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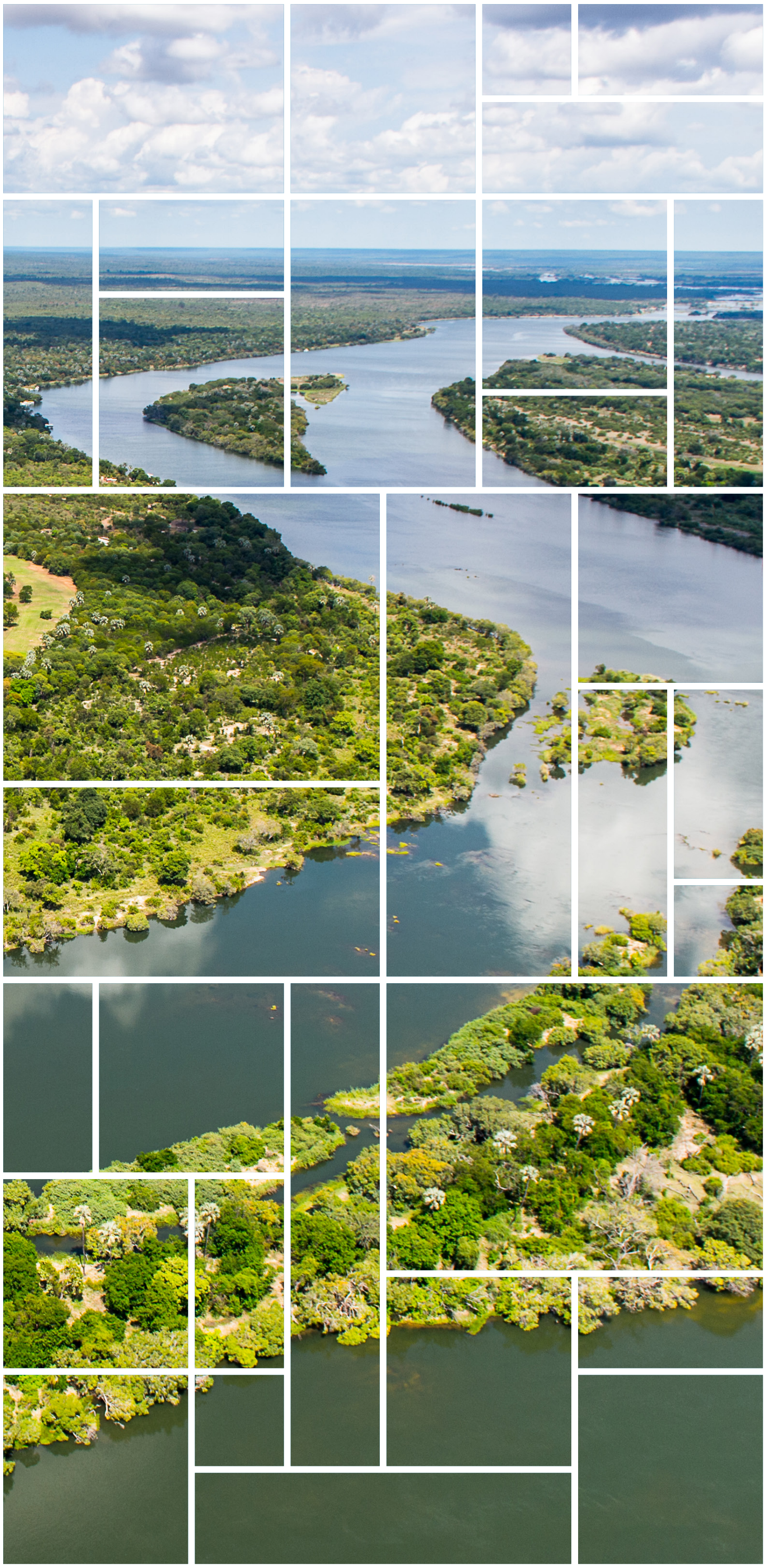

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TRAINING WORKSHOP No. 2

Volume 3
Case studies

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*Forthcoming

PREFACE

The Training Workshop on Water and Sustainable Development was carried out as part of "Capacity Development of Workers in the Water Sector" project funded by the Arab Gulf Programme for Development (AGFUND). The workshop was conducted in two editions, the first in October 2015 and the second in July 2016, both at the UN WWAP UNESCO premises in Perugia, Italy.

The overall aim of the training workshop was to enhance the capacity of countries to deal with water issues in a complex world environment by providing policy-makers with tools for managing water resources and competing uses, dealing with extreme events and the challenge of growing urban environments. The workshop also aimed to prepare countries to respond and implement the 2030 Agenda for Sustainable Development, in particular the water-related targets.

The second edition of the training workshop was structured into two main parts: lectures from international experts (see Capacity Development Training Workshop on Water and Sustainable Development – Volume 1 – Course book) and presentation of the case studies by the participants. The following were the topics discussed in the training modules presented by experts:

1. Water and sustainable development (Angela Renata Cordeiro Ortigara);
2. Data and information on water (Graham Jewitt);
3. Engendering water: WWAP gender & water toolkit in view of the 2030 Agenda for Sustainable Development (Michela Miletto and Paola Piccione);
4. Water, energy, food, environment nexus, including sustainable development and decent jobs (Stefan Uhlenbrook);
5. Planning sustainable urban water infrastructure (Franco Montalto);
6. Integrated water resources management (Pieter van der Zaag);
7. Transboundary water management (Pieter van der Zaag); and
8. Adapting to extreme events for resilient urban ecosystems (Fernando Nardi).

The lectures were organized in a way that fostered involvement and questions from participants. The second edition was enriched by a field trip that included visits to Clitunno Springs, a detention basin working site on Topino River, and the Regional Centre of Civil Protection in Foligno. During the wrap-up session, participants highlighted how they were enriched by the workshop methodology which combined lectures and case studies.

As previously done for the first training workshop (see Volume II), Volume III is the result of similarly participants' involvement in writing and presenting case studies from their countries related to the lectures' topics. The real-life examples show how countries are committed to achieve Sustainable Development Goal (SDG) 6, "Clean water and sanitation". Possible solutions to insufficient access to safe drinking water and adequate sanitation (SDG 6.1 and 6.2) are described in the case studies presented by Cameroon, Uganda, Zambia and Zimbabwe, where different scenarios are explored, such as involvement of society and stakeholders, improvement of sanitation services in peri-urban areas, involvement of women in decision-making and construction of sanitation devices in low-income communities (SDG 6.b). The case studies developed by Ethiopia, Kenya, Mauritius and Nigeria show the importance of monitoring water quality (SDG 6.3), supported by physical, chemical and biological analyses, as well as the adoption of wastewater treatment and reuse. The case study on Zimbabwe focused on the use of remote sensing to forecast periods of droughts for agriculture crops (SDG 6.4), while articles written by participants from South Africa and Sudan stress the importance of legal cooperation in transboundary aquifers and rivers (SDG 6.5, SDG 6.a). Finally, the case study on the city of Accra (Ghana) focuses on managing water in the scenario of increasing extreme events (SDG 6.a).

We would like to thank UN WWAP UNESCO colleagues who were involved in every step throughout the workshop organization and the publication of this Volume III. We are also thankful to Francisco Febronio Peña Guerra, Adeyinka Sobowale and Professor Gerald Galloway for providing useful inputs during the peer review process. Most of all, we are grateful to the professors and participants who made this training workshop a great experience for all.

LIST OF FIGURES AND TABLES

* The figures and tables are listed according to the order of the case studies in this publication.
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1 | ZAMBIA

A step towards groundwater protection in Mtendere, Lusaka

Lucy Tembo Millennium Challenge Account-Zambia Infrastructure

1 Introduction

Zambia, like many developing countries of Sub-Sahara, risks losing its groundwater source due to pollution from poorly constructed pit latrines. Studies have shown that unprotected pit latrines in densely populated areas have an impact on the quality of groundwater, hence posing a threat of contamination to groundwater (Nsubuga et al., 2004). In Lusaka, the capital city of Zambia, between 30 to 40% of its two million population live in planned areas, while the remaining 60-70% live in peri-urban areas (NWASCO, 2005). The peri-urban areas, in most cases, lack basic services such as water supply and sanitation. As a result, residents in these areas construct their own water and sanitation facilities, which in mostly shallow wells and poorly constructed pit latrines. In order to save the groundwater source, the government through its cooperating partners is acting to invest in sustainable water supply and sanitation services in these areas.

This paper highlights one such effort that the government is implementing, through the Millennium Challenge Account,[1] to protect groundwater from contamination due to poorly constructed pit latrines by providing off-site sanitation in Mtendere, one of the peri-urban areas in Lusaka.

Aerial view of part of Mtendere and existing sanitation in Mtendere

Source: World Bank/WSP (2016, Fig.3, p. 23).

This off-site sanitation is part of a major project funded by the American Government through the Millennium Challenge Cooperation. The Lusaka Water Supply, Sanitation and Drainage Project (LWSSDP) is aimed at reducing poverty through economic growth, by expanding access to and improving reliability of water supply and sanitation, and improving drainage services in selected areas of the city of Lusaka. This project is being implemented by the Millennium Challenge

* This case study benefitted from the editorial inputs of Josephine Chiila (Lusaka City Council, City Planning Department).

1 Millennium Challenge Account-Zambia [is] the accountable entity [designated by the Government] to implement the Program [described in the Compact] and to exercise and perform the Government's right and obligation to oversee, manage and implement the Program, including without limitation, managing the implementation of the Project [the Lusaka Water Supply, Sanitation and Drainage] and its Activities, allocating resources and managing procurements" (MCC/GRZ, 2012, Article 3).

Account Zambia (MCA-Z) on behalf of the Government of Zambia (GRZ) (MCA-Z, n.d.), and will only provide sewer and water networks (GRZ/SCAP, 2013). This entails that individual households will have to provide their own water-borne toilets to be able to connect to the new off-site sewer network. The government and MCA-Z are also aware of the high risk of people not connecting to the new off-site sewer network due to the cost associated with the construction of water-borne toilets. To this effect, and as part of the preceding conditions, GRZ and MCA-Z are committed to establishing a Sanitation Connection Action Plan (SCAP) aimed at assisting and motivating households to connect to the new infrastructure and make it sustainable and replicable to other peri-urban areas as well as achieve its main objective of groundwater protection (GRZ/SCAP, 2013).

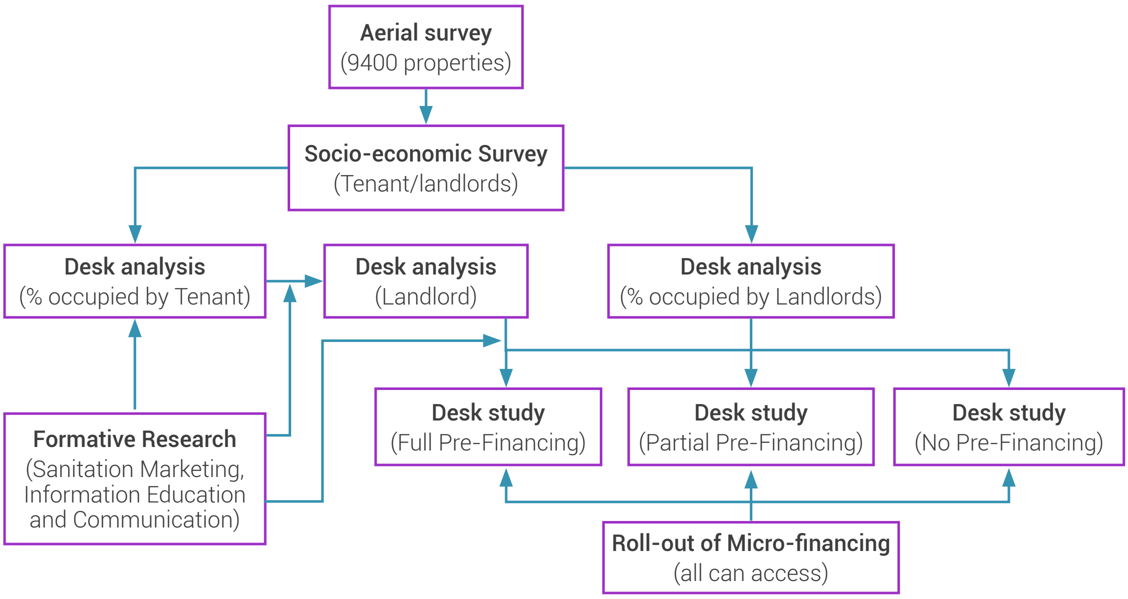
2 Project description

Mtendere is one of the peri-urban areas in Lusaka, the capital of Zambia. It has a population of about 90,000 people (CSO/MCA-Z, 2012). Like any other peri-urban areas in Zambia, it is has poor public services such as inadequate portable water supply, poor sanitation, poor drainage, poor road infrastructure and poor solid waste management. In terms of sanitation services, 96% of its population uses pit latrines as a form of sanitation service. The area also sits in proximity to the recharge zone for 12 boreholes for the city's utility company. These boreholes provide about 11% of the 60% groundwater contribution to the total water supplied in Lusaka (GRZ/SCAP, 2013). Given the large number of poorly constructed pit latrines in this area and the high densely populated nature of the area, there is a high chance of groundwater contamination. If this is left unchecked, it is likely to threaten water security not only in the area under study but in the country as a whole.

