain an average result of the three readings. Afterwards, the known volume of the bucket is divided by the average time needed to fill the bucket and the flow rate in litres per second is obtained (Hydromatch, n.d.; Michaud and Wierenga, 2005; Brown, 2006).

4.2 Water Quality

Drinking water should be suitable for human consumption and domestic purposes including personal hygiene. Regular quality check-ups and a verification of the compliance of limit and indicator values are crucial for the quality assurance of drinking water. Therefore, a microbiological and chemical examination of the water provided by Rwaza's water supply system was performed during the field research. A microbiological assessment of E.coli and coliform bacteria, as indicators for the presence of faeces and associated enteric pathogens, was conducted on-site (Lindner, 2013). In the master thesis the membrane-filter technique was used. In doing so, collected water samples were filtered via a hand operated vacuum pump through sterile 0.45 µm filter membranes. The membranes were then placed on petri dishes filled with ChromoCult® coliform agar ES, which compared to other culture media, suppresses the growth of interfering accompanying flora. This selective agar allows the simultaneous detection of total coliforms and E.coli due to the use of a combination of two specific chromogenic substrates (Merck KGaA, n.d.). Every sample was investigated twice, once filtered with 10 mL and once with 100 mL, in order to increase reliability of the results. Due to the given frame conditions on-site and the lack of a conventional laboratory incubator, the inoculated plates had to be incubated by means of body temperature. Experiments at the microbiological laboratory of the Institute of Sanitary Engineering and Water Pollution Control at BOKU showed that an incubation of the petri dishes for 24 hours at the body temperature of approximately 36℃ leads to comparable results with an incubation for 24 hours in the conventional laboratory incubator at 37℃. In order to achieve a more stable temperature of the on the body worn plates, the petri dishes were insulated with aluminium foil. Subsequently, they were attached to the thigh with a bandage, where they were kept for 24 hours. After the incubation period, the results could immediately be read and the grown colonies could be counted (Lindner, 2013). In the used medium, E.coli form dark-violet coloured colonies, whereas coliforms appear in a salmon to red colouration and accompanying flora grows colourless or turquoise colonies. Thus, the different colonies can easily be differentiated from each other and be enumerated (Merck KGaA, n.d.).

Due to a lack of proper laboratory equipment, it was not possible to perform chemical tests on-site. Therefore, water samples were collected on the day of departure and were brought to the chemical laboratory of the Institute of Sanitary Engineering and Water Pollution Control at BOKU, where the chemical testing was conducted according to standard procedure. In the course of this, the contents of the limit value parameters arsenic, lead, boron, cadmium, chrome, copper, nickel and selenium as well as contents of indicator value parameters such as aluminium, iron and manganese were measured and turbidity was evaluated. This was done for both dissolved and total contents of the samples.

4.3 Water Safety Plan

As already mentioned (see chapter 3.4) the Water Safety Plan (WSP) concept was used in order to ensure and improve the security of the drinking water supply of the parish Rwaza. The aim of this management tool is to support operators of water supply schemes in identifying and controlling risks to their water supply systems. The application of the WSP approach detects, assesses and manages risks along the whole water supply chain, from catchment to consumer and therefore helps to ensure long-term and proper functioning of the system and to provide a safe product. This is accomplished by the control of processes in the catchment area, at the extraction site and during treatment, storage and distribution of the water (Davison et al., 2005; UBA and TZW, 2014; WHO, 2012). In the course of the underlying fieldwork of this thesis, the manual of the World Health Organization "*Water Safety Planning for small community water supplies. Step-by-step risk management guidance for drinking-water supplies in small communities"* (2012) and the *"Das Water-Safety-Plan-Konzept: Ein Handbuch für kleine Wasserversorgungen"* (2014) of the German Federal Environment Agency (Umweltbundesamt) served as guidance manuals for the application of the WSP approach.

The WSP concept is actually not "a plan" in the narrow sense but rather represents a continuous process (UBA and TZW, 2014). This incremental improvement process consists of several tasks that need to be performed and is led by answering the following questions (Schmoll 2010 cited by NaWaTech, 2013):

- What can go wrong?
- What are the hazards and risks?
- How important are these hazards?
- How can they be handled and fixed?
- How can it be made sure that they are fixed and under control?
- What can be done if still something goes wrong?
- What can be improved?
- What could be learned from it?

In the course of the implementation of the WSP tool, different tasks or steps need to be accomplished. In the following the WSP-tasks according to the WHO (2012) are described and are in some respects supplemented by recommendations of the Umweltbundesamt (2014). The two WSP manuals from the WHO and the Umweltbundesamt consist of basically the same tasks, with the difference that the manual published by the Umweltbundesamt subdivides the processes of the risk assessment and the documentation and review of the WSP in several tasks and therefore is composed of ten instead of the six WHO WSP-steps. After the theoretical explanation of the WSP tool, the practical implementation of these tasks in the course of the fieldwork in Rwaza is delineated in chapter 4.4.

According to the WHO (2012), the process of developing and implementing a WSP for small community water supply schemes can be divided into six main tasks, which are shown in the following graph (Figure 2). Nevertheless, it is highlighted that these steps only serve as a guideline, but that a WSP should be developed and implemented in a flexible way and that local conditions should be taken into account in each specific case.

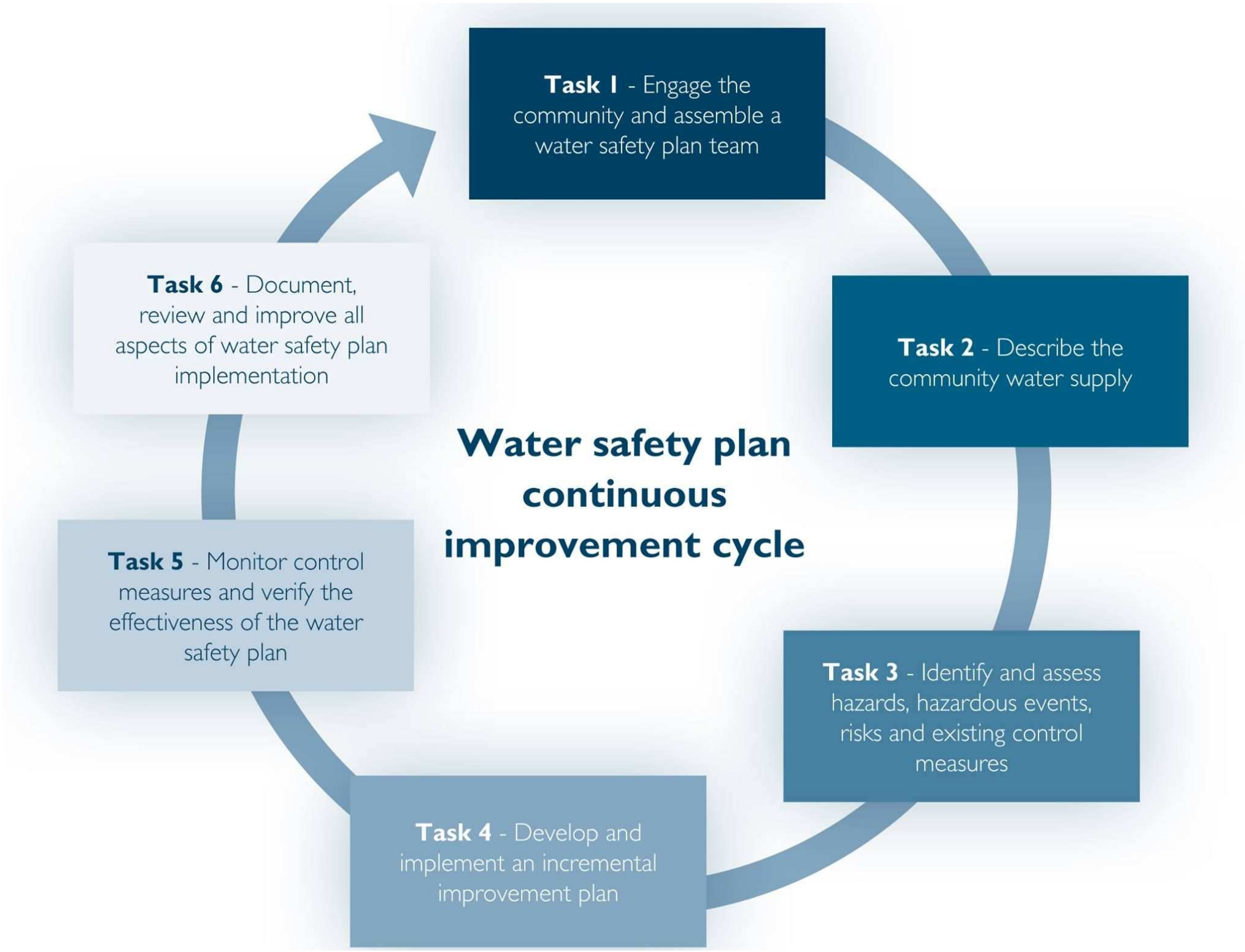

Figure 2: Six tasks to develop and implement a WSP in small community water supplies (WHO, 2012, p. 6)

Task 1: *Engage the community and assemble a WSP team.*

As a first step in the development of a WSP, a WSP team, which is in charge of developing, implementing and reviewing the WSP, needs to be established. Ideally, the WSP team consists of a multidisciplinary team and includes utility staff as well as other stakeholders such as site owners, external experts or representatives of the users. For a successful implementation of the WSP it is important that the affected community understands the benefits of the WSP approach and that it is as far as possible included into the process of the WSP development. Members of the community can for example be engaged in the operation, maintenance and management of the water supply system. The responsibilities and functions of all team members need to be clear and transparent (NaWaTech, 2013; UBA and TZW, 2014; WHO, 2012).

Task 2: *Describe the community water supply.*

In this task the whole water supply system needs to be described in detail. This step forms the basis of each WSP, as the description of the system is an important source of information and will help to identify hazards and their potential impacts on water safety. Before starting, the borders of the system need to be defined in order to specify which elements should be considered in the risk assessment. The system description should provide information that is crucial for understanding the system and for identifying possible hazards and needs to include the catchment area, extraction, treatment, storage, the distribution network and pressure chambers. The documentation is done with the help of overview maps of the water supply and relevant elements of the catchment area, flow diagrams from catchment to consumer, photos and water quality records. Also general information such as relevant water quality standards, land uses in the catchment area, details related to the treatment, distribution and storage of the water, management procedures, information about available financial and human resources, ownership of the used land, information about users and uses of the consumed water and details about existing sanitation facilities, needs to be gathered and recorded. It is important to carry out an on-site inspection walk along the whole water supply system for the mapping and system description (NaWaTech, 2013; UBA and TZW, 2014; WHO, 2012).

Task 3: *Identify and assess hazards, hazardous events, risks and existing control measures.*

After the system description is completed, hazards, hazardous events and associated risks to public health need to be identified for each component of the drinking water supply. According to the WHO a *hazard* is “a biological, chemical, physical or radiological agent that can cause harm to public health” (WHO, 2012, p. 17), a *hazardous event* is “an incident or situation that introduces or amplifies a hazard to, or fails to remove a hazard from, the water supply” (WHO, 2012, p. 17) and a *risk* is “the likelihood of a hazard causing harm to exposed populations in a specific time frame and the magnitude and/or consequence of that harm” (WHO, 2012, p. 17). Hazards can have negative effects on the health of the consumers, can influence the sensorial properties of the drinking water and can affect the technical security of supply in the network (WHO, 2012).

This task involves the identification of actual and potential dangers and their causes and should be led by the questions: What can go wrong? How, when, where and why? For answering these questions, on the one hand expertise from engineers, scientists and public health inspectors should be included into the hazard identification and risk assessment process, on the other hand also on-site visits, community knowledge, recurring local events, checklists from water supply guidelines and sanitary inspections should serve as sources of information (UBA and TZW, 2014; WHO, 2012).

In this step the present control measures that address potential hazards and hazardous events need to be assessed and reviewed with regard to their suitability and effectiveness. These barriers can be of technical, infrastructural or behavioural nature or can be related to the planning process. It needs to be assessed whether the existing mitigation measures are effectively eliminating or reducing the identified risks. For risks that are still considered as critical after reviewing the existing control measures, additional barriers need to be identified in the following WSP step (UBA and TZW, 2014; WHO, 2012).

The risk assessment itself can either be done by means of a descriptive risk assessment or by a risk ranking. In the present master thesis the method of risk ranking was applied in order to conduct the risk assessment. This approach represents a two-step process. In a first step, definitions of the categories of the likelihood of a hazardous event to occur and the severity of the consequences of an event need to be elaborated. Thereby, the effectiveness of existing control measures that are in place need to be taken into account. In a second step, a risk ranking into significant and less significant risks needs to be performed. In some cases further information needs to be gathered in order to being able to assess whether a risk is significant or not. The results of the risk analysis should be documented in clear overview tables (UBA and TZW, 2014; WHO, 2012).

Task 4: *Develop and implement an incremental improvement plan.*

The purpose of task four is to review opportunities to improve drinking water quality and to identify priority actions. Based on the results of the risk assessment of task three, it should be derived which water safety improvements should be implemented with highest priority and which ones can be deferred. Subsequently, control measures to address the as significant identified risks should be designed. Thereby mitigation measures should either eliminate or reduce contaminants in the raw water, in order to prevent their entering into the water supply system, remove particles and chemicals from the water or prevent contamination during drinking water storage, distribution and handling. Mitigation measures can be either one-time measures or they can be continuous, like for example regular O&M activities can help to prevent the occurrence of risks. Control measures influence either the probability of the occurrence of a hazardous event or the extent of the damage. Apart from technical measures also organisational and personnel measures or the definition of responsibilities, the development of work instructions or trainings of the technical staff can be implemented. According to the WHO, a multiple-barrier approach “which consists of an integrated system of activities and processes that collectively ensure drinking-water safety” (WHO, 2012, p. 30) should be considered. The advantage of this approach is that if one control measure fails, it may be compensated by remaining measures, in order to minimize the likelihood of hazards passing through the entire water system. The incremental improvement plan is a powerful tool to ensure the most effective use of limited economic resources (UBA and TZW, 2014; WHO, 2012).

Task 5: *Monitor control measures and verify the effectiveness of the WSP.*

In this step of the WSP, a monitoring programme should be established. So called *operational monitoring* demonstrates that the chosen control measures continue to work effectively. This is done by planned observations and on-site inspections of the water supply, the use of checklists and water quality measurements. The implementation of operational monitoring actions allows a timely detection of problems in the water supply, so that corrective actions can be taken before unsafe drinking water is supplied. Furthermore, *verification monitoring* actions confirm that water quality targets are met and that the WSP effectively protects drinking water safety. Verification monitoring is based on compliance monitoring, internal and external auditing and the checking of consumer satisfaction (UBA and TZW, 2014; WHO, 2012).

Task 6: *Document, review and improve all aspects of WSP implementation.*

In this final step of the WSP, the status of operation and management of the water supply system is documented. In the course of this, management procedures for normal, incident and emergency situations are documented and shared with the WSP team. Documenting operation, maintenance and inspection procedures is important as it helps operators to know what to do and when, supports an effective performance of tasks, concentrates the knowledge about the system, captures the experience that otherwise might get lost and forms a basis for a continuous improvement of the WSP. Furthermore, processes to review the WSP periodically are established and ensure that the WSP remains up to date and effective. A WSP is never “finished” in a narrow sense, but is continuously updated by the WSP team. Additionally to these periodically revisions, event driven adaptations of the WSP need to be done after breakdowns or relevant changes in the water supply system or changes in the governmental regulations. This procedure eventually results in incremental improvements to water safety in the target area (UBA and TZW, 2014; WHO, 2012).

4.4 Realization of the WSP Approach in the Field

The delineated tasks of the WSP were as far as possible applied and adapted to the given local conditions. As a first step, the affected local stakeholders were integrated into the operation of the existing water supply system of Rwaza. Therefore, an O&M team was established. The responsibilities and functions of the team members were defined and their contact data collected. After the establishment of the O&M team together with three local workers and the two helping students from *Future for Kids*, an on-site inspection of the whole water supply system was conducted. Initially, the system boundaries of the object of investigation were defined and in the course of the inspection, the used technologies of all system components – from the springs to the consumers – were identified and their present condition was checked. The inspection served the main purpose of collecting data for creating a detailed system description, but simultaneously hazards were identified, water samples for the microbiological water investigation were taken and flow measurements were conducted. Based on the collected data, a flow-chart of the whole water supply system inclusive flow rates and an overview map of the components of the water supply and wastewater system at the orphanage were created. During the system inspection also the present O&M situation was reviewed. Afterwards, the specific O&M requirements of the different system components were identified based on the "*Operation and maintenance manual*" (Klar, 2013) that has been provided by Werner Klar. This step was followed by a comparison of the present O&M situation with the previously identified requirements in the course of which gaps between the status quo and the intended state were pointed out. Subsequently to the data collection, the method of risk ranking was applied in order to conduct a risk assessment. Therefore the definitions of the likelihood and severity/consequence categories from the WHO (2012) manual were used in order to facilitate consistency in the assessment (Table 1).

Table 1: Likelihood and severity definitions for the risk ranking approach (WHO, 2012, p. 25)

Descriptor	Description
Likelihood	
Likely	Will probably occur in most circumstances; has been observed regularly (e.g. daily to weekly).
Possible	Might occur at some time; has been observed occasionally (e.g. monthly to quarterly or seasonally).
Unlikely	Could occur at some time but has not been observed; may occur only in exceptional circumstances.
Severity/consequence	
Major impact	Major water quality impact; illness in community associated with the water supply; large number of complaints; significant level of customer concern; significant breach of regulatory requirement.
Moderate impact	Minor water quality impact (e.g. not health related, aesthetic impact) for a large percentage of customers; clear rise in complaints; community annoyance; minor breach of regulatory requirement.
No/minor impact	Minor or negligible water quality impact (e.g. not health related, aesthetic impact) for a small percentage of customers; some manageable disruptions to operation; rise in complaints not significant.

All hazardous events, their likelihood and their consequences were listed according to these categories. Thereby it is important, that existing mitigation measures and their effectiveness are considered in order to being able to prioritize the risks. Each event was mapped in a risk matrix according to its attributed categories (Table 2) in order to obtain a risk ranking. Thereby the definitions of the WHO about what is considered as substantial risks (high and medium risks) were used to distinguish them from less significant risks (Table 3). When doing the classification and evaluation of the present risks, it needs to be considered, that concerning microbiological hazards – contrary to physical, chemical or sensorial ones – the severity always is a major impact. This can be explained by the fact that the presence of E.coli or coliform bacteria is always an indicator that the water has been in contact with excrements and that therefore a contamination with pathogens or viruses cannot be ruled out. Control measures can only influence the probability of occurrence of an event, and therefore at best only a medium risk for microbiological hazards can be achieved. Based on the obtained ranking, required improvement actions were prioritised according to the risk ranking approach (Figure 3) (UBA and TZW, 2014; WHO, 2012).

Table 2: Risk matrix for the risk ranking approach (WHO, 2012, p. 25)

		Severity/consequences		
		No/minor impact	*Moderate impact*	*Major impact*
Likelihood	*Likely*	Medium	High	High
	Possible	Low	Medium	High
	Unlikely	Low	Low	Medium

Table 3: Risk ranking definitions to prioritize actions (WHO, 2012, p. 26)

Risk ranking	**Meaning**	**Description**
High	Clearly a priority: requires urgent attention	Actions need to be taken to minimize the risk. Possible options should be documented (as part of the improvement plan developed in the next task) and implemented based on community priorities and available resources.
Medium	Medium- or long-term priority: requires attention	Actions may need to be taken to minimize the risk. Possible options should be documented (as part of the improvement plan developed in the next task) and implemented based on community priorities and available resources. **Or** where the likelihood of a hazard occurring is low because effective control measures are in place but the consequences are major (e.g. microbial risks), special attention should be given to maintaining the control measures and their appropriate operational monitoring to ensure that the likelihood remains low.
Low	Clearly not a priority	Actions may need to be taken but not a priority, or no action is needed at this time. The risk should be revisited in the future as part of the WSP review process. **Or** control measures are effective, and attention should be given to ensure that the risk remains low.

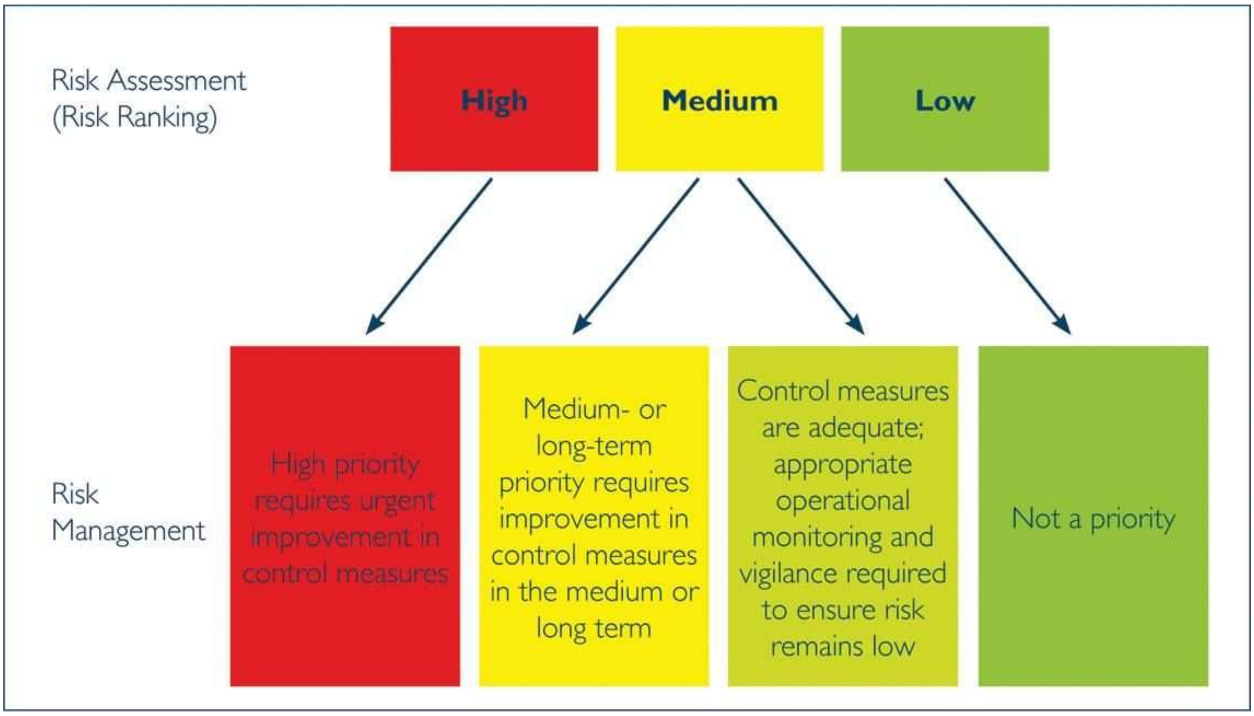

Figure 3: Diagram on how to prioritize actions using the risk ranking approach (WHO, 2012, p. 26)

Based on the outcomes of the risk ranking, priority actions to tackle the most critical points in the system were designed and control measures to improve the drinking water quality were identified and reviewed. In the course of this, O&M checklists and work instructions were developed that inter alia contain monitoring activities and serve for documentation purposes.

5. Results and Discussion

In this section, the main findings of the field research and the data analysis are discussed. The conducted on-site system inspection served several purposes. First of all, data and information for the description of the existing water supply system infrastructure from catchment to consumer were collected. In the course of that also flow measurements were done and samples for the microbiological and chemical water investigation were collected. In the following, the conducted flow measurements are described and compared to the water quantities that were measured with the "*Timed Volume Method*" (see chapter 4.1) in September 2013 and to reference values of the WHO. Afterwards, the results of the microbiological and chemical analyses are discussed and compared to governmental regulations. Subsequently, the outcomes of the application of the WSP approach are delineated, and finally, challenges that arose during the application of the WSP in the field are described.

5.1 Water Quantity

During the system inspection conversations with members of the WSP team revealed, that several times per year the water consumers, especially the consumers at the remote end of the system, had to suffer from water shortages. These observations contradicted the assessment from Werner Klar, that the water supply of the system should be sufficient for its consumers. Water flow measurements were carried out in order to verify the given conditions.

The results of the flow measurements are shown in Table 4. The investigation of the system showed higher water yields from the springs up to the pressure reduction and air release chamber 1 in September 2014 compared to water quantity measurements in August 2013. However, at the pressure reduction and air release chamber 2, where the public water station Bukara is connected, there was a significant drop in the amount of supplied water from 0.68 to 0.51 L/s and declined even below the value from September 2013. The considerable reduction at this point of the system resulted out of the breakage of the tap of the public water station at the time of the system investigation and thus flowed continuously. Owing to this fact, water was running the whole time (0.13 L/s) and was constantly lost and therefore missing in the subsequent parts of the water supply system. Two water flow measurements were conducted at the main storage tank in summer 2014. One in August at the end of the dry season (0.48 L/s) and one in September at the beginning of the rainy season (0.56 L/s). Due to the comparison of the two values, seasonal fluctuations could be verified. In August 2014, the water supply system provided 0.86 L/s before consumption and losses (Table 4), which amounts to a total of 74,304 L/d. For the approximately 800 consumers (inclusive the newly connected users from *Future for Kids*) this amounts to 92.9 L/(cap*d) in August 2014, in September 2013 0.71 L/s, 61,344 L/d and 76.7 L/(cap*d) respectively. According to the WHO (Howard and Bartram, 2003; United Nations, 2010), between 50 and 100 litres of water per capita per day are needed "to ensure that most basic needs are met and few health concerns arise" (United Nations, 2010, p. 8). It needs to be noted, that these numbers are indicative, as the needed amounts of water might vary for different groups depending on their health status, present climate conditions, work and other factors (United Nations, 2010). When comparing the amount of water provided by the water supply system of Rwaza (92.9 L/(cap*d) and 76.7 L/(cap*d)) to the reference values of the WHO (50-100 L/(cap*d)), there should be enough water delivered. Nevertheless, it is necessary that losses throughout the system are eliminated or at least reduced in order to ensure a sufficient amount of water for all consumers of the water supply system.

Table 4: Flow measurement

Flow Measurement		
System Checkpoint	**Flow September 2013 (L/s)**	**Flow August 2014 (L/s)**
Source Mikamo 1	0.29	0.32
Source Mikamo 2	0.16	0.2
Source Mikamo 3	0.1	0.11
Collection chamber 1 (Mikamo sources 1, 2, 3 together)	0.55	0.63
Source Mukono	0.16	0.23
Collection chamber 2 (Mikamo sources + Mukono source)	0.71	0.86
Pressure reduction and air release chamber 1	0.65	0.68
Public water station Bukara	/	0.13
Pressure reduction and air release chamber 2	0.58	0.51
Main storage tank	0.5	0.48 (19.8.2014, still dry season)
		0.56 (1.9.2014, start of rainy season)
Tank *Future for Kids*	/	0.63

5.2 Water Quality

The results of the microbiological and chemical examinations were compared to the Rwandan national drinking water quality standards, which comply with the WHO guidelines (REMA, 2010). For this purpose the potable water specifications of the Rwanda Bureau of Standards (RBS, 2011) were used as source of information (Tables 5, 6, 7).