The Government of Zambia and the Government of the United States, through the Millennium Challenge Cooperation, signed a Millennium Challenge Compact agreement for the total grant of US$355 million to implement the Lusaka Supply, Sanitation and Drainage Project (LWSSDP) (MCC/GRZ, 2012). Mtendere is benefiting from this grant through the provision of 82 km of off-site sewer networks and 64 km of water distribution networks. The provision of off-site sewer networks in Mtendere is aimed at encouraging households to connect to the sewer network to reduce the threat to groundwater contamination. Given that Mtendere area has about 96% of inhabitants on pit latrines, there is need for individual households to construct water-borne toilet and be able to connect to the off-site sewer network. However, the cost of constructing the water-borne toilet and the connection are to be afforded by individual households. It has been observed from literature that provision of physical infrastructure such as water pipes, sewers and other facilities associated with off-site sewer system alone, in an effort to improve access to sanitation have resulted in abandonment or misuse of the infrastructure (Okurut et al., 2013).

Therefore, the approach in the implementation of this project is to combine both the hardware intervention (provision of off-site sewers, water pipes) and the software intervention (creation of local demand, through sanitation marketing) which have proven to work in similar projects in order to made the project sustainable replicable (Okurut et al.,2013). Figure 1.1 highlights the steps being followed in the implementation of hardware and software interventions in order to assist households construct water-borne toilets and connect to the off-site sewer network provided by the company.

Figure 1.1 – Methodology



Source: Author.

The methodology began with the identification of the number of properties in Mtendere using literature review and aerial survey (GRZ, 2011). The survey identified 9,400 properties and further review indicated that there were 18,209 households (CSO/MCA-Z, 2012), which implied that some properties had more than one household. The estimation of properties was very necessary in order to estimate the total cost of building water-borne toilets and the cost of connecting to the off-site sewer system.

The CSO/MCA-Z survey report captured additional data on demography, such as population, social economic profile including income and expenditure. The information from the demographic details was used to determine the social and economic status and the ability to construct the water-borne toilet and connect to the sewer infrastructure and hence, prevent groundwater contamination. The information was further used to categorise the three groups of people who may or may not require financial assistance to construct water-borne toilets and connect to the off-site sewer network, as follows: i) no financing; ii) partial pre-financing, and iii) full pre-financing (Wilson & Associate/MCA-Z, 2014). The next step in the methodology was a formative research to establish people's attitudes and behaviour with regards to water and sanitation.

The information collected from the methodology highlighted above will be used in decision-making and in the implementation of the financing mechanism in Mtendere. Sanitation marketing (SM), which is also part of the strategy to create demand for the water-borne toilets, will then be streamlined to focus only on landlords with no water-borne toilets. To cushion the technological leap from pit latrines to water-borne toilets, a lot of information, education and communication (IEC) is planned to enable sustainability of the infrastructure. Based on the identified beneficiary, SM and IEC will be streamlined and specific messaging will be developed and disseminated to specific categories of the households.

2.1 Implementing the connection plan

As mentioned earlier, the main objective of the LWSSDP in Mtendere is to protect groundwater from contamination due to poorly constructed pit latrines. This objective can only be achieved if all the households construct water-borne toilets and connect to the off-site sewer network.

In addition, it is also important that government enforces the public health act; which requires property owners to connect to the sewer system whenever in place.

The first objective is to identify the three main groups, based on the ability to afford the cost of constructing the water-borne toilet and the cost of connecting to the off-site sewer network, and the number of properties. The plan used data form the World Bank socio-economic survey, which estimated the poverty level for urban areas (World Bank, n.d.).Thus, 2,585 properties were estimated as poor and vulnerable landowners who will need full pre-financing and will be facilitated by the community members and church leaders. For the remaining 6,815 properties, it is assumed that these will either use their own resources or may need partial pre-financing.

The second specific objective is to implement sanitation marketing. As mentioned earlier, the approach for this project is to provide and necessitate the hardware component; physical infrastructure (provide off-site sewer network and necessitate household construction of water-borne toilets and connect to the off-site sewer network) and the software part; sanitation marketing and Information, Education and Communication, IEC (demand driven approach) to enhance the sustainability of the infrastructure. The data from the formative research (WSUP/LWSC/MCA-Z/LCC, 2015) will enable a better understanding on the attitudes and behaviours of the people of Mtendere which will inform the sanitation marketing campaign and hence produce appropriate messaging. Some channels to be used in the implementation of the sanitation marketing messaging includes door-door, community drama, group meetings, focus group discussions, school sanitation and hygiene education, and print media and mass media.

The third specific objective is the activation of the Public Health Act (1957), which states that any building within 60.96 m of a public sewer network must connect to such facility. This objective compelled the people to connect to the sewer network and deterred those who would wanted to continue using pit latrines even after sanitation marketing programmes discouraged them to do so. In order to achieve these objectives, the sanitation marketing programmes included community awareness on the legal provisions and penalties for failure to comply with the law, inspections and serving of notices to defaulting households.

The project has endeavoured to take into account gender considerations in the implementation of the project. Such considerations included the 30% target for female recruitments in all labour categories contributing to the employment of women. For those households whose property has been affected by the project and are eligible for compensation, the project has made a deliberate policy to only pay in the presence of wife and husband, in case of a couple, thereby enabling the women to benefit directly from the project's interventions.

2.2 Challenges, opportunities and lessons learned

Providing basic services such as water supply and sanitation services in an already established peri-urban area such as Mtendere comes with a number of challenges due to the unplanned nature and small plot spaces. One of the major challenges anticipated in the implementation of the project was restricted working space including space to lay pipes as well as location for the water-borne toilets. This challenge will result in demolishing structures in the construction corridor leading to high compensation costs. The second challenge was the acceptability of the new technology and behaviour change by the households, who for years have been using pit latrines not only for faecal and urine disposal but also for solid waste disposal with minimal or no cost at all. The introduction of water-borne toilets came with its own costs such as toilet paper, cleaning detergents, maintenance cost, water bill and other related costs. Other challenges include low rate of connection, which affected the uptake, and performance of the system in the initial stages.

Despite the anticipated challenges, the project has provided an opportunity for decision-makers to make the right decisions when dealing with issues of land use management and city planning, and provide public services, such as adequate water supply, sanitation services, solid waste management and adequate drainage. Lack of such services poses a great threat to groundwater contamination. The project has also provided an opportunity to learn lessons, some of which were:

- The provision of off-site sewer systems in densely populated peri-urban areas can reduce the threat to groundwater contamination through poorly constructed pit latrines;
- Demand-driven approach in the provision of water supply and sanitation services can contribute to sustainability of the infrastructure based on the successes recorded in similar projects;
- Community engagement at all stages of project implementation is very important for the community to buy-in and support the project; and
- Sensitisation through educational messages on the impact of inadequate sanitation is necessary for the community to appreciate the adverse effects on the environment and health of the community.

3 Conclusions

The paper highlights that the threat to groundwater contamination due to poorly constructed pit latrines is real. Therefore, great efforts are required by decision-makers which should include, among others, improved investments in water and sanitation services to protect water resources. The protection of the ground water resource cannot be over emphasized, especially in the city of Lusaka where about 60% of the water supplied is from ground water sources (GRZ/BGR, 2011).

Once the project is completed in November 2018, it will contribute to the protection of about 60% of the groundwater source for the city of Lusaka. This will contribute to the total water production for the city hence enabling the accessibility by others who may not have access to adequate water supply. Provision of adequate water supply and offsite sanitation system in Mtendere will lead to economic growth due to the savings accrued as a result of no time required for fetching of water and also due to less money spent on medical bills due to reduced rate of inhabitants falling sick due to improved personal hygiene. Other benefits include a safer and healthier environment leading to happier residents, who in turn will have time to engage in more economically productive activities thereby improving their standards of living. All these benefits will result in reduced poverty and hunger, improved health among the inhabitants and safer environment to live in, and thus contribute to the achievement of the sustainable development goals (CDC, 2015).

In conclusion, a step has been taken towards protecting groundwater in Mtenedere contributing to sustainable management of water resources. These efforts should be replicated to other peri-urban areas in the country in order for the impact to be significant.

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2 | KENYA

Water resources management authority intervention on the quality of wastewater discharged in the river: a case study of North Kinangop Mission Hospital

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1 Introduction

Kenya is a water scarce country with the pressures of climate change, increased pollution, and population growth. The regions where rivers cross have the advantage of using this source for domestic, industrial and agricultural purposes. Ninety-five per cent of all rivers in Kenya have water of soft characteristics. However, most of the groundwater sources are hard and have high fluoride (Coetsiers et al., 2008; Barasa et al. 2016). Hence, the little water that is available requires efficient water resources management practices (WSREB, 2009; water.org, n.d.). In Kenya there is need for sensitizing the dischargers and others users to protect water resources and catchment areas.

North Kinangop hospital is a health facility operating under the Catholic diocese of Nyahururu in Kenya. It is located in Nyandarua, South of Gitiri of Rift Valley Catchment Area. The Effluent Discharge Control Plan (EDCP) of the hospital was designed by the Water Resources Management Authority (WRMA) in order to control water and soil pollution (MWI, 2007). EDCP is a regulatory tool used in the enforcement of compliance with effluent discharge requirements. The concept enables effluent dischargers to develop and undertake step-by-step implementation of waste management programmes to achieve compliance. It also enables effluent dischargers to practice self-audit and to be issued with the Effluent Discharge permit by WRMA.

Despite the treatment plant, the effluent discharged by the Kinangop hospital was not respecting the discharge standards fixed by Kenyan Standards (WMI 2007; MENR, 2006).The case study follow-up started in the year 2010. In response, WRMA monitoring the status of pollution on Kitiri River in Naivasha, inspected the treatment plant and found out that the treatment ponds were full and needed to be disludged. After the assessment WRMA recommended provided further recommendations, such as increasing the maturation pond, increasing the wetland and aerating the final wastewater before discharging into the river. The hospital funded this project and the quality of the discharged effluent increased.

2 Project description

WRMA is the lead agency in Kenya responsible for the protection of water resources from adverse effects. Most water resources in Kenya are faced with pollution from both point and non-point sources. The point sources include discharge from poorly treated sewage and wastewater from institutions and industries. WRMA undertakes assessment and enforces pollution control measures of water users. North Kinangop hospital has a sewage treatment plant consisting of four ponds. The waste from the hospital enters the treatment works via grids/screens which separate the solid and the liquid waste. The solid waste (from sludge and wastewater) is channelled to a digester whereas the liquid waste enters the ponds. The effluent from the fourth pond enters a series of lagoons and finally to Kitiri River via meandering stretches. Hospital used stabilization ponds with anaerobic, facultative and maturation ponds.

2.1 Methodology

WRMA water quality and pollution control officers visited the hospital for the first time in September 2010, inspected the treatment ponds and tested the final effluent released into the River. The tests performed included: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH and alkalinity, nitrates, phosphates and nitrites. EDCP was introduced as a regulatory tool to enforce compliance with effluent discharge requirements of

Water Resources Management Rules (MWI, 2007). The concept enables effluent dischargers to develop and undertake step-by-step implementation of waste management programs to achieve compliance. It also enables effluent dischargers to practice self-audit. This process leads to the issuance of the Effluent Discharge Permit by WRMA. The hospital was inspected for compliance using the EDCP form, which requires the following information;

- Name and details of applicant;
- Quantity and quality of inflow water;
- Type and source of effluent;
- Design of effluent treatment plant;
- Location and description of effluent;
- Description of treatment and operations, if any;
- Hydrology, hydrogeology, and hydrochemistry of receiving water body;
- Impacts on receiving water body in terms of quantity and quality; (impacts include how poor quality and quantity of effluent discharged into water Resource affects the River)
- Proposed water quality requirements for the permit and the timeframe for achieving compliance;
- Monitoring Programme (measuring device, controlling device, sampling records, and reporting procedures; and
- Emergency plan for accidental discharges and their risks.

2.2 Development

Four monitoring activities were undertaken in the hospital between 2010 and 2011. Table 2.1 shows the high Biochemical Oxygen Demand, Chemical Oxygen Demand and Total Suspended Solids released from the hospital's final ponds into the Kitiri River. These parameters were falling below effluent quality requirements by Kenya's, Environmental Protection and World Health Organizations standards (Mara and Cairncross, 1989; NSW EPA, 1997). The Kitiri River is a water source for the which the community comprising of approximately two hundred people use water for domestic, agriculture, animals and other economic activities (construction), which prompted WRMA to introduce EDCP and compliance.

Table 2.1 – Some of the results of analysis of effluent and the River (GPS location: S00.54947, E036.55941)

	Kenya Bureau of Standards Standard	Before WRMA actions		After dislodging and increasing one maturation pond			
		Kitiri River downstream after discharge from the hospital	2010/2011 Average before disludging	2012 March	2012 June Outlet pond	2012 December	Kitiri River upstream before discharge from the hospital
pH	6.5-8.5	9.52	7.2	7.9	8.07	7.93	7.38
Alkalinity	400	180	380		212	212	48
Conductivity	-	265	397		522	583	93
TDS	1 200	265	236	412	324	361.46	58
BOD	30 mg/l	10	100	42.1	44	40	9
COD	50 mg/l	23	132	54.86	66	56	21
TSS	30 mg/l	<5	569	100	11	10	9

Note: Standard methods were used for the analysis (Eaton and Franson, 2005).

Source: Compiled by the author (2010, 2012).

The assessment revealed that the treatment plants were full of sludge and hence affected the normal operations and efficiency of the treatment unit. The hospital management was advised to carry out disludging of the entire treatment works as a condition number nine of EDCP above to reach compliance. The disludging exercise was completed in 2012. Photo 1 shows the level of sludge. After it, new monitoring activities were undertaken and the quality of the effluent increased.

WRMA also recommended other solutions such as increasing one maturation pond, increasing the one pond wetland and aerating the final waste entering the river. This was done and the quality of the discharged effluent increased. The water now enters a zigzag small canal through a bamboo plantation. The photos below indicate the state of the ponds before and after disludging, increasing the maturation pond and vegetation in the wetland.

Sludge has accumulated in this pond One of the first ponds of North Kinangop Mission Hospital Waste treatment*

(2010)

Waste is being removed for the sludge to dry The last pond being disludged

(2011)

One of the ponds to be disludged

(2010)

Clear effluent Kinangop sewage pond 4 after disludging

(2012)

Clear effluent with reduced TSS, BOD and COD Kinangop sewage pond 2 after disludging

(2012)

Biodigester

(2012)

Wetland

(2012)

Final wetland before discharge into the river. The vegetation was increased to further reduce the wastewater quality

(2012)

**The photos in this case study were taken by Hellen Sewe during data compilation at Water Resources Management Authority in Nakuru..*

2.3 Challenges and lessons learned

2.3.1 Challenges

The whole process was faced with several challenges which ranged from time required for compliance with effluent discharge versus high costs of implementation. Amongst the challenges were:

1. The cost of disludging and fulfilling EDCP conditions is expensive and hence, required some time for funds to be obtained;
2. Site preparation and construction of drying beds took time as flood conditions, slope, pumping the sludge into dry beds, odour risk impact and monitoring of the performance of dry beds and actual disludging had to be considered;
3. EDCP is an essential tool as it makes the dischargers develop and undertake step-by-step implementation of waste management programs to achieve compliance to the waste they discharge into environment and water resources;
4. EDCP enables effluent dischargers to practice self-audit and to do activities geared towards continuous improvement to the treatment systems;
5. Disludging was an opportunity suggested to hospital management and this reduced the low quality of effluent being discharged into water body;
6. Disludging in wastewater management removes the settled waste that lower the efficiency of treatment;
7. After disludging, the ponds were to be filled and tested. During testing, it was found that some ponds were leaking. The repair took time and thus, it took time for the ponds to be operational again (more than six months). However, the result was worth the time taken; and
8. EDCP implementation requires set time limit in which the hospital would meet the required standards.

2.3.2 Lessons learned

The recommended activities of disludging made wastewater safe for discharge into environment. The river water is currently used by others economically and in a sustainable way without any conflicts of water quality with the community.

The solid waste from the pond and sludge are used to produce the biogas which is beneficial as a source of fuel to the hospital. This clearly shows how wastewater is used here in a sustainable and economical way.

EDCP as a tool is effective with discharges as WRMA had to use it to follow closely all the conditions of compliance. EDCP allows time limit for dischargers to take step by step measurements to comply.

3 Conclusions

The hospital has shown good responsibility and concern for the environment and Kitiri River. In the last pond tilapia fish are farmed. This is an indication of water which is not polluted. The last step is a small waterfall down to the river. This increases the dissolved oxygen levels of the wastewater before it is discharged into the river. Final effluent is regularly tested and BOD currently ranges between 25-44 mg/l. The limit in Kenya is the 30 mg/l although tolerance limit is 45 mg/l as in the Water Quality Regulations (MENR, 2006). The hospital embraced the idea of Effluent Discharge Control Plan and is practicing continuous improvement and self-audit.

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3 | ZIMBABWE

The application of remote sensing in operational drought monitoring

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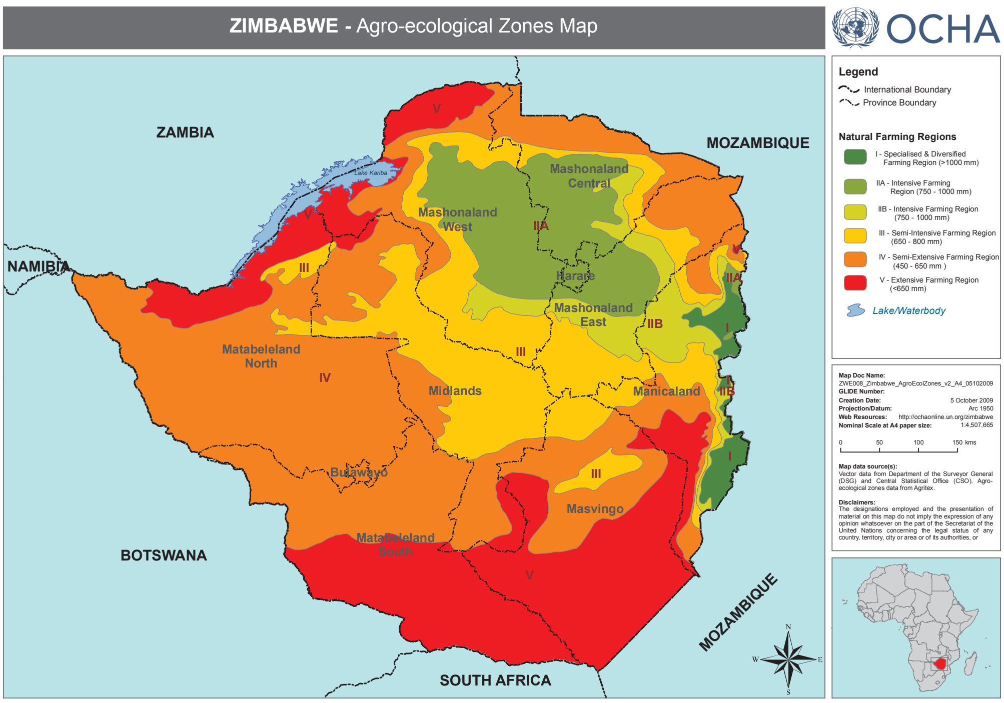
1 Introduction

Due to erratic or low rainfall, affected countries need early warning, preparedness measures and adaptation strategies to cope. This study examines the application of remote sensing drought indicators for operational drought monitoring at country scale. The sensitivity of the drought indicators in identifying drought occurrences was investigated using data from 1982 to 2010. The vegetation health index (VHI) and brightness temperature (BT) provided the clearest distinction between drought and normal or wet conditions, while the normalised difference vegetation index (NDVI) did not. Mid-season dry spells were evident in the analysis of monthly VHI values. The results of the study show that there is a great potential for the use of the freely available, high frequency, global vegetation health products for drought monitoring and early warning systems in Zimbabwe.

2 Project description

Zimbabwe is frequently affected by droughts, with different regions in the country experiencing droughts of varying intensity and duration (Figure 3.1). Recurrent droughts negatively impact food security especially subsistence farmers who practice rainfed agriculture and one third of children under five years old who are chronically malnourished (UNOCHA, 2016).

Figure 3.1 – Drought prone areas in Zimbabwe and differences in drought severity in the five agro-ecological zones



Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Source: UNOCHA (2009), based on vector data from the Department of the Surveyor General (DSG) and Central Statistical Office (CSO); and agro-ecological zones data from Agritex. Map provided courtesy of the UN Office for the Coordination of Humanitarian Affairs.

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[2] The author would like to thank B.H.P. Maathuis (University of Twente, Faculty ITC), who incorporated the data from NOAA STAR into the GEONetCast Toolbox.

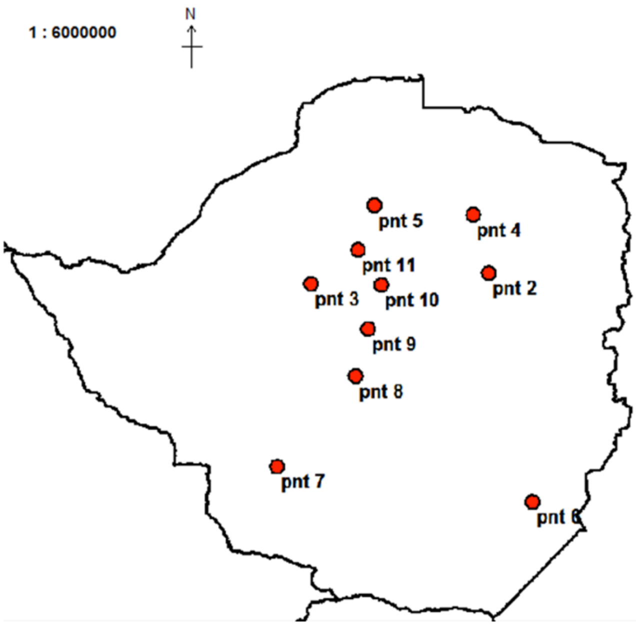
The frequent droughts in Zimbabwe generate impacts on food security, ecosystem services, and vulnerable members of the society. As a result of recurrent droughts, there is an urgent need for effective, easily accessible tools that can be applied in drought monitoring and early warning systems.

Due to the sparse meteorological networks in Zimbabwe, timely detection of drought onset from rainfall data is a problem (MSD, n.d.).[3] This lack of information at the required time negatively impacts drought risk management efforts. In this regard, remote sensing products have the potential to provide continuous assessment of the location, severity and spatial extent of drought by monitoring indicators of drought.

An analysis of the temporal characteristics of agricultural drought in Zimbabwe was carried out between 1982 and 2010 using freely available data from the National Oceanic and Atmospheric Administration Centre for Satellite Applications and Research (NOAA STAR, n.d.).

Drought indicators derived from the data were used in a retrospective study to identify the onset of drought and track its severity in selected locations of three agro-ecological regions in Zimbabwe. Global vegetation health products were extracted for 10 locations in different agro-ecological zones of Zimbabwe (Figure 3.2).

Figure 3.2 – Selected locations of farming areas in Zimbabwe



Source: Author, based on data from NOAA STAR (n.d.) and GADM database (www.gadm.org). Unpublished.

The study focused on ten locations in the agro-ecological zones II, III and IV (Figure 2) and addressed the following questions:

- Can the drought indicators derived from NOAA AVHRR (Advanced Very High Resolution Radiometer) data identify the onset and severity of drought in the main maize producing areas of Zimbabwe?
- Can forecasts be made about the annual maize yield from monitoring NDVI, VHI and BT in the critical month of January during maize growing season?
- Is there a threshold BT that indicates probable drought conditions?

[3] According to the Meteorological Services Department, there are currently 35 agro-meteorological stations in Zimbabwe.

The agro-ecological zones were selected for the following reasons:

- 65% of the Zimbabwean population live in communal areas – over 80% of whom live in the regions selected for further analysis (ZIMSTATS, 2012);
- the three zones combined produce 84% of maize in Zimbabwe (Anseeuw et al., 2012); and
- agro-ecological zone IV suffers frequent mid-season dry spells, while zones II and III have more reliable rainfall (Figure 3.1). The contrasts and similarities in these regions will provide valuable insights of the impacts of drought in different agro-ecological zones of the country. The locations (coordinates) of the areas are shown in Table 3.1. For each sub-region, homogenous areas with the same land use were identified and the analyses carried out for these representative units.

Table 3.2 – Locations of farming areas analysed

Point number	Coordinates		Agro-ecological zone
	x	y	
1	31.25214	-18.0743	IIa
3	29.01261	-18.2115	III
5	31.06008	-17.3382	IIa
12	29.80742	-17.2235	IIa
14	31.80432	-20.9551	V
15	28.58302	-20.5120	IV
16	29.57189	-19.3693	III
17	29.73158	-18.7778	III
18	29.89686	-18.2234	III
19	29.60438	-17.7848	IIa

Note: Point number is the same as location number. Each location in the study corresponds to the x y coordinates given, i.e. point number 1 corresponds to a red dot on Figure 2.

Source: Author, based on data from Google Earth© and Vincent and Thomas (1960).

2.1 Materials and methods

Target 6.4 of SDG 6 states:

> "By 2030, increase substantially water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity" (UNGA, 2015, p. 18).

Zimbabwean's heavy dependence on rain-fed agriculture increases its vulnerability to drought due to poor water use efficiency. Water scarcity management efforts need to focus on increasing water use efficiency through the development of irrigation schemes, rainwater harvesting, conservation agriculture and growing of drought tolerant crops. In addition, although agricultural water users are required to have permits for withdrawals of water in excess of basic requirements, there is evidence of poor compliance with this directive, especially for groundwater abstractions. This has negative implications for sustainable withdrawals of both ground and surface water. The proposed indicators for this target are two-fold. The first indicator is the percentage change in water-use efficiency over time, while the second indicator is the level of water stress quantified in terms of freshwater withdrawal versus available freshwater resources.

Zimbabwe's water scarcity challenge has two components. Firstly, the country suffers from absolute scarcity of water due to highly variable, low annual precipitation (Usman and Reason, 2004). Secondly, water scarcity results from inefficient use of available water resources as well as poor wastewater management that impairs surface water bodies. The maize-growing season in Zimbabwe coincides with the start of the rainy season from October to April/May. Typically, the rainfall peaks in December and January. There is usually a two-week dry spell in early January, which often coincides with the critical flowering period for maize. During this period, the maize is very sensitive to thermal conditions while in late March, the crop is sensitive to water stress. The rains resume by late January and continue through February/March. There is a close relationship between vegetation growth and rainfall variations, therefore drought indicators based on the NDVI can be used to monitor drought. A number of studies have used the NDVI as proxy for land surface response to rainfall patterns over semi/arid regions, (e.g. Unganai and Kogan (1998); Anyamba and Tucker (2005); Bayarjargal et al., (2006); Rojas et al. (2011); and Gebrehiwot et al. (2011).)