Table 5: Microbiological limits for potable water in Rwanda (modified from RBS, 2011)

Microbiological limits for potable water - Rwanda		
Type of micro-organism	**Drinking water**	**Containerised drinking water**
Total Coliforms in 100 mL	0	0
E.Coli in 100 mL	0	0

Table 6: Chemical quality for drinking water in Rwanda (modified from RBS, 2011)

Chemical quality requirements for drinking water	
Substance	**Drinking water (mg/L), max.**
Aluminium	max. 0.1
Iron	max. 0.3
Turbidity	max. 5 NTU

Table 7: Limits for inorganic contaminants in drinking water in Rwanda (modified from RBS, 2011)

Limits for inorganic contaminants in drinking water	
Substance	**Limit of concentration (mg/L), max.**
Arsenic	0.01
Cadmium	0.003
Lead	0.01
Copper	1
Manganese	0.1
Selenium	0.01
Chromium	0.05
Nickel	0.02
Boron	0.3

Concerning the microbiological water quality (Table 8), a dangerous contamination with E.coli and coliform bacteria was found, as limit values of the legislation (zero per 100 mL for both E.coli and coliforms; Table 5), were exceeded by a multiple. The results show that the contamination already enters the water supply system at the very beginning, as already in the spring chambers – especially in the Mikamo sources (Figure 4, left image) – the water shows a substantial contamination with faecal bacteria (31 E.coli in 100 mL, and 384 coliform bacteria in 100 mL). The high value indicates that the infiltration area is not properly protected and that therefore a pollution of the spring water was possible. The water from the main storage tank shows similar coliform and E.coli numbers as water from the spring chambers. In addition, the tank at *Future for Kids*, the water from the kitchen tap at *Future for Kids*, water from the tap at the parish and especially water from the tap at the public water station Bukara show higher numbers of coliform bacteria and significantly higher numbers of coliform bacteria and E.coli respectively. The accumulation of bacteria in the course of the cumulative system steps seems plausible, but the reason for the extraordinary high number of coliform bacteria (7 E.coli in 100 mL, and more than 800 coliform bacteria in 100 mL) at the public water station Bukara (Figure 4, right image) needs further investigation. Merely, the spring located underneath the orphanage buildings that is not part of the water supply system, but has been used by *Future for Kids* before they were connected to the piped system, did not show any contamination with E.coli (0 E.coli in 100 mL). Beyond that, only a minor pollution with coliform bacteria (4 coliform bacteria in 100 mL) was detected. As a result, this spring can be regarded as a relatively safe source of drinking water.

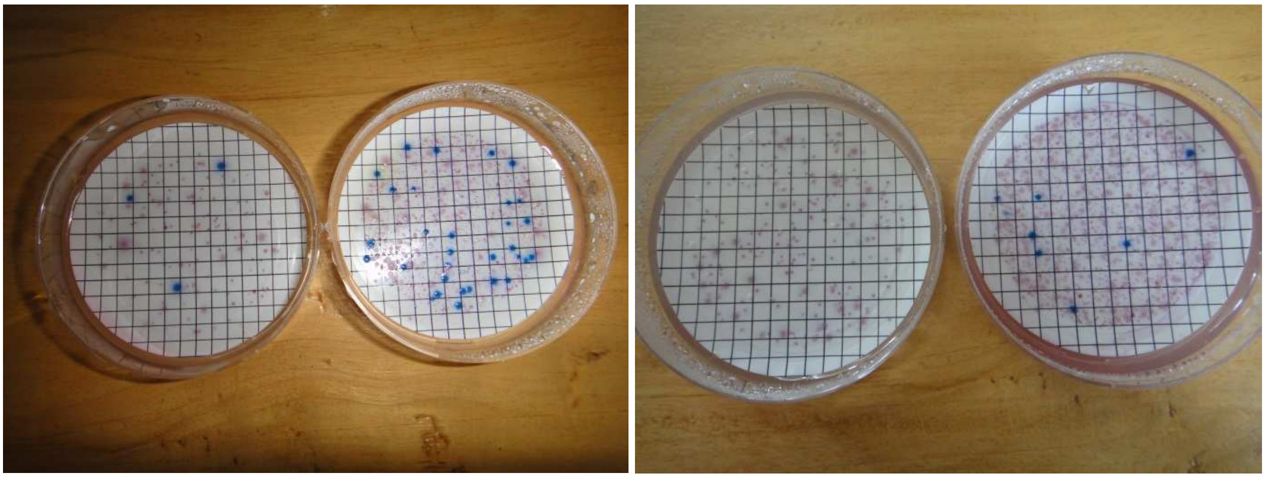

Figure 4: Samples of the microbiological examination. Sample number 2, Spring Mikamo (left) and sample number 8, Public water station Bukara (right). E.coli form dark-violet coloured colonies, whereas coliforms appear in a salmon to red colouration (own pictures, 2014)

Table 8: Results of the microbiological examination

Microbiological Examination								
Sample	**Location**	**Step in System**	**Date of Sampling**	**Date of Analysis**	**E.Coli in 10 mL**	**Coliform in 10 mL**	**E.Coli in 100 mL**	**Coliform in 100 mL**
1st	Spring under F4K (1)	1	18.08.2014, 14:00	19.08.2014, 13:50	0	0	0	10
10th	Spring under F4K (2)	1	26.08.2014, 15:10	27.08.2014, 15:10	0	0	0	2
13th	Spring under F4K (3)	1	02.09.2014, 15:30	03.09.2014, 15:25	0	0	0	4
2nd	Spring Mikamo (sample taken at collection chamber 2, where all 3 Mikamo sources combined in 1 pipe)	2	19.08.2014, 15:30	20.08.2014, 15:30	3	123	31	384
3rd	Spring Mukono (sample taken at collection chamber 2)	2	19.08.2014, 15:30	20.08.2014, 15:30	0	2	1	27
5th	Main storage tank (1)	3	20.08.2014, 17:15	21.08.2014, 17:15	2	58	6	320
12th	Main storage tank (2)	3	01.09.2014, 18:40	02.09.2014, 18:30	2	18	8	210
4th	Tank F4K	4	20.08.2014, 15:00	21.08.2014, 14:30	2	52	18	452
6th	Health Center (black plastic tank)	4	22.08.2014, 17:00	23.08.2014, 17:00	1	7	9	132
8th	Public water station Bukara	4	23.08.2014, 11:30	24.08.2014, 11:30	0	210	7	>800
9th	Tap at the parish	4	26.08.2014, 14:45	27.08.2014, 14:50	4	83	32	572
11th	Village tank Igiturushiya	4	01.09.2014, 18:20	02.09.2014, 18:25	2	35	42	394
7th	Kitchen tap at F4K (1)	5	22.08.2014, 17:10	23.08.2014, 17:05	0	102	25	532
14th	Kitchen tap at F4K (2)	5	02.09.2014, 15:50	03.09.2014, 15:30	4	76	67	291

As there is a direct correlation between the contamination of drinking water with faeces from humans or animals and the risk of waterborne diseases such as inter alia cholera, typhoid, hepatitis or polio, it is crucial to secure the microbial safety of drinking water supplies (Billman, 2014; WHO, 2011). Due to the fact, that drinking water safety is not given in the examined water supply system, the raw water should not be used for direct consumption. It is highly recommended to apply water treatment processes on the consumer level, as there are no treatment processes present in the water supply system of Rwaza at the present state. Effective measures would therefore for example be the application of household slow sand filters, domestic chlorination, or boiling of the water prior to usage. Thereby, boiling might be the easiest option, as in most cases no extra purchases need to be made and heating water is an effective way to kill or inactivate most microorganisms that cause diarrhoea. On the household level, water can be quite easily boiled in a pot on the stove. Care needs to be taken to not re-contaminate the disinfected water after boiling. Furthermore, it needs to be considered that fuel costs and the time needed for boiling and cooling the water, limits the usefulness of the method (Brikke and Bredero, 2003; WHO, 2011).

In order to examine the chemical drinking water quality (Table 9) contents of aluminium, arsenic, lead, boron, cadmium, chromium, iron, copper, manganese, nickel, selenium and uranium as well as turbidity were investigated. In a next step, the results were compared to the Rwandan drinking water standards (Tables 6, 7) and to the Austrian Drinking Water Ordinance (DWO) (Table 9) in the laboratory of the Institute of Sanitary Engineering and Water Pollution Control at BOKU. High aluminium and iron contents were found especially in the Mukono source, but there are no health risks associated to these values. The high iron content in the water can result from a naturally high iron content of the soil or can be the result of corrosion. In the present case, a high iron content of natural origin seems to be more plausible. Although high iron contents are not known to be harmful, the iron adds an unpleasant metallic taste and odour to the water, discolours food and stains laundry. It is possible that undesirable properties cause communities to consume contaminated water that has a neutral taste instead of using uncontaminated water that has a metallic taste (Brikke and Bredero, 2003; WHO, 2011). The contents of all the other examined substances were well below the accepted limits.

The final result of the conducted water quality investigation is that the quality delivered to the consumers does not meet health based quality standards. Water extracted from the spring should therefore not be used for human consumption without further treatment.

Table 9: Results of the chemical examination (modified from the laboratory of the Institute of Sanitary Engineering and Water Pollution Control at BOKU, 2014)

Chemical Examination																
Sample Nr.	**Sample**		**Aluminium** [µg/L]	**Arsenic** [µg/L]	**Lead** [µg/L]	**Boron** [µg/L]	**Cadmium** [µg/L]	**Chromium** [µg/L]	**Iron** [µg/L]	**Copper** [µg/L]	**Manganese** [µg/L]	**Nickel** [µg/L]	**Selenium** [µg/L]	**Turbidity** [NTU]	**Uranium** [µg/L]	**MW-Digestion**
		DWO-values	200 (Indicator)	10 (Limit)	10 (Limit)	1000 (Limit)	5 (Limit)	50 (Limit)	200 (Indicator)	2000 (Limit)	50 (Indicator)	20 (Limit)	10 (Limit)			
40519	Rwaza tank	dissolved	403	<0.50	0.8	<3.0	<0.05	0.6	577	1.3	11.4	<0.50	<0.50	64.7	<0.10	HNO_3/H_2O_2 Digestion
		total	5280	1.3	<4.0	n.a.	<0.10	6.7	3160	<3.0	19.2	<2.0	<2.0		<0.20	
40520	Rwaza spring under F4K	dissolved	<5.0	<0.50	<0.50	<3.0	<0.05	<0.50	6.0	<1.0	2.4	1.0	<0.50	0.23	<0.10	HNO_3/H_2O_2 Digestion
		total	14.2	2.3	<4.0	n.a.	<0.10	<2.5	<10.0	<3.0	2.4	<2.0	<2.0		<0.20	

DWO: Drinking Water Ordinance
MW-Digestion: Microwave Digestion
NTU: Nephelometric Turbidity Units

5.3 Water Safety Plan

In the following section the results of the implementation of the WSP approach are described:

Task 1: *Engage the community and assemble a WSP team.*

The set up O&M team includes the head priest of the church as a representative of the owners of the system, local workers and members of the NGO *Future for Kids*. The head priest, who has the authority to make substantial decisions, took over the function of a supervisor. In addition, the manager from *Future for Kids,* who is interested in a good water quality for the orphanage and therefore provides a part of the needed financial resources, has a control function. The three local workers, who already have experience in repairing Rwaza's water supply system, are responsible for system maintenance works and incidental repairs and the two students from the orphanage, which grew up and still live in their university holidays in the orphanage, hold a monitoring function. Additionally to the mentioned permanent O&M team members, Werner Klar as an external expert provided advice and expertise as a temporary member. He occupied a consulting function in the course of the system rehabilitation and gave important input concerning O&M activities, system hazards and risks. The O&M team members, their roles and their contact details are listed in an overview table.

Task 2: *Describe the community water supply.*

In the course of the conducted on-site system inspection data and information for the description of the existing water supply system infrastructure from catchment to consumer were collected.

The water supply system is privately owned by the parish in Rwaza and has been built in the late 1950s. Water from the system is mainly used for human consumption, hygiene and garden watering, but not for agricultural purposes. The original distribution network is made out of drawn steel pipes, but in case of pipe breakage, polyethylene pipes were used. The system extends over a length of approximately four kilometres and overcomes roughly 300 meters of altitude, from the springs that are situated in the surrounding mountains in approximately 1950 meters above sea-level to the lowest point in the system, the orphanage that is located on roughly 1650 meters. Due to the given height difference, the whole system is gravity-fed and no additional pumps are needed. As a result, the water system is independent from any kind of energy supply. No water treatment is implemented in the whole water supply network, and the water is delivered untreated to the consumers.

In Rwanda, there are two dry and two rainy seasons per year. Thus, corresponding seasonal variations in discharge can be observed. The rainy seasons in Rwanda used to be from February to May and from November to December (Billman, 2014), but according to observations by locals, these seasons started to shift in the last years. The system is fed by spring water, but the geology and hydrogeology patterns in the area are not known and therefore it is unclear where exactly the infiltration areas are located. The surrounding area consists of both forest and agricultural land, where mostly beans, bananas and sweet potatoes are cultivated. Furthermore, clay bricks are produced in the lower altitudes. There are no paved streets in the area, streets are either enforced with small stones or are made out of consolidated clay. As the region is very steep and hilly, erosion is an issue. The local population in the area mainly lives in scattered settlements without proper water or wastewater facilities. Water is collected from the public water stations with jerry cans, while holes that are dug in the earth behind the houses are used as toilets and also open defecation is practiced. There is no waste management present in the area, instead of proper treatment people incinerate solid waste in their backyards.