The deviation of NDVI from baseline "normal" conditions gives an indication of drought risk. The NDVI anomaly is expressed as the difference between the NDVI composite value for a specified period and the long-term mean value for that period. If deviations of the current year NDVI from the long-term average can be detected early in the season, forecasts can be made of the expected severity of the predicted drought (Anyamba and Tucker, 2005).

A number of drought indices based on the NDVI has been developed. This include the vegetation condition index (VCI), the thermal condition index (TCI) and the VHI. The various indices characterize vegetation health, moisture and thermal conditions. An analysis of the trends in the time series of these indices provides early indications of deteriorating conditions. This enables early detection of crop losses long before harvest, up to two months before; early warnings could be given from ground based data (Kogan, 2002). A good drought indicator should be responsive to short term environmental changes so that information obtained can be used in Early Warning Systems (Anderson et al., 2013).

2.2 Data sources

Most of the tools and data sources used in this study are freely available as described in this section.

Time series of weekly VHI, VCI, smoothed NDVI and BT images at 16 km resolution from the AVHRR sensor aboard the NOAA polar orbiting satellite series (NOAA-7, 9, 11, 14, 16) were obtained from the NOAA STAR.[4]

The data were imported using the GEONETCast Toolbox [5] that is integrated within ILWIS 3.2. ILWIS is an acronym for Integrated Land and Water Information System. It is an open source geographic information system (GIS) with image processing capabilities. ILWIS was developed by the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands. ILWIS 3.2 was used to perform the data processing and analysis of the imported data.[6]

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4 This data is freely available from: http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_ftp.php. The data covers the period 1982 (week 35) to the present time.

5 For further information on the GEONETCast Toolkit, please see https://www.itc.nl/Pub/WRS/WRS-GEONETCast/GEONETCast-toolbox.html

6 ILWIS can be downloaded from www.52north.org

GEONETCast is a near real time satellite reception and distribution system. Images are available on GEONETCast a few minutes after satellite observation. GEONETCast uses batch processing for time series data and enables rapid time series retrieval from various satellites, including the NOAA AVHRR data used in this study. GEONETCast was developed for various users, including academic institutions, environmental research institutes and (national) water authorities. Data are imported and processed, then by utilizing the GEONETCast toolbox, relevant products can be processed for (near real time) environmental assessment by national and international organizations to assist in policy making.

Since the NOAA AVHRR data set covers the entire globe, it was therefore necessary to extract data for just the selected locations in Zimbabwe. The coordinates of the selected locations were obtained from Google Earth. The point map of the selected locations was superimposed on the country boundary map in ILWIS 3.2 (Figure 3.2). The country boundary shapefile was downloaded from GADM[7], a database for the location of the world's administrative boundaries.

All the data were processed in ILWIS 3.2, and then imported to an Excel table to produce all the figures (Figure 3.3 - 3.10) that are presented in Section 2.3.

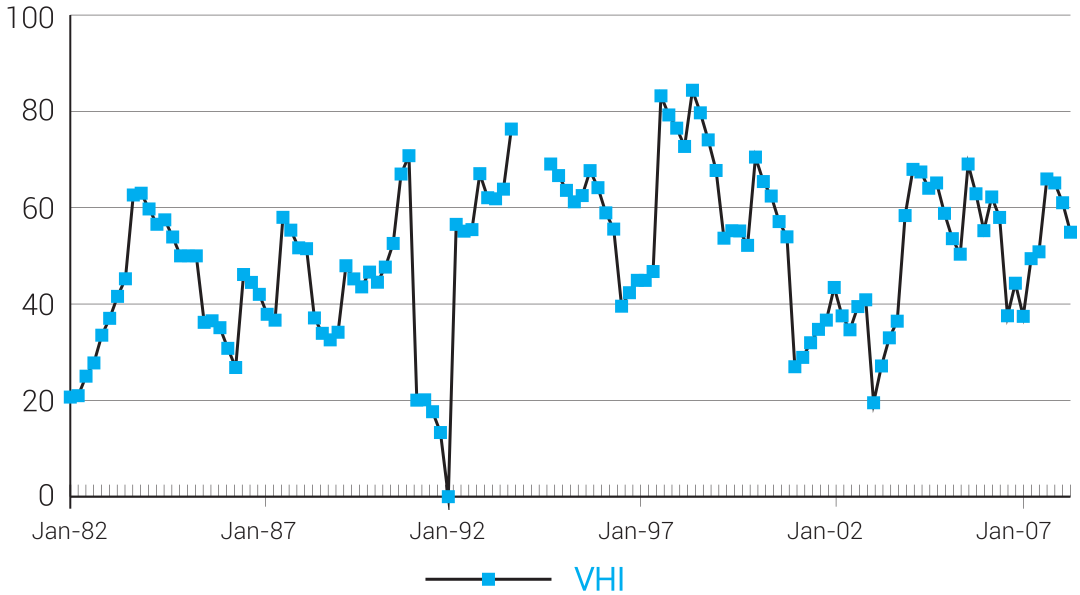
2.3 Results

The results of the analyses of time series of images are presented in this section.

2.3.1 Vegetation health index

The variation of the VHI from 1982 to 2010 is used to illustrate how different regions of the country experience drought of different severity. Figures 3.3 and 3.4 show weekly VHI during the month of January from 1982 to 2010 which is critical for maize growth. This is the time when the maize is at the pollination stage and dry spells are particularly damaging. The drought prone regions (Agro-ecological zones IV and V) have more VHI values that indicate drought conditions compared to the rest of the country. VHI values below 40 show vegetation stress which is indicative of drought conditions, values below 20 indicate severe drought.

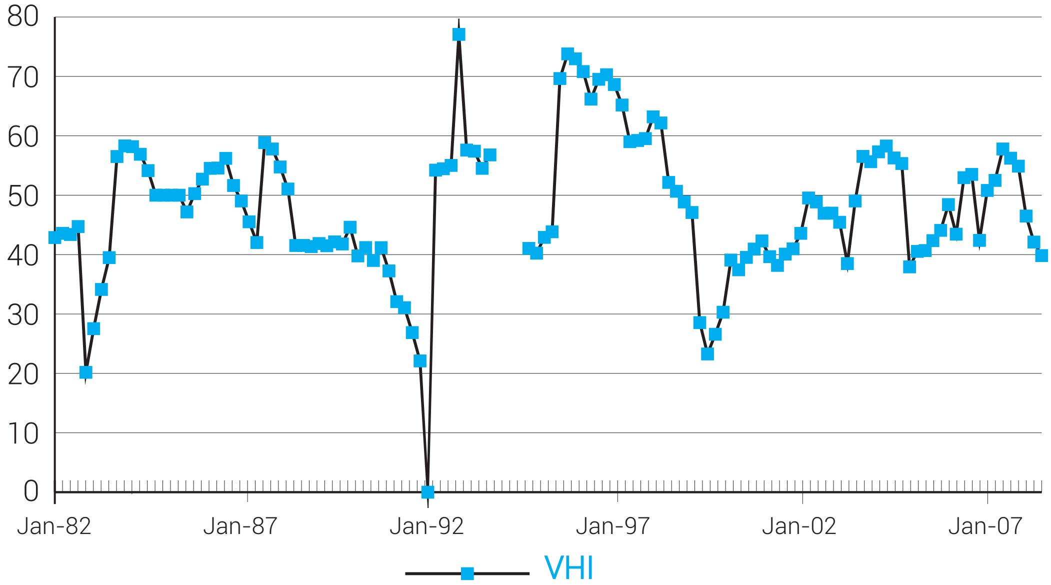
Figure 3.3 – Drought occurrences in Zone IV deduced from weekly VHI in January each year



Source: Author, based on data from NOAA STAR (n.d.).

[7] For further information on GADM database for Global Administrative Areas, please see http://www.gadm.org/

Figure 3.4 – Drought occurrences in Zone III deduced from weekly VHI in January of each year

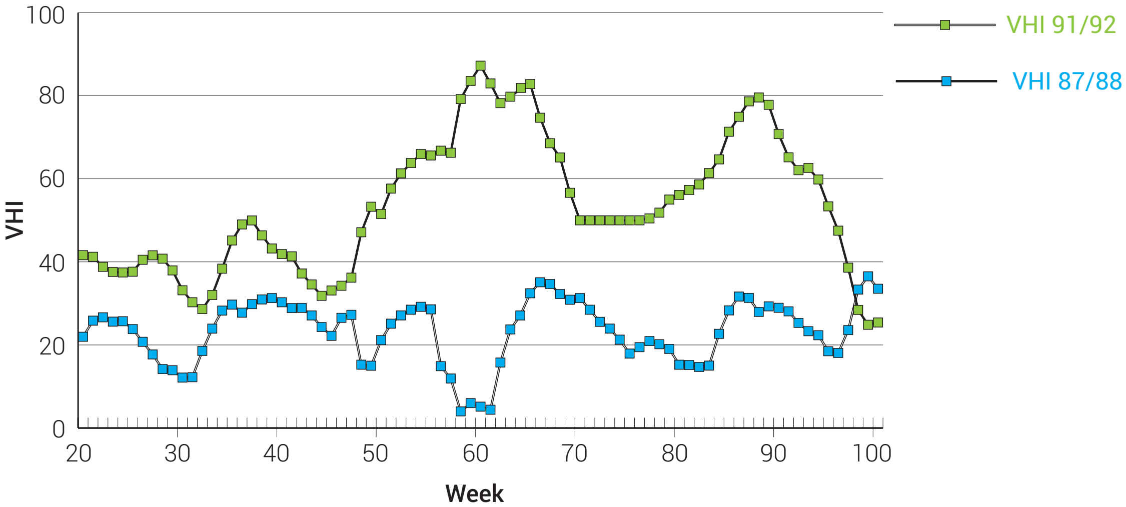


Source: Author, based on data from NOAA STAT (n.d.).

2.3.2 Comparison of VHI time series of wet and drought years

The VHI of a wet year and a drought year are compared in Figure 3.5. The rains in Zimbabwe and maize planting typically start in October (Week 42). The maize harvest begins in April of the following year (Week 68). The main growing period is between Weeks 50 (December) and 65 (March).

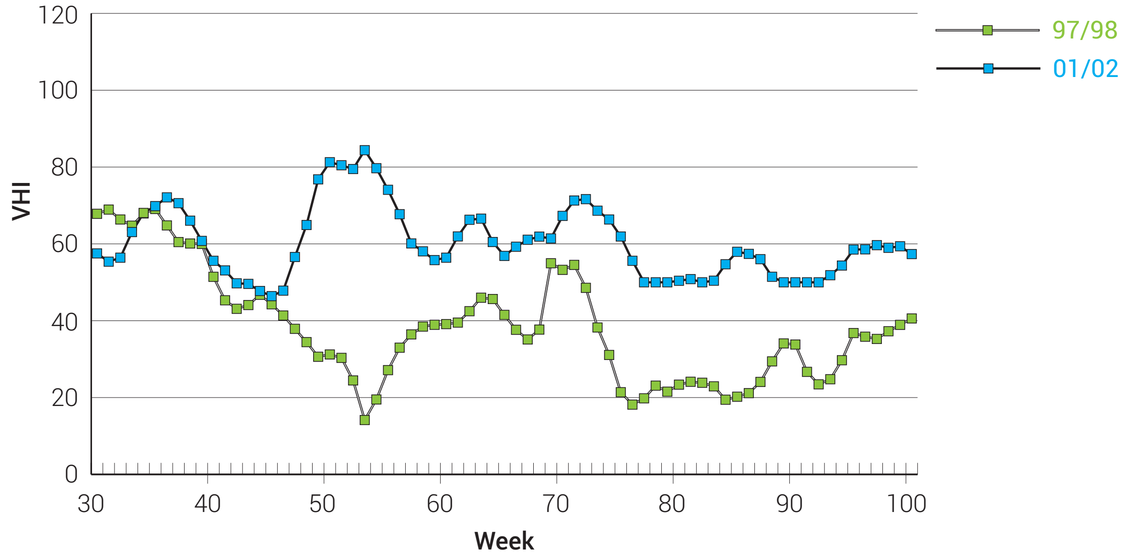
Figure 3.5 – Weekly VHI time series of a wet year (1987-1988) compared with VHI of drought year (1991-1992), Zone II



Source: Author, based on data from NOAA STAT (n.d.).

During the drought in 1991-1992, very low values of the VHI were recorded in the lead up to the rainy season. There was no quick recovery of the VHI at the start of the rainy season. By the end of January 1992 (Week 56), it was clear that crop yields would be severely affected. The same trend is observed in Zone IV when a drought year and a wet year were compared (Figure 3.6). By the end of December 2004, the declining trend of the VHI was evident and there was no recovery beyond drought conditions (VHI 40) by end of January 2005 (Week 56).