The system boundaries were defined in a way that the object of inquiry includes the whole water supply system from the springs to the household connection level. Only the *Future for Kids* complex also includes the household level. Since its extension to the orphanage in December 2013, the water supply system of the parish Rwaza supplies approximately 800 people and consists at present of the following parts (Figure 5):

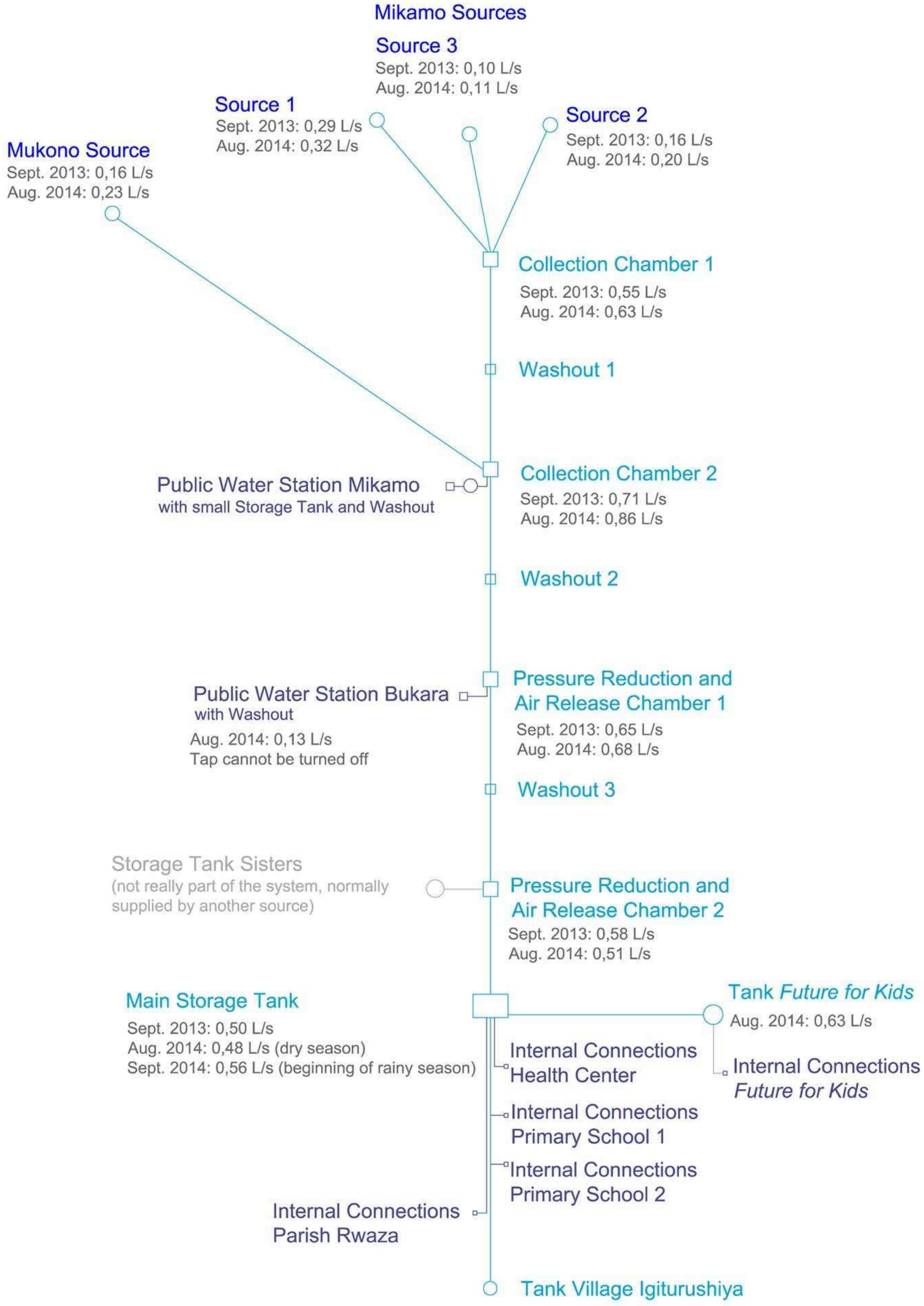

Figure 5: Flow chart of the water supply system of Rwaza

The buildings of the orphanage *Future for Kids* were connected to the old system (which is described in chapter 3.6) by a pipe that is attached on the side of the main storage tank (Figure 6, left image) approximately 30 centimetres above the bottom. This pipe conveys the water to the newly built brick tank of the centre (Figure 6, right image). The circular shaped tank has a capacity of 15,000 litres and is equipped with a float valve and a washout, but is missing a ventilation pipe. It is the starting point of the orphanage's internal connections, where the buildings of the centre are supplied from [Appendix 11.1 Water and wastewater system *Future for Kids*]. In the orphanage complex there are two outdoor taps (one at the cow stable and one in front of the girls' dormitory), 17 showers (seven for girls, seven for boys and three for the staff and guests), three water toilets (two night toilets for the children, one for girls and one for boys, and one for the staff and guests), three kitchen taps and one water tap in the guest bathroom, that are supplied via the water supply system.

Figure 6: Main storage tank (left) and tank *Future for Kids* (right) (own pictures, 2014)

In the course of the system description also the wastewater management at the orphanage was investigated and an overview plan of the wastewater facilities at the complex was drawn [Appendix 11.1 Water and wastewater system *Future for Kids*]. The black-water from the two flushed night toilets as well as from the guest toilet, is in all cases collected in brick made septic tanks that are situated in the ground next to the two dormitories and the guest house respectively. Each of these septic tanks consists of three separated chambers that are connected due to a crack between the partition walls and the ceiling of the tank. Solid material is therefore collected at the bottom of the first chamber, where it is decomposed, while liquids can flow into the second compartment as soon as the first one is full. When the second chamber is full, the third one gets filled and as soon as the third section reaches its capacity the liquid is conveyed into an attached soak pit via a pipe from where the fluid seeps into the ground. Apart from the flushed water toilets there are two older dry pit latrine facilities, with six pit latrines each (Figure 7, left image). Underneath the latrines there is a container, where the faeces are collected. When the container is full, the buried cover is dug out and the container is opened and emptied. Therefore a new hole is dug in a not yet specified place where the faeces are put inside. The grey water from the showers of the dormitories and of the guest house is directly conveyed into the soak pits that are next to the septic tanks. Grey water from the kitchen taps flows into a soak pit that is situated next to the kitchen, from where it seeps into the ground. Storm water runoff is drained via open rain water trenches next to the buildings that guide the water into the trench next to the guesthouse from where the water eventually infiltrates into the grass (Figure 7, right image).

Figure 7: Pit Latrines (left) and storm water gully at *Future for Kids* (right) (own pictures, 2014)

Besides the conducted data collection for the system description, the on-site inspection also served the purpose of hazard identification. Furthermore, it was reviewed, if the by Werner Klar in the "*Operation and maintenance manual*" (Klar, 2013) identified actions that should have been done in the course of the system rehabilitation in order to repair broken parts of the system, were executed. It was found that:

- The gate valves underneath the main storage tank have been replaced
- The main storage tank has been cleaned and painted
- The pipes in the pits of the filter galleries and the filter galleries of the Mikamo sources have been cleaned
- The missing valves of washout one and two have been installed
- Washout one and two have been cleaned
- The float valve in the village tank has been installed
- The leakages in the aqueduct have been repaired
- The pipes in the pits of the filter galleries and the filter galleries of the Mukono source have not been cleaned
- The missing fence around the main storage tank has not been replaced
- The missing fences around the spring chambers have not been replaced
- The missing locks at the covers of the spring chambers have not been installed
- The open lying pipes have not been placed in trenches underneath the surface - but the plastic pipes have been replaced by steel pipes in order to make them more robust against external influences
- Washout three has not been cleaned, it has not been opened since September 2013

Approximately half of the by Werner Klar recommended actions were implemented in the course of the system rehabilitation. The activities which were not yet done were incorporated into the developed O&M manual (see later in this chapter, Task 4).

Furthermore, the present O&M situation was examined in the course of the on-site inspection. It was found, that no preventive maintenance system was in place. The parish did not have sufficient economic resources in order to employ workers on a regular basis and to provide an adequate amount of spare parts. Additionally, the tool room was not lockable and hardly any tools were available in the first place. Moreover, a lack of O&M instructions and routines, a lack of clear responsibilities and the absence of on-site checks by governmental authorities contributed to the circumstance that no preventive O&M activities were set up. Instead, it was only reacted when problems with the water system occurred and thus a reactive maintenance was applied. The church employed three local workers on a daily basis in case system reparations had to be carried out.

With the help of the "*Operation and maintenance manual*" (2013) that was provided by Werner Klar, the specific O&M requirements of the different system components were identified and afterwards compared to the present O&M situation, in the course of which gaps between the status quo and the intended state were pointed out. According to the manual, it is necessary to contract two people for a minimum of two days per week for being able to maintain the water supply system of Rwaza. Therefore, the following activities need to be done:

- Each week, all taps at the consumers and public water stations need to be checked for leakages and it needs to be ensured that they are turned off when not in use
- Once a month, the whole aqueduct needs to be examined and it needs to be checked if there are any leakages. All valves in the system need to be operated in order to check their functionality
- Quarterly, the three washouts need to be opened and cleaned from sand and earth
- Twice a year, the spring pits and the pipes in the pits of the spring captures need to be cleaned, as well as the two collection chambers, the two pressure reduction and air release chambers, and the three storage tanks (main storage tank, tank village Igiturushiya, tank Future for Kids)

In addition, it is necessary to establish a lockable and safe tool room that is equipped with the needed tools. The comparison of the required O&M activities and the present O&M situation (status: August 2014) has shown that none of the requirements to properly maintain the system were fulfilled at that time.

Task 3: *Identify and assess hazards, hazardous events, risks and existing control measures.*

In the course of the risk assessment possible hazards, the types of hazards, the hazardous events, observations, existing control measures, the likelihood of the events and the consequences were identified according to the WHO likelihood and severity/consequence categories (Table 1, chapter 4.4) for each drinking water system component. Based on this, the risk ranking and the derived priorities for actions were obtained. This was done by means of a risk matrix for risk ranking (Table 2, chapter 4.4) and risk ranking definitions to prioritize actions (Table 3, chapter 4.4), both provided by the WHO. At this point it needs to be mentioned, that the conducted risk assessment was based on personal assessment only, and that for a holistic analysis, the chosen likelihood categories would need to be validated by local experts.

Due to the application of the risk ranking approach it was found, that there are in total 70 risks to the water supply system of Rwaza, thereof 21 high priority, 29 medium priority and 18 low priority risks, while two hazardous events could not be evaluated due to a lack of information (Table 10).

Table 10: Overview of risks to the water supply system of Rwaza

Risk Overview						
System-Nr.	**Supply-Step**	**High Priority Risk** (Quantity)	**Med. Priority Risk** (Quantity)	**Low Priority Risk** (Quantity)	**Not Evaluated**	**Sum Risks/ Supply-Step**
C-1	Catchment Area	5	3	0	0	8
E-1	Extraction	1	8	0	0	9
D-1	Distribution	2	11	5	0	18
S-1	Storage	3	4	8	2	17
U-1	User	8	1	5	0	14
T-1	Treatment	1	0	0	0	1
P-1	Processes	1	2	0	0	3
Total Number of Risks		21	29	18	2	70

The highest amount of risks can be found in the distribution system (18), the storage components (17) and on the user level (14). Most of the high priority risks occur on the user level (8) and in the catchment areas (5), while the majority of medium priority risks can be found in the distribution system (11) and the extraction components (8) and most low priority risks in the storage facilities (8). For illustration purposes the different types of high priority hazardous events are listed in Table 11. The complete hazard analysis is attached in the appendix [Appendix 11.2 Hazard analysis].

Concerning the high priority hazardous events, the majority of risks are due to microbiological hazards, while on the whole most hazards are of physical nature. The second biggest group in the total risk assessment is represented by microbiological hazards and a combination of microbiological and chemical hazards. The smallest percentage accounts for hazards of chemical nature only.

Table 11: High priority hazardous events

High Priority Hazardous Events										
System-Number	**Supply-Step**	**Possible Hazard**	**Type of Hazard**	**Hazardous Event**	**Observations**	**Existing Control Measure**	**Likeli-hood**	**Consequence**	**Risk Ranking**	**Priority for Action**
C-1	Catchment Area 1: Spring Mikamo	Microbial pathogens	Microbiological	Impact on water quality due to animals	Animals are grazing, urinating and defecating in the catchment area; Potential seepage of animal faeces into the groundwater	There used to be a fence, but it was stolen; No control measures in place	**Likely**	**Major impact** Cattle and sheep faeces may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place
		Microbial pathogens	Microbiological	Impact on water quality due to dwellers	Dwellings in higher elevation, on hill top; Possibility of seepage of waste water into groundwater	None	**Possible**	**Major impact** Human faeces may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place
		Microbial pathogens	Microbiological	Impact on water quality due to manure use	Use of manure in agriculture	None	**Possible**	**Major impact** Manure may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place
E-4	Extraction: Spring Chamber Mukono	High iron content	Chemical	Possibility of exceedance of limit values for iron	Raw water has high iron content and therefore a red colour	None	**Likely**	**Moderate impact** High iron content affects organoleptic drinking water quality and might have technical implications	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place
D-5	Distribution: Pressure Reduction and Air Release Chamber 1	Microbial pathogens	Microbiological	Impact on water quality due to animals	Dead animals inside the chamber	None	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place

D-9	Distribution: Distribution Water Main	Technical impairment	Physical	Damage of eroded pipes	Erosion occurring at some places; Some pipes in open area to overcome creeks	None	**Likely**	**Major impact** Eroded pipes are vulnerable to damages, sun radiation and temperature changes	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place
S-2	Storage: Main Storage Tank	Microbial pathogens	Microbiological	Impact on water quality due to animals	Ventilation pipe has no mesh; Frog sitting inside the tank	There is a cover on the top of the ventilation pipe	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no sufficient control measures are in place
S-4	Storage: Tank *Future for Kids*	Microbial pathogens	Microbiological	Impact on water quality due to animals	Birds sitting on the water tank roof while the cover is opened for aeration; Possibility of pollution of drinking water by bird faeces; Possibility of pollution by entering animals	None	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place
		Microbial pathogens	Microbiological	Stagnation of water in the tank	No ventilation pipe	None	**Likely**	**Moderate impact** Consequence is for a small percentage of consumers, but could be health related	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place
U-1	Users	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place

U-2	User: Public Water Station Bukara	Loss of water	Physical	Broken tap	Tap cannot be turned off	None	**Likely**	**Moderate impact** No health related impact; Loss of water for large amount of consumers	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place
T-1	Treatment:	Microbial pathogens	Microbiological	Potential growth of pathogens	No treatment steps in the whole system	None	**Likely**	**Major impact** Potential growth of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place
P-3	Processes: Hygiene of workers	Pollution	Microbiological	Pollution of water during maintenance activities and system reparations	Possibility of pollution of water due to improper safety measures and personal hygiene of workers during system works	None	**Possible**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place

Task 4: *Develop and implement an incremental improvement plan.*

Based on the conducted risk assessment, mitigation measures to control the identified hazards and hazardous events were determined. As for most hazardous events there were no control measures present to eliminate or reduce the identified risks, new mitigation measures needed to be defined. In Table 12 some example measures for risk control are depicted as an illustration. The whole list can be found in the appendix [Appendix 11.2 Hazard analysis].

Furthermore, an incremental improvement plan to tackle the identified hazards and to improve the drinking water quality was formulated. This was done by means of O&M checklists and work instructions for one-time, weekly, monthly, quarterly and half yearly activities [Appendix 11.3 Activity and timetable one-time activities, Appendix 11.4 Activity and timetable weekly activities, Appendix 11.5 Activity and timetable monthly activities, Appendix 11.6 Activity and timetable quarterly activities, Appendix 11.7 Activity and timetable half-yearly activities]. Thereby the defined one-time activities, such as the protection of the areas around the spring chambers and the infiltration areas, the protection of the spring chambers and the storage tanks, the reparation of leakages, the establishment of a safe tool room and the disinfection of the system with chlorine, were identified as to have the highest priority. An immediate implementation of these tasks is therefore recommended. Nevertheless, also the continuous maintenance measures need to be executed in a thoroughly manner in order to operate and maintain the system appropriately and to contribute to the long-term sustainable operation of the water supply system and to a secured water supply with safe drinking water in the area. Weekly activities include the checking of the tools in the tool room for completeness and the inspection of the taps at the consumers for leakages and damages. For illustration purposes the activity and timetable for weekly activities is illustrated (Table 13). The monthly activities contain the examination of the whole aqueduct for leakages and the operation of all valves in order to check their functionality. Quarterly, the washouts of the water supply system need to be flushed. Every half year, the pipes in the pits of the spring chambers, the spring chambers, the collection chambers, the pressure reduction and air release chambers and the storage tanks need to be cleaned and the completed O&M activities need to be monitored and inspected. The developed checklists were translated into Kinyarwanda, so that an easy handling by the local O&M team members is ensured.

Table 12: Control measures

Control Measures						
Possible Hazard	**Type of Hazard**	**Hazardous Event**	**Observations**	**Existing Control Measure**	**Consequence**	**Measures of Risk Control**
Microbial pathogens	Microbiological	Impact on water quality due to animals	Animals are grazing, urinating and defecating in the catchment area; Potential seepage of animal faeces into the groundwater	There used to be a fence, but it was stolen; No control measures in place	**Major impact** Cattle and sheep faeces may contain a variety of pathogens, which may cause illness in the community	Fencing of catchment area (or prohibition of animal access in combination with cutting grass by hand); Regular inspection of the condition of the fence
Microbial pathogens	Microbiological	Impact on water quality due to dwellers	Dwellings in higher elevation, on hill top; Possibility of seepage of waste water into groundwater	None	**Major impact** Human faeces may contain a variety of pathogens, which may cause illness in the community	Implementation of proper waste water management of dwellings
Microbial pathogens	Microbiological	Impact on water quality due to manure use	Use of manure in agriculture	None	**Major impact** Manure may contain a variety of pathogens, which may cause illness in the community	Implementation of protection zone around springs, where fertilizer use is restricted
High iron content	Chemical	Possibility of exceedance of limit values for iron	Raw water has high iron content and therefore a red colour	None	**Moderate impact** High iron content affects organoleptic drinking water quality and might have technical implications	Cleaning of spring chamber, removal of ferrous soil inside chamber
Microbial pathogens	Microbiological	Impact on water quality due to animals	Dead animals inside the chamber	None	**Major impact** Pollution of drinking water may cause illness in the community	Regular checks of chamber, removal of captured animals
Technical impairment	Physical	Damage of eroded pipes	Erosion occurring at some places; Some pipes in open area to overcome creeks	None	**Major impact** Eroded pipes are vulnerable to damages, sun radiation and temperature changes	Bury eroded pipes; Implement measures against erosion

Table 13: Weekly O&M activities

Activity and Timetable WEEKLY ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Checking the tool room							
Week 17 (20.4.-26.4.)	W1	Checking the completeness of the tools in the tool room	Every Week	Alphred, Caetan, Bonifas			
Checking of all taps at the consumers for leakages and damages							
Week 17 (20.4.-26.4.)	W2	Checking of tap at "Public water station Bukara"	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W3	Checking of tap at "Public water station Mikamo"	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W4	Checking of taps at the Health Centre	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W5	Checking of taps at Primary School 1	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W6	Checking of taps at Primary School 2	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W7	Checking of taps at the Parish	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W8	Checking of taps at *Future for Kids*	Every Week	Alphred, Caetan, Bonifas			

Task 5: *Monitor control measures and verify the effectiveness of the WSP.*

In the course of the O&M checklist development, regular operational monitoring activities were scheduled. Twice a year, an inspection walk is planned, in the course of which the whole system is examined by the two students from *Future for Kids,* who are holding a monitoring function. The by the contracted workers completed O&M works are inspected during this inspection walk. In this process also the tool room will be checked for completeness and possible grievances in the effectiveness of the WSP shall be detected.

Task 6: *Document, review and improve all aspects of WSP implementation.*

The developed O&M checklists also serve documentation purposes. Via the utilisation of the checklists, it is documented what kind of activity was done by whom and when. This approach shall make the whole O&M processes more comprehensible and transparent, shall help to detect gaps in routine maintenance and sources of errors and shall facilitate to improve the mode of operation.

5.4 Practical Challenges during Implementation

Even though the WSP is a suitable tool to support operators of small water supply schemes in identifying and controlling risks to their water supply systems, when transferring the method into practice there were some challenges arising and it was not possible to apply the method consistently. In the case of the water supply system of Rwaza, the system was already built and therefore the O&M activities could not be implemented already in the planning and construction phases of the scheme. Furthermore, no participation process in appropriate technology selection took place due to the same reason. Only in the system extension to *Future for Kids,* the technology was chosen with respect to O&M activities. Management procedures for incident and emergency situations still need to be developed and the relevant information needs to be provided to the maintenance workers. In addition, periodic revisions of the WSP and event driven adaptations after breakdowns or relevant changes in the system or in governmental regulations, need to be performed in the future. Furthermore, in the course of the fieldwork several challenges to the effectiveness and sustainability of the designed O&M activities arose due to managerial, economic, social and technical reasons.

Managerial challenges due to the underdevelopment of national and local O&M policies came up. There was no local O&M system present that could be built upon. Therefore preventive O&M activities and management responsibilities had to be established from scratch. Furthermore, it was not possible to find available hydrogeological or geological maps of the region. As due to this reason the exact location of the infiltration areas – that could be located many kilometres away from the actual springs (Matula, 2005) – is not known, a proper protection of the recharge areas was not possible. For being able to protect the springs in an effective and appropriate way, further investigations need to be conducted.

Concerning the economic challenges, it was not possible to implement a tariff system, where appropriate fees for water consumption are collected from the consumers, in order to ensure financial viability of the water supply network and to set up a preventive maintenance system (Jain et al., 2010; Lupu, 2010). When this idea of cost recovery at affordable tariffs was presented to the head priest, he stated that this is not an option, as the residents of Rwaza are very poor and would not be able to afford paying water fees, and that furthermore it is the duty of the church to provide water to its followers free of charge. But, like already mentioned, the church also had not enough economical resources to come up for preventive O&M activities and expenditures for spare parts and reparations. Therefore, the NGO *Future for Kids* stepped in and started to provide the money for the preventive O&M activities, while the church has to come up for spares and repair works, in case parts of the system are broken. Additionally, the necessary tools for maintaining and repairing the system were provided by *Future for Kids* and the BOKU.

Social challenges were inter alia arising from the difficulty of hygiene behaviours becoming a common practice, and often people prefer to defecate in the bush instead of using a toilet – quite apart from the fact that toilets or latrines are often not available. This custom promotes a contamination of water resources with faecal bacteria (Lupu, 2010). Another challenge arises from the fact that every community is composed of people who differ in gender, ethnicity, socioeconomic status, politics, age and religion. O&M management needs to make sure that all different groups are represented equally and work together, so that an effective water supply service can be ensured to the whole community (Brikke and Bredero, 2003). Also the fact that several times the fences, that have been set up in order to protect the springs and the main storage tank, were stolen by poor residents is part of the social challenges that have to be faced. Additionally, in the case of Rwaza some difficulties have been experienced due to hierarchical challenges. The head priest who was initially willing to cooperate and thankful for the support, seemed to have changed his mind when it came to the implementation of the preventive O&M activities. In the initial phase of the execution of the O&M activities it was very difficult to contact him and the determined workers, and therefore it was not possible to start with the implementation at the scheduled date. After a delay of several months though, it was possible to get started with the preventive O&M activities.

Technical challenges resulted inter alia from the fact that there was no influence on technology selection and the avoidance of poor quality materials, as the system was already built in the late 1950s. Therefore, some parts of the system might not be appropriate for the special settings (Lupu, 2010). Additionally, the age of the system influences the spare part availability, which can be a major constraint in the sustainability of water supply systems (Brikke and Bredero, 2003). Another problem arises from the circumstance that some parts of the system have been misused or even vandalised by users. This happened especially to publicly accessible parts of the system such as the taps of the public standposts. In those cases, a dialogue between the providers and the users of the water supply system would be necessary.

Those arising challenges demonstrated that the implementation of a WSP is not a rapid one-time undertaking, but rather a continuous process in the course of which the plan is steadily revised, updated and adjusted to the local setting.

6. Summary

Still nowadays Rwanda has to suffer from its history and the aftermaths of the terrible genocide in 1994. In a time period of approximately 100 days, around one million people (mostly Tutsi) were killed. The human tragedy not only killed hundreds of thousands of people, but was accompanied by the widespread destruction of the country's infrastructure and a loss of capacity. Due to the terrible events, the water supply and waste water infrastructure in the country was heavily destroyed. In the sector of water supply, a decline in improved water supply coverage of more than 20 percent compared to the reference year 1990 could be observed after 1994 and thus dropped from more than 60 to 39 percent. After the tragic incident and its destructive effects, a subsequent period of emergency programmes lead to low investment, neglected maintenance and an abandonment of cost recovery in the Rwandan water sector. Since then, the country tries with political will and the commitment to several international programmes, such as the *Economic Development and Poverty Reduction Strategy* 2012 (EDPRS), the *Millennium Development Goals* 2015 (MDG) and *Vision 2020*, to reach the aim of water supply and sanitation coverage rates of 100 percent by the year 2020. Although Rwanda is making visible progress, the way to reach the targets is still long and difficult. Especially in the rural water supply sector many investments and improvements still need to be done in order to supply Rwanda's inhabitants with safe drinking water. Besides the construction of water supply systems, the training of operators and the set-up of proper Operation and Maintenance (O&M) systems form a crucial step to a secured and safe water supply, as proper O&M activities are indispensable for the improvement of the efficiency, effectiveness and sustainability of water supply schemes.

A study of the World Bank found that in 2004, half of the piped rural water supply systems in Rwanda were, due to poor management and poor cost coverage, not functional. As a response to the problem and to improve the performance of rural water supply systems, the Rwandan government started to promote the participation of the local private sector in the management of piped rural schemes. The authorities aimed to improve cost recovery by switching from a central management model towards one of public-private partnership. The introduction of this management approach has been a success and has increased Rwandans' access to water supply. In 2010, already 30 percent of rural water systems were managed on a private basis and served approximately one million people. With the introduction of public-private partnerships in the management of water supply systems, also the maintenance of existing infrastructures has been improving.

An adequate access to safe drinking water and improved sanitation is a fundamental human right and a precondition for health. The improvement of inhabitants' access to potable water and sanitation services can lead to clear benefits to public health and should therefore be an important health and development issue on a national, regional and local level. The central task of every drinking water provider is to provide potable water that complies with international and national governmental regulations. However, especially small rural community water supplies are often subject to hindering framework conditions and tend to lack personnel, financial, organisational and technical capacities for ensuring the desired product of clean and safe drinking water. These special conditions create a particular need to support providers and operators of small water supply facilities, in order to being able to ensure an appropriate water quality. The Water Safety Plan (WSP) concept developed by the WHO (2004), detects, assesses and manages risks along the whole water supply chain, from catchment to consumer, and aims to prevent the whole water supply system from contamination. The application of this integrated preventive management approach shall help operators to ensure long-term and proper functioning of their water supply system and to provide a safe product regardless of their size.

According to the WHO (2012), the process of developing and implementing a WSP for small community water supply schemes can be divided into the following six main tasks:

- Engage the community and assemble a WSP team
- Describe the community water supply
- Identify and assess hazards, hazardous events, risks and existing control measures
- Develop and implement an incremental improvement plan
- Monitor control measures and verify the effectiveness of the WSP
- Document, review and improve all aspects of WSP implementation

A unique characteristic of the WSP tool is its applicability at different scales and its practicability not only for newly planned water supply systems, but also for already existing schemes. In the course of the application of this method, O&M activities play an important role. O&M is a term that is commonly used to identify all implemented activities in order to run and keep provided facilities in a good condition. As O&M activities encompass not only technical aspects, but cover also managerial, financial, social, community, gender, environmental, political and institutional issues, they help to improve the performance, efficiency and sustainability of rural water supply and sanitation services.