Figure 3.6 – Weekly VHI time series of a wet year (1999-2000) compared with a drought year (2004-2005), Zone IV

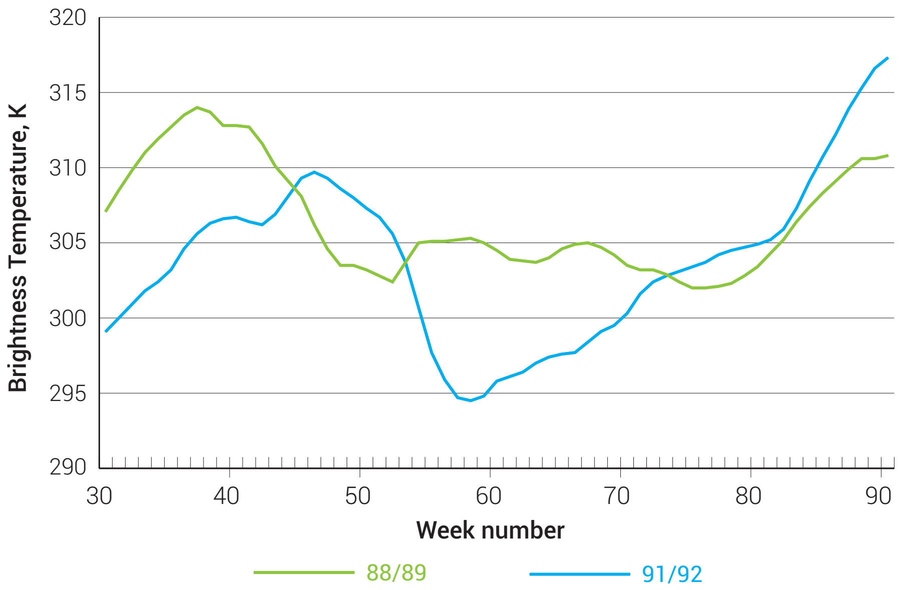


Source: Author, based on data from NOAA STAR (n.d.).

2.3.3 Brightness temperature of wet and dry years

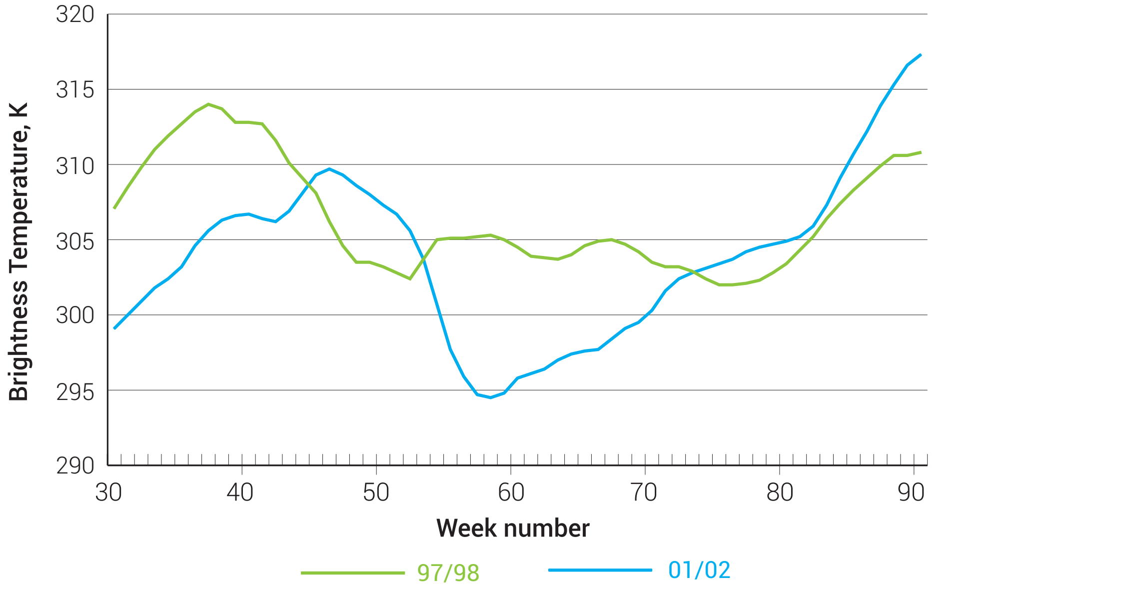
The differences between BT of drought years (red) and wet years (green) is presented in Figures 3.7 and 3.8. In all cases analysed, the brightness temperature is persistently above 300 K for the greater part of the growing season (Weeks 50 to 65) during drought years. For the few locations that were investigated, the drought years also seem to have a higher brightness temperature in the lead up to the rainy season. As early as Week 30 of the year, the brightness temperature is higher before a bad rainy season.

Figure 3.7 – Brightness temperature for a wet year (1997-1998) compared with a drought year (2001-2002), Zone II



Source: Author, based on data from NOAA STAR (n.d.).

Figure 3.8 – Brightness temperature for a wet year (1988-1989) compared with a drought year (1991-1992), Zone IV

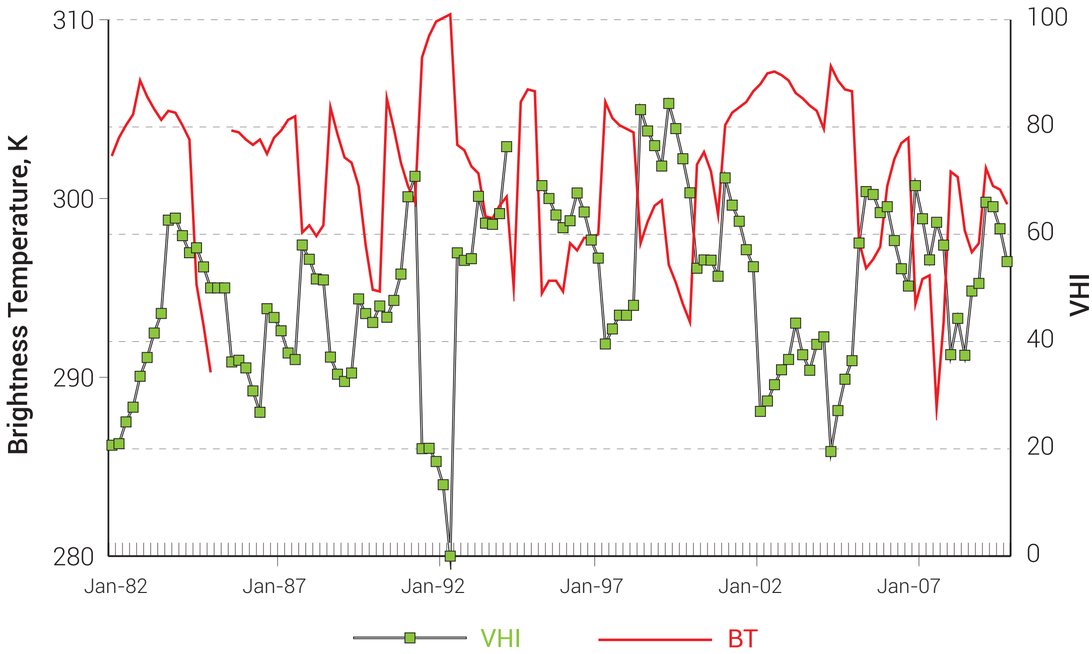


Source: Author, based on data from NOAA STAR (n.d.).

2.3.4 Vegetation health index and brightness temperature

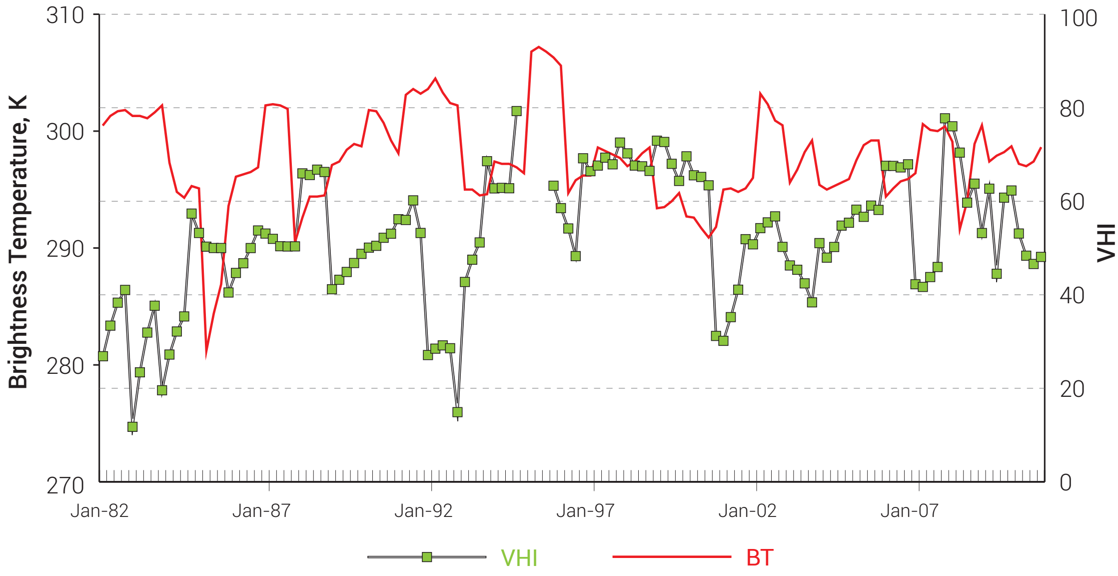
First, the correlation between low VHI and high BT in January (1982-2010) is shown in Figures 3.9 and 3.10). The BT is shown here because it has been demonstrated that droughts are more severe if low rainfall is accompanied by high temperatures (Kogan, 2002). The effects of high temperature intensify the impacts of moisture stress on vegetation. In Zone IV (Figure 9), drought events where VHI < 40 are associated with high BT values, generally above 300 K. For favourable vegetation conditions, VHI > 60, the cooling effect of evaporation is evident in the lower canopy and surface temperatures.

Figure 3.9 – Weekly VHI and BT for the month of January (1982-2010), Zone IV



Source: Author, based on data from NOAA STAR (n.d.).

Figure 3.10 – Weekly VHI and BT for the month of January, 1982-2010, Zone II



Source: Author, based on data from NOAA STAR (n.d.).

4 Limitations

The study included large-scale commercial farming areas which provided uniform land cover per pixel. This is because AVHRR data have a coarse spatial resolution (16 km). Applying this data for the analyses of smallholder farms was complicated by heterogeneity in land cover. However, the impact of drought is similar for both small and large scale farms due to heavy dependence on surface water for irrigation.

Some factors that are independent of actual vegetation cover influence the NDVI. For example, large areas of bare soil, atmospheric aerosol content, and seasonal variations in atmospheric water vapour all cause variations in the NDVI (Anyamba and Tucker, 2005). Where vegetation canopies are sparse, the NDVI is influenced by the colour of the soil. For the same partial cover canopy conditions, a brighter soil background results in a higher NDVI than a dark soil.

The interpretation of the results of this analysis would have improved significantly if they had been compared with rainfall data from the same period. This would have allowed the determination of the lag time between rainfall and NDVI peaks for the study areas. With this information, the timing of drought events could be better constrained.

5 Conclusions

Despite the coarse resolution of the images and the biased sample of areas investigated, the NOAA AVHRR drought products have provided good insights into the temporal drought characteristics of the main maize producing regions of Zimbabwe. All historical droughts in Zimbabwe were identified by the drought indices derived from NOAA AVHRR data (NOAA STAR, n.d.). The differences in drought severity and frequency in different zones of the country are well identified by the VHI product. This composite drought indicator successfully identifies mid-season dry spells in the critical months of January and February. During drought years, the BT was higher than 300 K in the rainy season, while in wet years, the BT was depressed. Of note was the elevated BT in the months before the rainy season.

Although the country has a national policy on drought management, its effectiveness is questionable judging from the lack of preparedness for drought events. The current dissemination of seasonal forecast information appears to be ineffective in minimising the impacts of drought. Recently, Zimbabwe, as part of the Southern Africa Development Community (SADC), launched an appeal for drought disaster response valued at US$2.4 billion. A regional response team to deal with the effects of the drought was established in May 2016, well after the impacts of drought had started showing in the Southern African Region (SADC, 2016).

The information source used in this case study has the potential to improve drought risk management efforts. It is clear that the severity of drought differs in parts of the country. Depending on the frequency of drought in an area and its associated risks, interventions and adaptation strategies for each area can be developed. Instead of the traditional drought management that focuses on reactive, short term drought relief, there should be proactive long term drought risk management effort.

In addition to the long range seasonal forecasts, there is need for continuous updates of drought progression. The data source used in this study can be used for near real time drought monitoring due to its weekly update of data. When regular updates show drought progression, the government can act early to minimise impacts on food security and livestock. There should be structures in place to protect livestock, a major source of livelihood for rural Zimbabweans and action must be taken well before the irreversible livestock deaths.

Groundwater has been used as a buffer to mitigate surface water shortages and sustain livestock and people in times of severe drought. However, there is very limited knowledge on the country's groundwater reserves and their capability to act as an emergency source during drought. Policy should include capacity building in the management of surface and groundwater resources of the country. To complement drought risk management efforts, it is important to have an adequate number of hydro-meteorological observation networks, as well as an effective information dissemination network.

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Persistent organic pollutants (POPs) and groundwater quality: A case study of contamination levels of POPs in groundwater within selected obsolete pesticide stores and electric power stations in Nigeria

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1 Introduction

Most of the potable water used for both domestic and industrial purposes is channelled from rivers and groundwater (Ekiye and Zejiao 2010). However, the supply of this potable water is still weak in Nigeria and most people have resorted to using groundwater from wells and boreholes, which they perceive is devoid of or have very minimal pollution and contamination. Although this perception has been buttressed by Edet et al. (2011) who did some research on groundwater quality in Nigeria, these studies excluded groundwater quality with reference to levels of organic pollutants. The present case study therefore presents the findings of analytical investigation carried out on selected groundwater sources in Nigeria which are situated close to or within vicinity of pesticide stores and electric power stations. The investigation was focused on contamination levels of persistent organic pollutants (POPs).

The case study first provides a brief background on POPs and the Stockholm Convention. The highlights and results of a study by Moma (2013) are then presented, followed by the challenges in carrying out the study. The case study concludes by recommending steps to address challenges as identified and possible next steps.

2 Project description

2.1 Background

Persistent organic pollutants (POPs) are toxic chemicals and have an adverse effect on human health and the environment (USEPA, 2002). They persist for long periods in the environment and can accumulate (bioaccumulate) and pass from one species to the next through the food chain (biomagnification) (Ritter et al., 1995). POPs are also semi-volatile, enabling them to move long distances in the atmosphere and aquatic environment before deposition occurs (Fiedler, 2007). Being semi volatile, POPs can occur in the vapour phase or absorbed by atmospheric particles, thus facilitating their long-range transport through the atmosphere (Ritter et al., 1995).

The properties of unusual persistence, when coupled with other characteristics such as semi-volatility, have resulted in the ubiquitous nature of these compounds, as they are found all over the world; even in regions where they have never been used such as the arctic region (Srogi, 2008; Fiedler, 2007; USEPA, 2002; Wania and Mackay 1996; Ritter et al., 1995). The Stockholm Convention on Persistent Organic Pollutants of May 2001, which entered into force on 17 May 2004, is an international treaty aimed at restricting and ultimately eliminating POPs production, storage, use and release (UNEP, 2001). Nigeria is a Party to the Convention and ratified it same on the 24 May 2004 (FMEnv, 2007).

POPs, as identified by the Stockholm Convention, include the following;

1. 2001 initial twelve ("dirty dozen") which are the following;
    - **Pesticides**: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, [hexachlorobenzene], mirex, toxaphene;

- **Industrial chemicals**: polychlorinated biphenyls (PCBs);
- **By-products and unintentionally produced (UPOPs)**: polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF).

2. 2009: "Nasty Nine"; which are Alpha hexachlorocyclohexane, Beta hexachlorocyclohexane, Gamma hexachlorocyclohexane (Lindane) Hexabromodiphenyl ether and Heptabromodiphenyl ether, Tetrabromodiphenyl ether and Pentabromodiphenyl ether, Chlordecone; Hexabromobiphenyl, Pentachlorobenzene; Perfluorooctane sulfonic acid, its salts and Perfluorooctane sulfonyl fluoride;
3. 2011: Technical endosulfan and its related isomers;
4. 2013: Hexabromocyclododecane with specific exemptions; and
5. 2015: Hexachlorobutadiene, pentachlorophenol and its salts and esters; and polychlorinated naphthalenes.

In Nigeria, anthropogenic activities in agriculture, industrial manufacturing, waste burning, energy production and use are identifiable sources of POPs release into the environment (IPEN, 2006). Inventory conducted by the Nigerian Ministry of Environment indicated potential for POPs contamination in farmlands, industrial soils and dumpsites (FMEnv, 2009). The inventory report also indicated that the Power Holdings Company of Nigeria (PHCN) uses a lot of POPs-containing oil coolant in the operation of electric transformers. Moreover, dumpsites are potential POPs hotspots especially in developing counties such as Nigeria (Minh et al., 2006), largely because there is little or no application of waste management technologies (Osibanjo, 2009).

Obsolete pesticides are of global concern because most of them are POPs which are banned from use under the Stockholm Convention (Haylamicheal and Dalvie, 2008). Where research has been done, it was clear that these pesticides could enter the soil and eventually contaminate ground and surface water, with consequent further toxic effects on humans, livestock and biota (Osibanjo et al., 1994;, Khwaja, 2008).

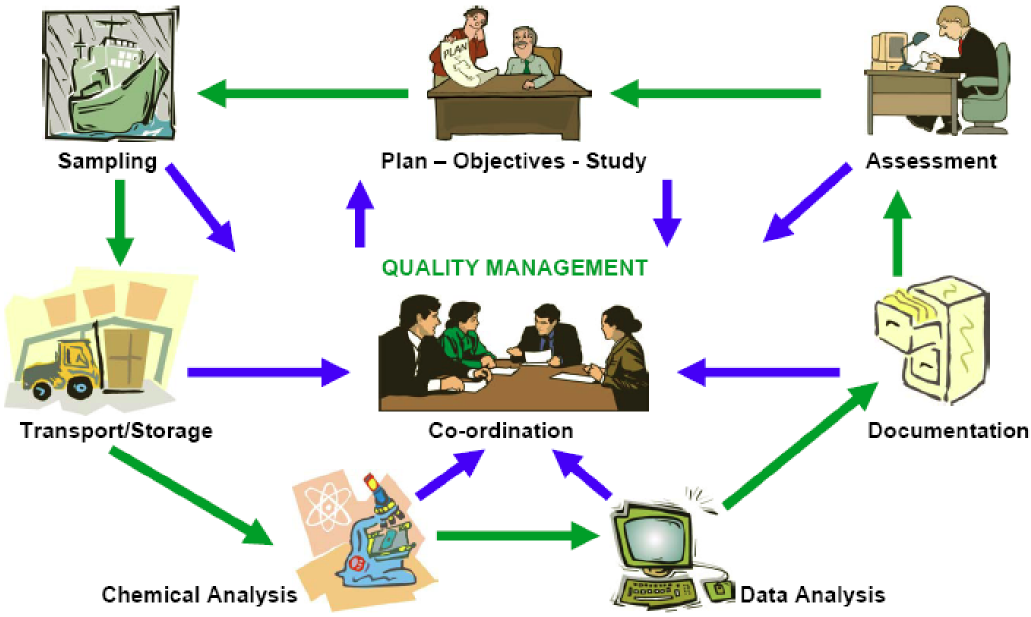
Inventories conducted in Nigeria have revealed that there were scientific research gaps in terms of assessing levels of POPs in groundwater, surface water, soil and therefore recommended analytical investigation of these environmental compartments especially those situated close to potential POPs sources in order to prioritize such sites for possible remediation in an environmentally sound manner (NES, 2006; N-ASP, 2009; FMEnv, 2007).

Accordingly, Moma (2013) conducted a research work to ascertain POPs contamination level in groundwater located near obsolete pesticide stores and electric power generation stations own by PHCN where PCB-containing transformer oil is still in use. The objectives of the research work were to:

- contribute to the Nigerian data on POPs contamination which is presently scarce;
- ascertain the effects of location of obsolete pesticide stores and electric power stations (potential POPs hotspots) on adjacent groundwater sources; and
- determine contamination levels of POPs in the groundwater sources studied.

The methodology used by Moma (2013) was in line with the UNEP's standard protocol for POPs sampling, transport, storage and analysis (UNEP, 2007). The methods conform to those used by other researchers in other countries working on POPs, including Toan et al. (2007), Jan et al., (2009), Minh et al. (2006), and Muir and Sverko (2006). The general scheme for POPs analysis is depicted in Figure 4.1.

Figure 4.1 – Schematic of standard operating procedure for POPs analysis



Source: UNEP (2007).

Groundwater sources within vicinity of selected pesticide store were studied in Lagos, Kano, Oyo and Rivers States, while groundwater source within electric power station was studied in Benue State. The pesticide store sites were selected based on the inventory of the Nigerian African Stockpile programme (N-ASP), while the electric power station was selected based on the inventory conducted by the Nigerian Federal Ministry of Environment (FMEnv, 2007). These sites are listed in Table 4.1.

Table 4.1 – Groundwater samples collected from study and control sites

Study and control sites in Lagos State (A)*					
	Sample code	Matrix	Name of site	GPS coordinates	Visual observation
1	AAIIKSTGW	Groundwater	Lagos State Agricultural Input Supply Authority (Farm Centre), Ikpara Badagary	N06.495130 E002.99774	The water looked a bit turbid
	ACTRLGW	Groundwater	NIOMR staff quarters	N06.421300 E003.412220	Control groundwater sample
Study and control sites in Oyo State (B)**					
2	BAIOYSTGW	Groundwater	Groundwater adjacent to Oyo OYSIAU Pesticide Store, Awe Oyo	N07.834400 E003.947870	The groundwater appeared clean
3	BTcScSTGW	Groundwater	Groundwater close to TCDU Pesticide Store, State Secretariat	N07.411920 E003.905850	The water appeared a little turbid
	BCTRLGW	Groundwater	Groundwater (well) at Queen Idia Hall UI. Ibadan	N07.437700 E003.895180	The water appeared clear
Study sites control sites in Benue State (C)***					
4	CYdPHGW	Groundwater	PHCN sub-station, Yandev	N07.405850 E008.988090	The water appeared clean
9	CCTRLGW	Groundwater	Open Well at North Bank, Makurdi		The water appeared very clear
Study and control sites in Kano State (D)****					
5	DKdSpStGW	Groundwater	Kadawa Seed Processing Complex, Kadawa Kano	N11.647830 E008.426800	The groundwater appeared a bit cloudy
	DCTRLGW	Groundwater	Mariri Housing Estate	N11.935280 E008.622470	The water appeared clean
Study and control sites in Rivers State (E)*****					
6	EDGDASTGW	Groundwater	Divisional Agricultural Farm, off Degema Road, Degema	N04.764540 E006.766500	Appeared clean
7	EAHDASTGW	Groundwater	Divisional Agricultural Office Ahoda	N05.071490 E006.651030	Appeared clean
10	ECTRLGW	Groundwater	School compound at old GRA, PH	N04.773370 E007.019080	The water appeared clean

* *Source: Adapted from Moma (2013, Table 3.1, p. 105).*

** *Source: Adapted from Moma (2013, Table 3.2, p. 107).*

*** *Source: Adapted from Moma (2013, Table 3.2, p. 108).*

**** *Source: Adapted from Moma (2013, Table 3.2, p. 109).*

**** *Source: Adapted from Moma (2013, Table 3.2, p. 110).*

The targets compounds which levels were determined in the work of Moma (2013) were 20 organochlorine pesticides (OCPs) (including metabolites) and 27 congeners of polychlorinated biphenyls (PCBs).

2.2 Findings

2.2.1 Groundwater within the vicinity of pesticide stores

In Lagos, for example, the range of concentration of total individual OCPs for n (n =3) samples was BDL[8] – 0.646, while the range of concentration (in mg/L) of individual OCP was BDL – 0.219, with a mean of 0.028 (see Table 4.2). The level of the individual OCPs are outlined in Table 4.3.

Table 4.2 – OCP concentrations in groundwater adjacent to LAISU pesticide store, Ikpara-Badagary, Lagos State

OCPs	Range and mean concentration (mg/L)	
	Range	Mean ± SD
α-HCH	0.018 - 0.023	0.02 ± 0.003
β-HCH	BDL	BDL
γ-HCH (Lindane)	0.211 - 0.219	0.22 ± 0.004
δ-HCH	BDL	BDL
Heptachlor	0.004 - 0.005	0.005 ± 0.001
Aldrin	BDL	BDL
Heptachlor-epoxide(B)	0.009 - 0.012	0.01 ± 0.002
cis- Chlrodane	BDL	BDL
Endosulfan I	0.007 - 0.009	0.01 ± 0.001
trans-Chlordane	0.005 - 0.008	0.01 ± 0.003
o,p' –DDE	BDL	BDL
Dieldrin	0.008 - 0.013	0.01 ± 0.003
Endrin	0.102 - 0.106	0.10 ± 0.002
Endosulfan II	0.056 - 0.063	0.06 ± 0.004
p,p" – DDD	BDL	BDL
Endrin aldehyde	BDl	BDL
Endosulfan Sulfate	0.111 - 0.118	0.12 ± 0.004
p,p'-DDT	BDL	BDL
Endrin Ketone	BDL	BDL
Methoxychlor	BDL	BDL
Indv [OCPs]*	BDL – 0.219	0.03 ± 0.056
Σindv OCPs**	BDL – 0.646	0.09 ± 0.168
T.OCPs***	0. 55	

**Indv [OCPs]:* *Concentration of individual OCP*
*** ∑indv. OCPs:* *Total of individual OCPs for the n (3) sampling points in the study site*
**** T.OCPs:* *OCP concentration of study site = Total sum of the individual OCPs*

Source: Adapted from Moma (2013, Table 3.2, p. 268).

[8] Below Detection Limits

Table 4.3 – Maximum permissible concentration/guidelines for OCPs

The maximum permissible concentration (MPC) of analysed pesticides in soil in Lithuania*		PTS guideline values for pesticide consideration in soil and water**		
OCPs	Soil (mg/kg)	OCPs	Soil (mg/kg)	Water (mg/L)
Aldrin	0.10	DDT	0.10	0.1
Chlordane	0.10	∑HCH	0.10	0.020
DDT	0.10	Heptachlor	0.05	0.001
Deildrin	0.05			
Endrin	0.10			
Heptachlor	0.05			
∑HCH	0.10			

* *Since Nigeria has not established Maximum Permissible Limits guidelines, the results of the works reported in this case study was compared with the guidelines of Lithuania.*

Source: Bagdonas et al. (2005) and UNEP (2002).