The object of investigation of this master thesis was the rural water supply system of “Paroisse Rwaza du Diocèse de Ruhengeri”, that is located in the border triangle of Rwanda, Uganda and the Democratic Republic of the Congo. The parish is situated in the district Musanze, in the Sector Rwaza, which is approximately 90 kilometres Northwest of Kigali. Within the territory of the parish located is the Austrian non-governmental organisation *Future for Kids*. In 2007, the organisation took over the responsibility for 50 orphans and since then provides them a home and ensures their education. In 2008, the new orphanage buildings were constructed, and in 2013 the connection to the existing water supply system of Paroisse de Rwaza was conducted. In the course of the extension of the system, the old system was rehabilitated and necessary reparation works were done. In the process of the system renovation, it was detected that the water quality of the system has actually never been checked. Furthermore, it was found that several times per year the water consumers suffer from water shortages – even though according to water flow measurements there should be enough water available – and that parts of the system were broken and stopped to work. These problems can be traced back to an inappropriate O&M of the water supply system. In fact, there was no preventive maintenance system available at all and it was only reacted when problems with the water system occurred. This absence of a maintenance system can be explained by 1) a lack of money, which is reflected in a very low budget for spare parts and in the non-employment of permanent employees, 2) a lack of O&M instructions and routines, 3) a lack of clear responsibilities, and 4) the absence of on-site checks by governmental authorities as the system is privately owned by the church. Now that the rehabilitation works are completed, it is crucial that the repaired and extended water supply system is maintained and operated suitably, so that a continued future use can be ensured and the lifetime of the system can be expanded. Therefore, the main objective of this master thesis was to contribute to the long-term sustainable operation of the water supply system of Paroisse de Rwaza and the system extension to the non-governmental organisation *Future for Kids*, and thus to a secured water supply with safe drinking water in the region. To achieve this target, a set of sub-objectives has been developed:

- Investigation of the local water quantity and quality
- Identification of the used rural water supply and sanitation technologies
- Identification of the specific O&M requirements of the used technologies
- Review of the present O&M situation and its comparison to the requirements
- Identification of possible critical points in the system, hazards, risks and mitigation options via the application of the WSP approach

To meet this set of sub-targets, and thus the main objective, the used methodologies were best possible adapted to the study site in the course of the fieldwork, that was performed in August and the beginning of September 2014 in Rwaza.

Firstly, the water quantity as well as the microbiological and chemical quality of the delivered water were investigated and compared to reference values of the WHO and the Rwandan national drinking water quality standards as well as to the Austrian Drinking Water Ordinance respectively. It was detected that the water quantity provided by the springs, 76.7-92.9 L/(cap*d), should be sufficient for the supplied consumers, as according to the WHO most basic needs are met and few health concerns arise at a reference value of 50-100 L/(cap*d). But nevertheless it is necessary that losses throughout the system are eliminated or at least reduced for being able to really provide a sufficient amount of water to all consumers of the water supply system. As a result of the microbiological examination it was found, that the water quality delivered to the consumers does not meet health based quality standards. The samples show a significant contamination with E.coli and coliforms and the investigation unveiled that already the water that enters the system via the springs (especially from the Mikamo sources) is contaminated with bacteria. Due to the direct correlation between the contamination of drinking water with faeces from humans or animals and the risk of waterborne diseases, the delivered water should not be used for human consumption without further treatment. As at the point of system examination there was not a single treatment step in the water supply system of Rwaza present, it is highly recommended to apply water treatment processes on the consumer level. Concerning the chemical water quality there are no health-concerns observable.

Secondly, the WSP approach was implemented in practice. An O&M team was established and the roles of the team members were defined. Furthermore, the water supply system of Paroisse de Rwaza was described and the rural water supply and sanitation technologies were identified. Afterwards, the specific O&M requirements of the used technologies were determined and compared to the present O&M situation. It was found that no preventive O&M system was in place and none of the requirements to properly maintain the system were fulfilled. By means of the WSP approach implementation, possible hazards, hazardous events, risks, their likelihood and their consequences were identified. Due to the application of the risk ranking it was found, that there are in total 70 risks to the water supply system of Rwaza, thereof 21 high priority, 29 medium priority and 18 low priority risks, while two hazardous events could not be evaluated due to a lack of information. The distribution system, the storage components and the user level represent the components, which are at highest risk. Concerning the high priority hazardous events, the majority of risks result out of microbiological hazards, while in general most hazards are of physical nature.

Based on the conducted risk assessment, mitigation measures to control the identified hazards and hazardous events were determined. As there were no control measures present to eliminate or reduce the identified risks for most hazardous events at the point of system investigation, new mitigation measures needed to be defined. Furthermore, an incremental improvement plan to tackle the identified hazards and to improve the drinking water quality was formulated. This was done by means of O&M checklists and work instructions for one-time, weekly, monthly, quarterly and half yearly activities. Thereby, the defined one-time activities, such as the protection of the areas around the spring chambers and the infiltration areas, the protection of the spring chambers and the storage tanks, the reparation of leakages, the establishment of a safe tool room and the disinfection of the system with chlorine, were identified as to have the highest priority and should therefore be implemented immediately. Nevertheless, the continuous maintenance measures need to be executed in a thoroughly manner in order to operate and maintain the system appropriately and to contribute to a sustainable operation of the water supply system and to a secured water supply with safe drinking water in the area.

In the course of the O&M checklist development, regular operational monitoring activities were scheduled. Twice a year an inspection walk is planned, in the course of which the whole system is examined, the tool room is checked for completeness, the by the contracted workers completed activities are inspected and possible grievances in the effectiveness of the WSP shall be detected. Furthermore, the used O&M checklists also serve documentation purposes. Via the utilisation of the checklists, it is documented what kind of activity was done by whom and when. This approach shall make the whole O&M processes more comprehensible and transparent, shall help to detect gaps in routine maintenance and sources of errors and shall facilitate to improve the mode of operation.

Even though the WSP is a suitable tool to support operators of small water supply schemes in identifying and controlling risks to their water supply systems, there were some challenges arising when it came to transferring the method into practice. In the case study, it was not possible to apply the method consistently. Furthermore, several challenges in terms of effectiveness and sustainability of the designed O&M activities arose due to managerial, economic, social and technical reasons in the course of the fieldwork.

Those arising challenges demonstrated that the implementation of a WSP is not a rapid one-time undertaking, but rather a continuous process in the course of which the plan is steadily revised, updated and adjusted to the local setting.

7. Conclusion and Outlook

The overall objective of this master thesis was to contribute to the long-term sustainable operation of the water supply system of Paroisse de Rwaza and the system extension to the non-governmental organisation *Future for Kids.* Therefore, it aimed at a secured water supply with safe drinking water in the area. To achieve this target, the applied methodology of the WSP was best possible adapted to the study site.

In the course of the implementation of the WSP approach it was found that at the moment of system investigation in August 2014:

- The water quantity provided by the springs (76.7-92.9 L/(cap*d)) should be sufficient for the supplied consumers, but it is necessary that losses throughout the system are eliminated in order to reach the required quantity
- The water quality delivered to the consumers did not meet health based quality standards and should therefore not be used for human consumption without further treatment on the consumer level
- No preventive O&M system was in place and none of the requirements to properly maintain the system were fulfilled
- There were 70 risks to the water supply system existing
- Nearly no mitigation measures to control present risks were in place

As a result, the 70 determined risks are to be eliminated through the application of identified, preventive one-time, weekly, monthly, quarterly and half yearly O&M activities, which were developed during the implementation of the WSP approach.

The master thesis mainly focused on the water supply system of the area. Nevertheless, it is crucial that in follow-up projects also sanitation and hygiene aspects are entirely taken into account. At the time of the fieldwork, construction works at the *Future for Kids* complex were performed. A new education facility, including toilets, a shower, a septic tank and a soak pit were constructed. As at the time of the field research (August and beginning of September 2014) the building was under construction, it was not yet included into the system description of the thesis. In future investigations also the new building and its facilities need to be incorporated into a holistic system description and risk analysis.

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9. List of Figures

10. List of Tables

11. Appendix

11.1 Water and wastewater system

Future for Kids

Legend:

- Water from Supply System
- Storm Water
- Collected Rain Water
- Waste Water System
- Ventilation Pipe
- Under Construction
- Storm Water Runoff only
- Storm Water and Pathway

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Water and wastewater system *Future for Kids*

11.2 Hazard analysis

Forming the basis for tables 11/12/13

Hazard Analysis											
System-Number	**Drinking Water System Component**	**Possible Hazard**	**Type of Hazard**	**Hazardous Event**	**Observations**	**Existing Control Measure**	**Likelihood**	**Consequence**	**Risk Ranking**	**Priority for Action**	**Measures of Risk Control**
C-1	Catchment Area 1: Spring Mikamo	Microbial pathogens	Microbiological	Impact on water quality due to animals	Animals are grazing, urinating and defecating in the catchment area; Potential seepage of animal faeces into the groundwater	There used to be a fence, but it was stolen; No control measures in place	**Likely**	**Major impact** Cattle and sheep faeces may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place	Fencing of catchment area (or prohibition of animal access in combination with cutting grass by hand); Regular inspection of the condition of the fence
		Microbial pathogens	Microbiological	Impact on water quality due to dwellers	Dwellings in higher elevation, on hill top; Possibility of seepage of waste water into groundwater	None	**Possible**	**Major impact** Human faeces may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Implementation of proper waste water management of dwellings
		Microbial pathogens	Microbiological	Impact on water quality due to manure use	Use of manure in agriculture	None	**Possible**	**Major impact** Manure may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Implementation of protection zone around springs, where fertilizer use is restricted
		Chemical health hazardous substances	Chemical	Impact on water quality due to artificial fertilizer use	Possibility of artificial fertilizer use in agriculture	None	**Unlikely**	**Major impact** Artificial fertilizers may contain harmful chemicals, which may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Implementation of protection zone around springs, where fertilizer use is restricted
C-2	Catchment Area 2: Spring Muknono	Microbial pathogens	Microbiological	Impact on water quality due to animals	Animals are grazing, urinating and defecating in the catchment area; Seepage of animal faeces into the groundwater	There used to be a fence, but it was stolen; No control measures in place	**Possible**	**Major impact** Cattle and sheep faeces may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Fencing of catchment area (or prohibition of animal access in combination with cutting grass by hand); Regular inspection of the condition of the fence

		Microbial pathogens	Microbiological	Impact on water quality due to dwellers	No dwellings observed	None	**Unlikely**	**Major impact** Human faeces may contain a variety of pathogens, which may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Implementation of proper waste water management of dwellings
		Microbial pathogens	Microbiological	Impact on water quality due to manure use	Use of manure in agriculture	None	**Possible**	**Major impact** Manure may contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Implementation of protection zone around springs, where fertilizer use is restricted
		Chemical health hazardous substances	Chemical	Impact on water quality due to artificial fertilizer use	Possibility of artificial fertilizer use in agriculture	None	**Unlikely**	**Major impact** Artificial fertilizers may contain harmful chemicals, which may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Implementation of protection zone around springs, where fertilizer use is restricted
E-1	Extraction: Spring Chamber Mikamo 1	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the spring chamber	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Reduced water flow	Physical	Clogging of pipes	Recurring growth of roots inside the pipes of the spring chamber	None	**Possible**	**Moderate impact** Decrease of water flow in spring chamber, reduced discharge	**Medium**	**Medium priority** Hazardous event is possible and has moderate consequences, and no control measures are in place	Cleaning of the pipes with a plumber's snake
E-2	Extraction: Spring Chamber Mikamo 2	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the spring chamber	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Reduced water flow	Physical	Clogging of pipes	Recurring growth of roots inside the pipes of the spring chamber	None	**Possible**	**Moderate impact** Decrease of water flow in spring chamber, reduced discharge	**Medium**	**Medium priority** Hazardous event is possible and has moderate consequences, and no control measures are in place	Cleaning of the pipes with a plumber's snake

E-3	Extraction: Spring Chamber Mikamo 3	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the spring chamber	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Reduced water flow	Physical	Clogging of pipes	Recurring growth of roots inside the pipes of the spring chamber	None	**Possible**	**Moderate impact** Decrease of water flow in spring chamber, reduced discharge	**Medium**	**Medium priority** Hazardous event is possible and has moderate consequences, and no control measures are in place	Cleaning of the pipes with a plumber's snake
E-4	Extraction: Spring Chamber Mukono	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the spring chamber	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Reduced water flow	Physical	Clogging of pipes	Recurring growth of roots inside the pipes of the spring chamber	None	**Possible**	**Moderate impact** Decrease of water flow in spring chamber, reduced discharge	**Medium**	**Medium priority** Hazardous event is possible and has moderate consequences, and no control measures are in place	Cleaning of the pipes with a plumber's snake
		High iron content	Chemical	Possibility of exceedance of limit values for iron	Raw water has high iron content and therefore a red colour	None	**Likely**	**Moderate impact** High iron content affects organoleptic drinking water quality and might have technical implications	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place	Cleaning of spring chamber, removal of ferrous soil inside chamber
D-1	Distribution: Collection Chamber 1	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the collection chamber	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
D-2	Distribution: Washout 1	Unauthorised misuse	Physical	Possibility of misuse of the structure	Lock in place and functioning	Lock	**Possible**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and control measures are in place	Control measures are in place (lock)

		Technical impairment	Physical	Soil can enter and pollute the washout chamber	Washout pipe is submerged in soil	None	**Likely**	**Minor impact** No health related impact; Pollution of washout chamber	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Washout chamber needs to be excavated and cleaned
		Technical impairment	Physical	Chamber can not be opened	Lock of cover is rusty	None	**Likely**	**Minor impact** No health related impact; Damage of lock	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Lock needs to be changed
		Technical impairment	Physical	Valve can not be opened	Valve is submerged in water and rusty	None	**Likely**	**Minor impact** No health related impact; Damage of valve	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Water in washout chamber needs to be pumped out, valve needs to be changed
D-3	Distribution: Collection Chamber 2	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	Lock at the cover of the collection chamber	Lock	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Low**	**Low priority** Hazardous event is unlikely and control measures are in place	Control measures are in place (lock)
D-4	Distribution: Washout 2	Unauthorised misuse	Physical	Possibility of misuse of the structure	No Lock in place	None	**Possible**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Installation of a lock
		Technical impairment	Physical	Soil can enter and pollute the washout chamber	Washout pipe is submerged in soil	None	**Likely**	**Minor impact** No health related impact; Pollution of washout chamber	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Washout chamber needs to be excavated and cleaned
		Technical impairment	Physical	Chamber can not be opened	Lock of cover is rusty	None	**Likely**	**Minor impact** No health related impact; Damage of lock	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Lock needs to be changed