The total sum of the individual OCPs (T. OCPs) of the groundwater was 0.55 mg/L and this was seven times higher than the control. Levels of most of the OCPs detected were above the persistent toxic substances (PTS) guideline (see Table 4.3). At Oyo State Agricultural Input Supply Unit (OYAISU) pesticide store and Tree Crop Development Unit (TCDU) pesticide store (all in Oyo state), results obtained by Moma (2013) indicated POPs contamination of the groundwater within vicinity of these stores. The T. OCPs in the OYAISU and TCDU groundwater were 0.72 mg/L and 0.67 mg/L respectively which were almost 10 times higher than the [OCP] of the groundwater at the background site and therefore indicated contamination relative to the background samples. With the present level of OCPs in the water, it may be unsafe for drinking and domestic use as these levels are higher than WHO allowable limits for OCPs in drinking water. Table 4.4 compares the values of the prominent OCPs in the two groundwater sites and their corresponding WHO limits for drinking water (WHO, 2008).

In Kano state the T. OCPs of groundwater was 0.71 mg/L. This value was more than five times higher than that taken from the background site. This therefore indicated contamination relative to the background samples. Other hand, ∑HCH was 0.32 mg/L, which is 16 times higher than the WHO guideline value of 0.020mg/L (WHO, 2008).

The Rivers State Divisional Agriculture pesticide store Degema and Divisional Agriculture pesticide store Ahoda had groundwater within their vicinity. The T. OCPs of Degama and Ahoda groundwater were 0.5 mg/L and 0.41 mg/L, respectively. These OCPs were compared with that of the control and it was observed that the [OCP] of the two groundwater samples was a little over four times higher than the [OCP] of the groundwater at the background site.

Table 4.4 – Comparing WHO Limits for OCPs in drinking water with the mean concentration of OCPs in groundwater*

OCPs	Concentration in mg/L		
	Groundwater OYAISU Store Awe Road	Groundwater TCDU store Secretariat, Ibadan	WHO mean limit*
Aldrin	0.013 ± 0.003	BDL	0.00003
DDT	0.074 ± 0.003	0.104 ± 0.002	0.001
Endosulfan 1	0.024 ± 0.002	0.011 ± 0.001	0.020
Endrin	0.166 ± 0.003	0.112 ± 0.002	0.0006
Heptachlor	0.007 ± 0.002	BDL	0.00003
Heptachlor Epoxide (B)	0.034 ± 0.002	BDL	0.00003
Lindane	0.026 ± 0.001	0.125 ± 0.001	0.0002

** Undertaken in Oyo State Agricultural Input Supply Unit (OYAISU) pesticide store, Awe road Oyo and Oyo State Tree Crop Development Unit (TCDU) pesticide store, Moor Plantation. Ibadan. WHO Limits (WHO, 2008).*

Source: Moma (2013).

2.2.2 Groundwater within the vicinity of Electric Power Station

The range of concentration of total individual PCB congeners in the groundwater within the electric power station (belonging to Power Holdings Company of Nigeria) at Yandev, in Benue state was BDL-4.036 mg/L with mean concentration 0.58 mg/L. PCB 2, PCB 24, PCB 22, PCB 75, PCB 72, PCB 105, PCB 101 and PCB 153 were BDL. The contamination profile of groundwater at the study site was:

> tetrachlorobiphenyls > hexachlorobiphenyls > trichlorobiphenyls > dichlorobiphenyls > chlorobiphenyls > heptachlorobiphenyls (pentachlorbiphenyls was BDL).

On the other hand, the contamination profile of the soil was:

> pentachlorobiphenyls > heptachlorobiphenyls >tetrachlrobiphenyls > hexachlrobiphenyls > trichlrobiphenyls > dichlorobiphanyls > chlorobiphenyls.

It was reasoned that the similarity of the contamination profile of the soil and the groundwater; suggests the soil of the electric station acting as a primary PCB contamination source to the groundwater. The soil of the electric power station as observed by Moma (2013) was visibly spilt with transformer oil.

3 Discussion

The United Nations 2030 Agenda for Sustainable development and Sustainable Development Goals (SDGs) recognize the crucial role of access to water that is really safe for human uses and the urgent need to protect the quality of world's water resources in achieving many SDGs (UNGA, 2015).

The potential threat of water pollution by hazardous chemicals to human health and ecosystems is, furthermore, emphasized in other SDGs. In particular, Goals 3 and 12 stress the urgent need to significantly reduce the release of wastes and hazardous chemicals to air, water and soil to minimize their adverse impacts on human health and on the environment (UNGA, 2015). The study carried out by Moma (2013) established probably for the first time that contamination of POPs (OCPs and PCBs) occurs in groundwater within obsolete pesticide stores and electric power stations located in the selected sites of Nigeria.

Given the enormous groundwater resources of Nigeria, its population, and the present use of groundwater directly for domestic and drinking purposes, there is still a need for data and, hence the need for a coordinated monitoring which is presently very weak. A similar observation was made in a recent case study on emerging pollutants (EPs) developed by UNESCO (2016), which reported that in Nigeria, monitoring of EPs and organic pollutants in water is almost none existent.

4 Challenges, opportunities and lessons learned

The analysis of POPs in Nigeria is a real analytical challenge because there is inadequate infrastructure and human capacity. Moreover, the analytical instrumentation used in POPs analysis is very expensive like [GC-MS-MS]. Moma (2013) also observed that there is indeed very low awareness on POPs and to that end, there is a need for an elaborated awareness activity, targeted at decision-makers inside and outside the water box, on the importance of POPs and other organic pollutants with respect to water contamination.

5 Conclusion

The study has presented the contamination levels and potential sources of POPs in groundwater. Indeed, POPs present in those study sites and levels were in most cases higher than standard guideline and background levels. Challenges identified included lack of POPs standards for various media, low capacity for handling POPs analysis, low awareness and almost inexistent monitoring of POPs in water resources. In order to address the findings and observation in the study and work towards achieving SDGs, with particular reference to significantly reducing the release of wastes and hazardous chemicals to air, water and soil, the following actions are suggested:

- develop coordinated monitoring of POPs in groundwater (and other water resources) in Nigeria;
- develop a database on levels of POPs in various media;
- build and strengthen human and infrastructure capacity for the analysis of POPs and other organic pollutants, including emerging pollutants;
- as a Party to the Stockholm Convention, the country should establish POPs maximum permissible levels in various media and guidelines on POPs containing materials, i.e. spoilt transformers, and implement the polluter-pays principle;
- develop a national policy on sound management of POPs and establish a regulatory framework, including an enforcement strategy for POPs contaminated sites; and
- formulate an awareness plan for POPs for Nigeria.

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5 | ZIMBABWE

Accelerating the implementation of water-related Sustainable Development Goals in Zimbabwe

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1 Introduction

In September 2015, Heads of State and Government and distinguished representatives met at the United Nations Headquarters in New York and agreed upon the new 2030 Agenda for Sustainable Development (UNGA, 2015). The new agenda[9] with 17 goals and 169 associated targets came into effect on the 1 January 2016, and created the impetus for countries to advance policy actions critical for political, socio-economic and environment development. Zimbabwe as a member of the United Nations has adopted the global 2030 development agenda, and is expected to have already started initiating national processes and mechanisms for the implementation of these Sustainable Development Goals (SDGs). In this paper, Zimbabwe's national capacity and level of preparedness will be addressed, in terms of translating the SDGs, in particular SDG 6[10], into concrete actions for setting an enabling environment for achieving the water related goals.

2 Background

The effective implementation of sustainable development initiatives in the water sector demands multi-layered decision-making and multi-level coordination from different institutions and stakeholders- both at national and subnational levels (Steurer, 2009; Rodgers and Hall, 2003). This is often discussed in contemporary literature as water governance. The quality of governance plays a defining role in supporting the economic, social and environmental pillars of the SDGs (UNDP, 2014).

In our approach, the water governance systems in Zimbabwe will be analysed using research perspectives drawn from the water governance theory (Rodgers and Hall, 2003), OECD Multi-level Governance Framework (OECD, 2011) and the contextual interaction theory (Bressers et al., 2016). Through this, an overall picture will be presented, as well as the most relevant details to understand better the dynamic relationships between different stakeholders and the processes on which the objectives of the SDGs could be realized in the water sector (see also Pisano et al., 2014).

The current governance systems to manage water resources in Zimbabwe will be analysed, and finally, policy recommendations for accelerating a transition towards effective water governance in Zimbabwe.

3 Our approach

Now that the SDGs have been promulgated and adopted by all countries, there is a need to assess national capacities to implement these goals. Implementing the water-related SDGs will require countries to translate concrete actions on a number of water topics, such as access to drinking water and sanitation, water resources management, water quality and wastewater treatment, and water related disasters (OECD, 2015). Although we acknowledge the plurality of water management domains, this research will only focus on establishing the capacity of Zimbabwe and

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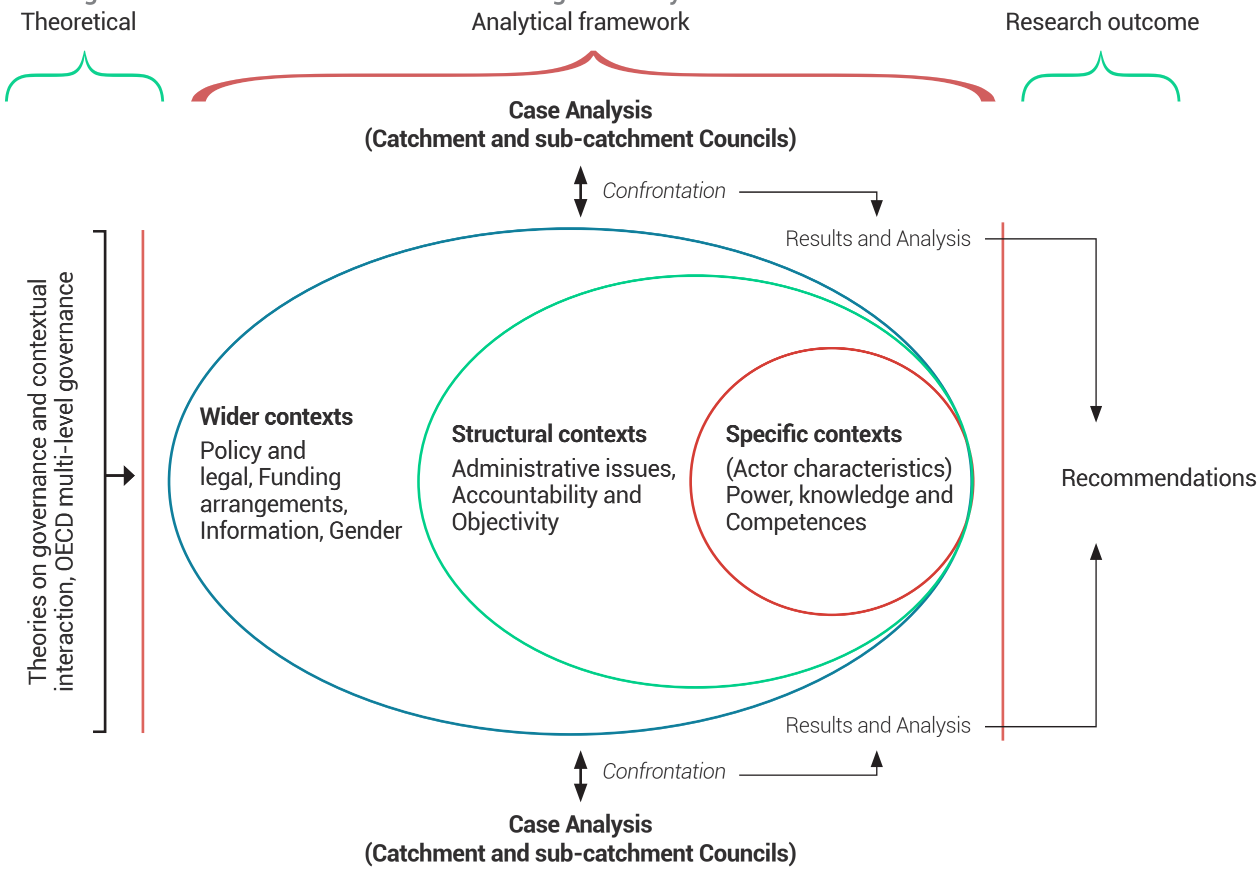
9 For more information on the 2030 Agenda for Sustainable Development, please visit sustainabledevelopment.un.org

10 SDG 6 calls for ensuring the availability and sustainable management of water and sanitation for all.

its level of preparedness in implementing the SDG 6 in the facet of water resources management. To achieve our objective, we critically examined water governance systems in Zimbabwe using an analytical model drawn from the water governance theory (Rodgers and Hall, 2003), OECD Multi-level Governance Framework[11] (OECD, 2011) and the contextual interaction theory (Bressers et al., 2016). This research was designed in such a way that analysis was done at three levels (Figure 5.1).

1. Level 1: Policy and legal arrangements, funding arrangements, information and gender aspects were assessed at catchment and sub-catchment levels. Document reviews and key informant interviews were used as methods of data collection.
2. Level 2: Administrative, accountability and objectivity issues were assessed at catchment and sub-catchment levels. Document reviews and expert interviews were used for data collection.
3. Level 3: Characteristics of the actors involved in the water sector, such as power, knowledge and competences, were assessed through expert discussions, review of policy documents and strategies.