		Technical impairment	Physical	Valve can not be opened	Valve is submerged in water and rusty	None	**Likely**	**Minor impact** No health related impact; Damage of valve	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Water in washout chamber needs to be pumped out, valve needs to be changed
D-5	Distribution: Pressure Reduction and Air Release Chamber 1	Microbial pathogens	Microbiological	Impact on water quality due to animals	Dead animals inside the chamber	None	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place	Regular checks of chamber, removal of captured animals
D-6	Distribution: Washout Public Water Station Bukara	Technical impairment	Physical	Possibility of misuse of the structure	Washout chamber has no cover	None	**Possible**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Installation of a cover with a lock
D-7	Distribution: Washout 3	Unauthorised misuse	Physical	Possibility of misuse of the structure	No Lock in place	None	**Possible**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Installation of a lock
		Technical impairment	Physical	Soil can enter and pollute the washout chamber	Chamber and washout pipe is submerged in soil	None	**Likely**	**Minor impact** No health related impact; Pollution of washout chamber	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Washout chamber needs to be excavated and cleaned
		Technical impairment	Physical	Chamber can not be opened	Chamber submerged in soil	None	**Likely**	**Minor impact** No health related impact; Pollution of washout chamber	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Chamber needs to be excavated
		Technical impairment	Physical	Valve can not be opened	Valve is submerged in soil	None	**Likely**	**Minor impact** No health related impact; Damage of valve	**Medium**	**Medium priority** Hazardous event is likely and has minor consequences, and no control measures are in place	Soil in washout chamber needs to be excavated, valve needs to be changed

D-8	Distribution: Pressure Reduction and Air Release Chamber 2	Microbial pathogens	Microbiological	Impact on water quality due to animals	None	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there would be major consequences, and no control measures are in place	Regular checks of chamber, removal of captured animals
D-9	Distribution: Distribution Water Main	Technical impairment	Physical	Damage of eroded pipes	Erosion occurring at some places; Some pipes in open area to overcome creeks	None	**Likely**	**Major impact** Eroded pipes are vulnerable to damages, sun radiation and temperature changes	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place	Bury eroded pipes; Implement measures against erosion
S-1	Storage: Tank Public Water Station Mikamo	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	None	Lock in place	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Low**	**Low priority** Hazardous event is unlikely and control measures are in place	Control measures are in place (lock)
		Microbial pathogens	Microbiological	Impact on water quality due to animals	*	*	*	**Major impact** Pollution of drinking water may cause illness in the community	*	*	*
		Unauthorised misuse	Physical	Possibility of misuse of the structures	*	*	*	**Minor impact** No health related impact; Misuse of structure	*	*	*
S-2	Storage: Main Storage Tank	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No fence around the main storage tank; No lock at the cover of the main storage tank	There used to be a fence, but it was stolen; No control measures in place	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a fence around the tank; Installation of a lock
		Microbial pathogens	Microbiological	Impact on water quality due to animals	Ventilation pipe has no mesh; There was a frog sitting inside the tank	There is a cover on the top of the ventilation pipe	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no sufficient control measures are in place	Installation of proper cover; Regular checks of tank, removal of captured animals

		Unauthorised misuse	Physical	Possibility of misuse of the structures	No lock at the cover of the outlet chamber to the Health Centre, Primary Schools and village Igiturushiya	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock
		Unauthorised misuse	Physical	Possibility of misuse of the structures	No lock at the cover of the outlet chamber to the parish	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock
		Unauthorised misuse	Physical	Possibility of misuse of the structures	No lock at the cover of the outlet chamber to Tank Future for Kids	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock
		Unauthorised misuse	Physical	Possibility of misuse of the structures	No lock at the Washout chamber	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock
S-3	Storage: Tank Village Igiturushiya	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the storage tank	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Microbial pathogens	Microbiological	Impact on water quality due to animals	None	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Regular checks of tank, removal of captured animals
		Unauthorised misuse	Physical	Possibility of misuse of the structures	None	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock

S-4	Storage: Tank Future for Kids	Microbial pathogens; Chemical health hazardous substances	Microbiological; Chemical	Possibility of pollution of drinking water by unauthorised persons	No lock at the cover of the storage tank	None	**Unlikely**	**Major impact** Pollution of drinking water may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Installation of a lock
		Microbial pathogens	Microbiological	Impact on water quality due to animals	Birds sitting on the water tank roof while the cover is opened for aeration; Possibility of pollution of drinking water by bird faeces; Possibility of pollution by entering animals	None	**Likely**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place	Keep cover closed
		Microbial pathogens	Microbiological	Stagnation of water in the tank	No ventilation pipe	None	**Likely**	**Moderate impact** Consequence is for a small percentage of consumers, but could be health related	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place	Installation of a ventilation pipe
		Unauthoris ed misuse	Physical	Possibility of misuse of the structures	No lock at the cover of the inlet- and washout chamber	None	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely and has minor consequences, and no control measures are in place	Installation of a lock
		Unauthoris ed misuse	Physical	Possibility of misuse of the structures	No lock at the cover of the outlet chamber	Handle for valve is in tool room, to prevent misuse	**Unlikely**	**Minor impact** No health related impact; Misuse of structure	**Low**	**Low priority** Hazardous event is unlikely, and control measures are in place	Installation of a lock
U-1	User: Public Water Station Mikamo	Microbial pathogens	Microbiological	Contaminatio n of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption

		Loss of water	Physical	Broken tap	None	None	**Possible**	**Moderate impact** No health related impact; Loss of water for large amount of consumers	**Medium**	**Medium priority** Hazardous event is possible and has moderate consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect
U-2	User: Public Water Station Bukara	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	Tap cannot be turned off	None	**Likely**	**Moderate impact** No health related impact; Loss of water for large amount of consumers	**High**	**High priority** Hazardous event is likely and has moderate consequences, and no control measures are in place	Reparation of the broken tap
U-3	User: Internal Connections Health Centre	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	None	None	**Possible**	**Minor impact** No health related impact; Loss of water for small amount of consumers	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect
U-4	User: Internal Connections Primary School 1	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	None	None	**Possible**	**Minor impact** No health related impact; Loss of water for small amount of consumers	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect

U-5	User: Internal Connections Primary School 2	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	None	None	**Possible**	**Minor impact** No health related impact; Loss of water for small amount of consumers	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect
U-6	User: Internal Connections Parish Rwaza	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	None	None	**Possible**	**Minor impact** No health related impact; Loss of water for small amount of consumers	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect
U-7	User: Internal Connections Future for Kids	Microbial pathogens	Microbiological	Contamination of water in household storage containers as a result of poor hygiene	Exceedance of indicator organism limit values is possible	None	**Possible**	**Major impact** Dirty containers can contain a variety of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Information and courses about hygiene, health and waterborne diseases; Boiling of water prior to consumption
		Loss of water	Physical	Broken tap	None	None	**Possible**	**Minor impact** No health related impact; Loss of water for small amount of consumers	**Low**	**Low priority** Hazardous event is possible and has minor consequences, and no control measures are in place	Regular checks of taps and reparation in case of defect
T-1	Treatment:	Microbial pathogens	Microbiological	Potential growth of pathogens	No treatment steps in the whole system	None	**Likely**	**Major impact** Potential growth of pathogens, which may cause illness in the community	**High**	**High priority** Hazardous event is likely and has major consequences, and no control measures are in place	Consideration of incorporation of treatment processes into water supply system; Treatment of water on the household level

P-1	Processes: Cleaning of spring chambers	Detergent residues	Chemical	Possibility of contamination due to improper safety measures during cleaning activities	Contamination of spring chambers in course of cleaning activities	None	**Unlikely**	**Major impact** Chemical contamination may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Implementation of safe mode of operation standards
P-2	Processes: Cleaning of storage tanks	Detergent residues	Chemical	Possibility of contamination due to improper safety measures during cleaning activities	Contamination of water in storage tanks in course of cleaning activities	None	**Unlikely**	**Major impact** Chemical contamination may cause illness in the community	**Medium**	**Medium priority** Hazardous event is unlikely, but in case it occurs there are major consequences, and no control measures are in place	Implementation of safe mode of operation standards
P-3	Processes: Hygiene of workers	Pollution	Microbiological	Pollution of water during maintenance activities and system reparations	Possibility of pollution of water due to improper safety measures and personal hygiene of workers during system works	None	**Possible**	**Major impact** Pollution of drinking water may cause illness in the community	**High**	**High priority** Hazardous event is possible and has major consequences, and no control measures are in place	Implementation of safe mode of operation standards

* Could not be assessed, due to limited information

11.3 Activity and timetable one-time activities

Activity and Timetable ONE-TIME ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Protection of area around spring chambers							
Week 49 (1.12.-7.12.)	O1	Protection of area around spring chambers Mikamo (with a fence/ with a marking)	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O2	Protection of area around spring chamber Mukono (with a fence/ with a marking)	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O3	Protection of infiltration area springs Mikamo (with a fence/ with a marking)	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O4	Protection of infiltration area spring Mukono (with a fence/ with a marking)	Once	Alphred, Caetan, Bonifas			
Protection of chambers							
Week 49 (1.12.-7.12.)	O5	Protection of spring chamber cover (Mikamo 1) with a lock	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O6	Protection of spring chamber cover (Mikamo 2) with a lock	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O7	Protection of spring chamber cover (Mikamo 3) with a lock	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O8	Protection of spring chamber cover (Mukono) with a lock	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O9	Protection of main storage tank with a fence	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O10	Protection of main storage tank cover with a lock	Once	Alphred, Caetan, Bonifas			
Reparations and installations							
Week 49 (1.12.-7.12.)	O11	Reparation of the broken tap at public water station Bukara	Once	Alphred, Caetan, Bonifas			
Week 49 (1.12.-7.12.)	O12	Installation of a safe and well-arranged tool-room	Once	Alphred, Caetan, Bonifas			
	O13	Disinfection of the water supply system by a specialist (with chlorine)	Once	Specialist (Water Engineer)			

11.4 Activity and timetable weekly activities

Activity and Timetable WEEKLY ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Checking the tool room							
Week 17 (20.4.-26.4.)	W1	Checking the completeness of the tools in the tool room	Every Week	Alphred, Caetan, Bonifas			
Checking of all taps at the consumers for leakages and damages							
Week 17 (20.4.-26.4.)	W2	Checking of tap at "Public water station Bukara"	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W3	Checking of tap at "Public water station Mikamo"	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W4	Checking of taps at the Health Centre	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W5	Checking of taps at Primary School 1	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W6	Checking of taps at Primary School 2	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W7	Checking of taps at the Parish	Every Week	Alphred, Caetan, Bonifas			
Week 17 (20.4.-26.4.)	W8	Checking of taps at Future for Kids	Every Week	Alphred, Caetan, Bonifas			
Checking the tool room							
Week 18 (27.4.-3.5.)	W1	Checking the completeness of the tools in the tool room	Every Week	Alphred, Caetan, Bonifas			
Checking of all taps at the consumers for leakages							
Week 18 (27.4.-3.5.)	W2	Checking of tap at "Public water station Bukara"	Every Week	Alphred, Caetan, Bonifas			
Week 18 (27.4.-3.5.)	W3	Checking of tap at "Public water station Mikamo"	Every Week	Alphred, Caetan, Bonifas			
Week 18 (27.4.-3.5.)	W4	Checking of taps at the Health Centre	Every Week	Alphred, Caetan, Bonifas			
Week 18 (27.4.-3.5.)	W5	Checking of taps at Primary School 1	Every Week	Alphred, Caetan, Bonifas			
Week 18 (27.4.-3.5.)	W6	Checking of taps at Primary School 2	Every Week	Alphred, Caetan, Bonifas			
Week 18 (27.4.-3.5.)	W7	Checking of taps at the Parish	Every Week	Alphred, Caetan, Bonifas			

Week 18 (27.4.-3.5.)	W8	Checking of taps at Future for Kids	Every Week	Alphred, Caetan, Bonifas			
Checking the tool room							
Week 19 (4.5.-10.5.)	W1	Checking the completeness of the tools in the tool room	Every Week	Alphred, Caetan, Bonifas			
Checking of all taps at the consumers for leakages							
Week 19 (4.5.-10.5.)	W2	Checking of tap at "Public water station Bukara"	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W3	Checking of tap at "Public water station Mikamo"	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W4	Checking of taps at the Health Centre	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W5	Checking of taps at Primary School 1	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W6	Checking of taps at Primary School 2	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W7	Checking of taps at the Parish	Every Week	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	W8	Checking of taps at Future for Kids	Every Week	Alphred, Caetan, Bonifas			
Checking the tool room							
Week 20 (11.5.-17.5.)	W1	Checking the completeness of the tools in the tool room	Every Week	Alphred, Caetan, Bonifas			
Checking of all taps at the consumers for leakages							
Week 20 (11.5.-17.5.)	W2	Checking of tap at "Public water station Bukara"	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W3	Checking of tap at "Public water station Mikamo"	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W4	Checking of taps at the Health Centre	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W5	Checking of taps at Primary School 1	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W6	Checking of taps at Primary School 2	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W7	Checking of taps at the Parish	Every Week	Alphred, Caetan, Bonifas			
Week 20 (11.5.-17.5.)	W8	Checking of taps at Future for Kids	Every Week	Alphred, Caetan, Bonifas			

11.5 Activity and timetable monthly activities

Activity and Timetable MONTHLY ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Checking the aqueduct for leakages							
Week 19 (4.5.-10.5.)	M1	Checking the whole aqueduct for leakages and broken pipes	Every Month	Alphred, Caetan, Bonifas			
Opening and closing all valves, to check their functionality							
Week 19 (4.5.-10.5.)	M2	Opening and closing the valves of Washout 1	Every Month	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	M3	Opening and closing the valves of Washout 2	Every Month	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	M4	Opening and closing the valves of Washout 3	Every Month	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	M5	Opening and closing the valves under the main storage tank (connection to the parish)	Every Month	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	M6	Opening an closing the valves under the main storage tank (connection to Future for Kids)	Every Month	Alphred, Caetan, Bonifas			
Week 19 (4.5.-10.5.)	M7	Opening an closing the valves under the main storage tank (connection to Health Centre and Village Igiturushiya)	Every Month	Alphred, Caetan, Bonifas			
Checking the aqueduct for leakages							
Week 23 (1.6.-7.6.)	M1	Checking the whole aqueduct for leakages and broken pipes	Every Month	Alphred, Caetan, Bonifas			
Opening and closing all valves, to check their functionality							
Week 23 (1.6.-7.6.)	M2	Opening and closing the valves of Washout 1	Every Month	Alphred, Caetan, Bonifas			
Week 23 (1.6.-7.6.)	M3	Opening and closing the valves of Washout 2	Every Month	Alphred, Caetan, Bonifas			
Week 23 (1.6.-7.6.)	M4	Opening and closing the valves of Washout 3	Every Month	Alphred, Caetan, Bonifas			
Week 23 (1.6.-7.6.)	M5	Opening and closing the valves under the main storage tank (connection to the parish)	Every Month	Alphred, Caetan, Bonifas			
Week 23 (1.6.-7.6.)	M6	Opening an closing the valves under the main storage tank (connection to Future for Kids)	Every Month	Alphred, Caetan, Bonifas			

Week 23 (1.6.-7.6.)	M7	Opening an closing the valves under the main storage tank (connection to Health Centre and Village Igiturushiya)	Every Month	Alphred, Caetan, Bonifas			
Checking the aqueduct for leakages							
Week 27 (29.6.-5.7.)	M1	Checking the whole aqueduct for leakages and broken pipes	Every Month	Alphred, Caetan, Bonifas			
Opening and closing all valves, to check their functionality							
Week 27 (29.6.-5.7.)	M2	Opening and closing the valves of Washout 1	Every Month	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	M3	Opening and closing the valves of Washout 2	Every Month	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	M4	Opening and closing the valves of Washout 3	Every Month	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	M5	Opening and closing the valves under the main storage tank (connection to the parish)	Every Month	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	M6	Opening an closing the valves under the main storage tank (connection to Future for Kids)	Every Month	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	M7	Opening an closing the valves under the main storage tank (connection to Health Centre and Village Igiturushiya)	Every Month	Alphred, Caetan, Bonifas			
Checking the aqueduct for leakages							
Week 31 (27.7.-2.8.)	M1	Checking the whole aqueduct for leakages and broken pipes	Every Month	Alphred, Caetan, Bonifas			
Opening and closing all valves, to check their functionality							
Week 31 (27.7.-2.8.)	M2	Opening and closing the valves of Washout 1	Every Month	Alphred, Caetan, Bonifas			
Week 31 (27.7.-2.8.)	M3	Opening and closing the valves of Washout 2	Every Month	Alphred, Caetan, Bonifas			
Week 31 (27.7.-2.8.)	M4	Opening and closing the valves of Washout 3	Every Month	Alphred, Caetan, Bonifas			
Week 31 (27.7.-2.8.)	M5	Opening and closing the valves under the main storage tank (connection to the parish)	Every Month	Alphred, Caetan, Bonifas			
Week 31 (27.7.-2.8.)	M6	Opening an closing the valves under the main storage tank (connection to Future for Kids)	Every Month	Alphred, Caetan, Bonifas			
Week 31 (27.7.-2.8.)	M7	Opening an closing the valves under the main storage tank (connection to Health Centre and Village Igiturushiya)	Every Month	Alphred, Caetan, Bonifas			

11.6 Activity and timetable quarterly activities

Activity and Timetable QUARTERLY ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Opening of the 3 washouts and cleaning of the deep point from sand and earth							
Week 27 (29.6.-5.7.)	Q1	Flushing of Washout 1	Every 3 Months	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	Q2	Flushing of Washout 2	Every 3 Months	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	Q3	Flushing of Washout 3	Every 3 Months	Alphred, Caetan, Bonifas			
Opening of the 3 washouts and cleaning of the deep point from sand and earth							
Week 40 (28.9.-4.10.)	Q1	Flushing of Washout 1	Every 3 Months	Alphred, Caetan, Bonifas			
Week 40 (28.9.-4.10.)	Q2	Flushing of Washout 2	Every 3 Months	Alphred, Caetan, Bonifas			
Week 40 (28.9.-4.10.)	Q3	Flushing of Washout 3	Every 3 Months	Alphred, Caetan, Bonifas			
Opening of the 3 washouts and cleaning of the deep point from sand and earth							
Week 1 (4.1.-10.1.)	Q1	Flushing of Washout 1	Every 3 Months	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	Q2	Flushing of Washout 2	Every 3 Months	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	Q3	Flushing of Washout 3	Every 3 Months	Alphred, Caetan, Bonifas			
Opening of the 3 washouts and cleaning of the deep point from sand and earth							
Week 13 (28.3.-3.4.)	Q1	Flushing of Washout 1	Every 3 Months	Alphred, Caetan, Bonifas			
Week 13 (28.3.-3.4.)	Q2	Flushing of Washout 2	Every 3 Months	Alphred, Caetan, Bonifas			
Week 13 (28.3.-3.4.)	Q3	Flushing of Washout 3	Every 3 Months	Alphred, Caetan, Bonifas			

11.7 Activity and timetable half-yearly activities

Activity and Timetable HALF-YEARLY ACTIVITIES							
Target Date	**Task Nr.**	**Activity**	**Schedule**	**Executing Person**	**Completed (Day/Time)**	**Signature Executing Person**	**Signature Controller**
Cleaning of the pipes in the pits of the spring chambers							
Week 27 (29.6.-5.7.)	H1	Cleaning of the pipes in the pits of spring chamber Mikamo 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H2	Cleaning of the pipes in the pits of spring chamber Mikamo 2	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H3	Cleaning of the pipes in the pits of spring chamber Mikamo 3	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H4	Cleaning of the pipes in the pits of spring chamber Mukono	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the spring chambers							
Week 27 (29.6.-5.7.)	H5	Cleaning of the spring chamber Mikamo 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H6	Cleaning of the spring chamber Mikamo 2	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H7	Cleaning of the spring chamber Mikamo 3	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H8	Cleaning of the spring chamber Mukono	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the 2 collection chambers							
Week 27 (29.6.-5.7.)	H9	Cleaning of collection chamber 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H10	Cleaning of collection chamber 2	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the 2 pressure reduction and air release chambers							
Week 27 (29.6.-5.7.)	H11	Cleaning of pressure reduction and air release chamber 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H12	Cleaning of pressure reduction and air release chamber 2	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the storage tanks							
Week 27 (29.6.-5.7.)	H13	Cleaning of the main storage tank	Two Times per Year	Alphred, Caetan, Bonifas			
Week 27 (29.6.-5.7.)	H14	Cleaning of the storage tank of Village Igiturushiya	Two Times per Year	Alphred, Caetan, Bonifas			

Week 27 (29.6.-5.7.)	H15	Cleaning of the storage tank Future for Kids	Two Times per Year	Alphred, Caetan, Bonifas			
Inspection & monitoring of completed activities							
Week 27 (29.6.-5.7.)	I1	Inspection walk, to monitor and inspect the completed activities	Two Times per Year	Gasore, Rene Maxime			
Cleaning of the pipes in the pits of the spring chambers							
Week 1 (4.1.-10.1.)	H1	Cleaning of the pipes in the pits of spring chamber Mikamo 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H2	Cleaning of the pipes in the pits of spring chamber Mikamo 2	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H3	Cleaning of the pipes in the pits of spring chamber Mikamo 3	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H4	Cleaning of the pipes in the pits of spring chamber Mukono	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the spring chambers							
Week 1 (4.1.-10.1.)	H5	Cleaning of the spring chamber Mikamo 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H6	Cleaning of the spring chamber Mikamo 2	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H7	Cleaning of the spring chamber Mikamo 3	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H8	Cleaning of the spring chamber Mukono	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the 2 collection chambers							
Week 1 (4.1.-10.1.)	H9	Cleaning of collection chamber 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H10	Cleaning of collection chamber 2	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the 2 pressure reduction and air release chambers							
Week 1 (4.1.-10.1.)	H11	Cleaning of pressure reduction and air release chamber 1	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H12	Cleaning of pressure reduction and air release chamber 2	Two Times per Year	Alphred, Caetan, Bonifas			
Cleaning of the storage tanks							
Week 1 (4.1.-10.1.)	H13	Cleaning of the main storage tank	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H14	Cleaning of the storage tank of Village Igiturushiya	Two Times per Year	Alphred, Caetan, Bonifas			
Week 1 (4.1.-10.1.)	H15	Cleaning of the storage tank Future for Kids	Two Times per Year	Alphred, Caetan, Bonifas			
Inspection & monitoring of completed activities							
Week 1 (4.1.-10.1.)	I1	Inspection walk, to monitor and inspect the completed activities	Two Times per Year	Gasore, Rene Maxime			

12. Curriculum Vitae

Susanne Lehner, BA BSc

Email: lehner.susanne@gmx.net

Telefon: +43 699 11482724

Geboren am 18.06.1988, in Wien

BILDUNGSWEG

03/2013 – heute

Natural Resources Management and Ecological Engineering

Internationales Double Degree Masterstudium: Universität für Bodenkultur Wien und Czech University of Life Sciences Prague

- Schwerpunkte:

Kulturtechnik und Wasserwirtschaft, Bodenkunde, Bodenchemie, Umwelt und (Bio-) Ressourcenmanagement, Sozial-, Rechts- und Wirtschaftswissenschaften

- Masterarbeits-Thema:

"Design of a sustainable operation and maintenance concept for the water supply system of Paroisse de Rwaza (Rwanda)", Feldforschung in Ruanda (Sommer 2014)

10/2007 – 02/2013

Umwelt- und Bio- Ressourcen Management

Bachelorstudium: Universität für Bodenkultur Wien

- Schwerpunkte:

Umwelt- und Ressourcenökonomie, Betriebliches Umweltmanagement, Umweltpolitik, Umweltrecht und Umweltsoziologie, Ökosystemlehre, Landnutzung und Naturschutz, Abfall- und Wasserwirtschaft

10/2006 – 11/2013

Kultur- und Sozialanthropologie

Bachelorstudium: Universität Wien

- Schwerpunkte:

Anthropologie und Entwicklungszusammenarbeit, Interkulturelle Anwendungsfelder in Organisationen und Projekten, Recht-Frieden-Konflikt

09/1998 – 06/2006

AHS BG Bachgasse Mödling

- Maturafächer:

  Schriftlich: Deutsch, Englisch, Mathematik
  Mündlich: Englisch +Vertiefung, Biologie, Geographie, Psychologie

PRAKTISCHE ERFAHRUNG

08/2015

Praktikum beim OeAD

Österreichischer Austauschdienst, Wien

- Unterstützung bei der Förderprogramm-Administration
- Gutachter-Recherche für die Projektantrags-Begutachtung

07/2015

Praktikum bei der KEF

Kommission für Entwicklungsforschung bei der OeAD-GmbH, Wien

- Gestaltung einer Radiosendung der Sendereihe Welt im Ohr, Ö1-Campusradio (*KEF on Air: Ruanda, das Land der tausend Hügel gut 20 Jahre nach dem Genozid*)
- Aufbereitung eines entwicklungspolitisch relevanten Themenschwerpunktes im KEF-Forum
- Administrative Unterstützung

08/2014 – 09/2014

Masterarbeits-Feldforschungsaufenthalt

NGO Future for Kids, Rwaza (Ruanda)

- Wasserflussmessungen, mikrobiologische Wasseruntersuchungen, Risikoanalyse (Water Safety Plan), Entwicklung eines nachhaltigen Operation & Maintenance Systems

09/2013

Praktikum bei der AWI

Bundesanstalt für Agrarwirtschaft, Wien

- MS Access-unterstützte Aufbereitung von Daten für ÖPUL
- Administrative Unterstützung

07/2011

Ferialpraktikum bei der Stadtgärtnerei

Stadtgärtnerei, Stadtgemeinde Mödling

09/2008 - heute

Gelegentliche Promotionsarbeit

Skalar Entertainment GmbH (Musicnet), Wien

09/2006 – 06/2007

Samstagsaushilfe bei Ikea

Ikea, Shopping City Süd, Vösendorf

07/2004 - 08/2009

Diverse Ferialpraktika

Humanic, Ikea, Merkur, Erdbeerwelt

WEITERE KENNTNISSE

Sprachen:

Deutsch – Muttersprache

Englisch – fließend in Wort und Schrift (Cambridge First Certificate)

Niederländisch – Grundkenntnisse

Französisch – Grundkenntnisse

Software:

MS Office (inkl. Access), GAMS, AutoCAD

Sonstige:

Führerscheinklasse B

AUSLANDS-ERFAHRUNG

09/2014 – 06/2015

Studienjahr 2014/15 an der Czech University of Life Sciences Prague, Tschechien

Auslandsjahr im Rahmen des Internationalen Double Degree Masterstudiums

08/2011 – 02/2012

Wintersemester 2011/12 an der Universiteit Antwerpen, Belgien

Erasmus-Auslandssemester

13. Affirmation

I certify, that the master thesis was written by me, not using sources and tools other than quoted and without use of any other illegitimate support.

Furthermore, I confirm that I have not submitted this master thesis either nationally or internationally in any form.

Vienna, 23.11.2015, Susanne Lehner,