Figure 5.1 – Research framework showing the analytical model



Source: Adapted from Bressers et al. (2016, Fig. 3.4, p. 52).

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[11] The OECD Multi-level Governance Framework is a tool for diagnosing seven key co-ordination "gaps" in the water sector, regardless of countries' institutional setting. It was originally developed for addressing the interdependencies across levels of government and it has been tested to appraise water governance challenges in 17 OECD countries (Akhmouch, 2012).

4 Results

4.1 Policy coherence and alignment

Like other African countries, Zimbabwe began the process of water sector reforms in 1995 to redress the colonial injustices in the water sector and promote efficient and sustainable management of water resources. This led to the promulgation of both the Water Act (Government of the Republic of Zimbabwe, 1998a) and the Zimbabwe National Water Authority (ZINWA) Act (Government of Republic of Zimbabwe, 1998b) in 1998. The Water Act of 1998 was meant to bring economic efficiency, environmental sustainability and equity of use in the water sector to ensure a more equitable distribution of water and ensure stakeholder involvement in the management of water resources. The ZINWA Act of 1998 led to the creation of the Zimbabwe National Water Authority (ZINWA) which is a parastatal responsible for providing coordinated framework for planning, development and management of water resources. Moreover, a policy document, "Towards Integrated Water Resources Management: Water resources strategy for Zimbabwe" was also produced, which recognized stakeholder participation as an important policy and strategy instrument.

The Environmental Management Act (Government of the Republic of Zimbabwe, 2002) is another piece of legislation that has direct implications on water resources management in Zimbabwe. Its objectives include the provision of sustainable management of natural resources, protecting the environment and prevention of pollution and environmental degradation. The Act mandates the undertaking of Environmental Impact Assessments (EIAs) before certain projects perceived to have high impacts on the environment are implemented. The government of Zimbabwe has also developed some other policy documents and economic development blueprint which have a direct and indirect implication on water resources management. These include the constitution of Zimbabwe, the National Environmental Policy and Strategies of 2009, the National Climate Change Response Strategy, the National Energy Policy of 2012, the Zimbabwe Agenda for Socio-Economic Transformation and a number of associated statutory instruments.

Current policies in Zimbabwe have been developed with much coordination across ministries, between levels of government and across local actors leading to policy coherence leading to policy coherence at central government level, which is a better condition for cross-sector coordination at sub-national level.

4.2 Stakeholder participation

Through the Water Act and the ZINWA Act both promulgated in 1998, the government of Zimbabwe managed to introduce structural changes regarding the participation and representation of water users in the management of water. The Water Act of 1998 provided a legal basis for the representation and participation of previously excluded water users, namely communal, resettlement and small-scale commercial farmers (Makurira and Mugumo, 2005). The new politics of inclusiveness and participation, at least stated formally, has fundamentally created opportunities for local level participation in water management at the sub-catchment council level. In this regard, it is foreseen that Zimbabwe will slowly shift from conventional forms of water governance, which is normally dominated by top-down approaches, towards a governance system characterised by bottom-up approaches which combine experience, knowledge and understanding of various local groups and people. The Water Act of 1998 has also paved the way for better institutional coordination to facilitate efficient water management.

4.3 Gender mainstreaming

The statistics presented at many catchment and sub-catchment councils show that women are still underrepresented in water management structures. Hence participation by women in decision making processes is still very limited (Table 5.1), in spite of their roles as significant users of water.

Table 5.1 – Participation of women in local management structures

Buhera District	Women in local water management institutions (% of total)	Women in sector position of authority (% of total)
Chipwanya (Ward 1)	21.9	7.2
Nerutanga (Ward 2)	33.3	17
Maburutse (Ward 3)	14.0	4.3
Gosho (Ward 5)	22.0	9.0
Chigavakava (Ward 17)	10.4	2.0

Source: Chifamba (2013, Table 2, p. 12).

Although, in some cases women are represented in village-level meetings, their presence is just to make up the numbers as a token gesture to gender inclusiveness (Chifamba, 2013). At public meetings, men are in most cases vocal, while women learn in silence, but things are slowly changing.

4.4 Information asymmetry

Stakeholders in the water sector in Zimbabwe consist of representatives from local authorities, industry, commercial farmers, communal farmers and other interested parties. It has been observed that the communal farmers are the weakest and most disadvantaged group since they lack precise, accurate and up to date information on water demand and availability, users registry, water permits, and on the status of networks and infrastructure. This situation has severely affected the participation of farmers in water management issues despite the creation of sub-catchment councils which were believed to involve such vulnerable user groups.

5 Challenges, opportunities and lessons learned

5.1 Institutional capacity

Key institutions for water resources management, such as the Zimbabwe National Water Authority (ZINWA), Agricultural Research and Extension Services (AREX) and the Environmental Management Agency (EMA), are not adequately staffed to respond to increasing demands for the provision of expert services. In such circumstances, these institutions do not have sufficient personnel to provide professional services, nor can they fulfil their statutory functions due to limited fiscal space to finance operations. With staffing levels inadequate and depth of expertise questionable (Gumbo, 2006), the question of whether Zimbabwe will effectively implement water related SDGs remain unanswered until radical changes are made in the way in which water resources are managed.

In the past, water resources management processes have been utterly dependent on donors (Makurira and Mugumo, 2005). But is dependence on donors sustainable? If not, what are the possible alternative funding arrangements? These are some of the transient questions which need answers if the objectives of the ambitious 2030 agenda are to be realized. Although translating global water related SDGs into concrete actions for operationalization at local level is still a challenge, there is sufficient evidence that a lot of work has been done in-terms of disseminating information through trainings on the recently launched SDGs.

Achieving our objective was challenging as the diverse set of factors that potentially influence sound water governance demands a broad overall perspective, while the ambition to develop policy recommendations requires a detailed and mechanistic understanding of the system. Although Zimbabwe has an established legal framework to support stakeholder participation at all levels, the participation and representation of water users which have been previously excluded in water management processes is fraught with problems. One major problem has been the limited fiscal space for stakeholders to travel to attend sub-catchment council meetings (Musingafi, 2013).

Stakeholder perspectives may vary remarkably depending on their perceptions and interest, hence council meetings both at catchment and sub-catchment level can take too long to be concluded. There is greater risk that if reforms that promote stakeholder involvement and participation are instituted, their effectiveness can be hindered by powerful stakeholders who may hi-jack the process with the motivation to protect their own interests. There is some risk that stakeholders may use their political positions to influence certain decisions which may in-turn impede the participation process. In this regard, political influence should always be kept at minimum levels.

Three ministries[12] have developed policies upon which hold effective stakeholder dialogue, better vertical and horizontal sharing of information amongst stakeholders, conflict resolution at a range of different scales and planning procedures to ensure better and efficient management of water resources in Zimbabwe. Water management committees have been set up at catchment and sub-catchment levels, which involve representatives from relevant ministries and other stakeholders.

6 Conclusions

Despite undertaking some reforms that promote mainstreaming of principles which foster effective governance in the water sector, its practice at the local level is still lagging behind. The findings have shown that the process has not yet led to the full participation of all the stakeholders, even fully addressing the issues of gender in water resources management. Although Zimbabwe has created mechanisms for effective stakeholder participation under the theory of decentralization through the creation of catchment and sub-catchment councils, a phenomenon described as "distributed governance" (Batchelor, 2007) we learn that this does not always guarantee participation from all stakeholder groups. Moreover, without sound technical and financial support coupled with reduced political interference from other politically inclined stakeholder groups, accelerating the implementation of water related SDGs could be difficult.

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6 | GHANA

Exploring solutions to resolve extreme water conditions in Ghana

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1 Introduction

In Ghana, frequent floods, droughts and water scarcity in some regions is an issue. The inability of institutions to mandated to predict accurately the impact of climate variability imposes large economic costs such as, such as: high importation of food leading to weak currency, money spent on rebuilding of affected infrastructure such as broken dams, washed or eroded dug-outs, electricity transmission lines, etc.

This paper is based on some actions taken on extreme water conditions in Ghana and addresses the measures for adaptation, such as advocacy for infrastructure development for annual and multi-year flow regulation on floods and droughts, multi-purpose storage facilities, water quality and basin protection.

2 Project description

Natural disasters that are considered to be severe and sometimes extreme have occurred in Ghana. These include frequent floods and drought and its attendants impacts including damage to properties and lives, crops and animals and economic cost to restore most of the properties. Managing such extremities is a challenge in Ghana.

On the other side, experts are grappling with ways and means to contain floods in order to save lives and property during rainy seasons. Over the past decade, beginning in 1995, floods have claimed several lives and destroyed public infrastructure and private properties (Asumadu-Sarkodie et al., 2015). Table 6.1 shows how natural events, including floods and droughts in Ghana affect lives and infrastructure (buildings, roads and farms).

Table 6.1 – Overview of natural disasters in Ghana from 1900-2014

Type of natural disaster	Events	No. of deaths	Total affected	Damage (in US$)
(in US$)	3	0	12 512 000	100 000
Flood	18	415	3 885 695	108 200 000
Epidemic	19	875	33 799	-
Earthquake	1	17	-	-

Source: Guha-Sapir et al. (n.d.).

2.1 Proposed solutions to extreme water conditions

The following are some of the proposed engineering solutions to solve extreme water conditions in the country. There may be other solutions which may not necessarily be engineering, such as land use controls, advocacy, attitudinal change on waste management, etc.

2.1.1 Adjustments of building codes

As part of controlling the water stress that mounts on many homes and facilities in Ghana, especially in Accra, the government through the association of engineers should make it mandatory to include water storage facilities and rain harvesting structures, underground tanks, wells and dug-outs for the storage of water in every household. This can be done by adjusting the existing building codes to contain such clauses. Furthermore, people must not be allowed to build in waterways and on wetlands or dump refuse into such places.

2.1.2 Expansion of water treatment companies in Ghana

There is a water deficit in terms of supply in the country. Water deficit in Accra stands at 57 million gallons (GWCL, 2015). The gap between demand and supply of water, as well as between consumption and potentially available safe water resources, is expected to widen with potential threat to government's sustainable efforts in addressing the threat. It is estimated that 33 % of Ghanaians use groundwater and 80.3 % of the urban population as well as 18.8 % of rural dwellers had access to potable water supply. The effective access to potable water is 72 % or less (GWCL, 2015). To bridge the gap, Ghana Water Company and other water treatment companies should be equipped by government to invest in desalination of sea water. Even though this process is expensive, water from this process can be channelled to factories.

2.1.3 Extraction of underground water

Groundwater makes up 20% of the world freshwater extraction (WMO, 1997). This makes it an important resource that can serve as natural buffer against shortages of surface water during times of drought. The rate of groundwater extraction increased significantly in the later part of the twentieth century in most semi-arid or arid countries. In some cases, uncontrolled groundwater extraction has depleted some aquifers and also land subsidence, interference with streams, surface water bodies, and ecological impacts on wetlands or riparian forests (Llamas, 2001).

Accra should engage in more extraction of groundwater especially during times of drought to increase water availability in the country. However, the disadvantage of this method of adaptation is that a little overdraft of the groundwater can result in land subsidence and differential settlements of soils resulting in damage to roads and infrastructures. Groundwater also recharges wells, rivers and lakes therefore a significant decrease of the water table as a result of over-extraction can cause loss of yield of water from existing wells and drying out of some rivers.

The issues about groundwater overdraft can, nonetheless, be dealt with when a regulatory agency is put in place to monitor both the extraction and recharge of the groundwater system especially by mineral water producers.

2.1.4 Sub-surface and covered drains

Every year from June to July, during the raining season, many Ghanaians lose their precious lives and properties because of floods. Children stay out of school because classrooms and even churches are not spared by the floods. Many public and private properties are destroyed. A choked drain (see photos) is one of the main causes of flooding in the country but has not been given the needed attention. Flooding during the rainy season has therefore become a cyclic cataclysm especially in Accra. The majority of drains in Accra are not covered and therefore highly exposed to misuse by individuals and industries who dispose all manner of solid and liquid waste into them. Some residents of the city indiscriminately pollute drains and choke them with filth. A walk through some principal streets of Accra during day and night reveals numerous food vendors who use drains (gutters) as refuse dump and drop virtually anything they create as waste into them. This inappropriate act causes the city's drainage system to be choked and emit unpleasant stench.

Sub-surface drains should be designed and the uncovered drains covered for certain parts of the city to prevent this misuse of the drains as dumping sites. This will ease the flow of water during rainy seasons thus preventing flooding.

Chokked drains in Accra

Source: Author (2016).

2.1.5 Enlargement of drains on new catchment distributions

Most drains of the city have been blocked based on old water catchment distributions which have changed due to high infrastructural changes, for example increase in real estates in the city. There is the need to reconstruct drains based on the new volumes of runoff. Some of the drains are too shallow and not big enough to contain the volume of the water that flows through them during the rainy season. This limitation of the city's drainage system causes water to overflow onto the streets destroying them and in some cases carry vehicles and their unfortunate occupants away.

2.1.6 Systematic de-silting/dredging and maintenance of dams, drains and waterways

Siltation of many dams, drains, culverts and waterways is another cause of flooding in the city; silt is deposited during floods through water ways and drains. The desilting of these drains, culvert and waterways are supposed to be done yearly, whereas dams may be desilted- after every 30 years or more. However, this is not really adhered to and the accumulated silt becomes significant enough to impede smooth flows. During heavy rainfall, the incoming rainwater has no option but to overflow the drains and end up in people's homes and offices and the devastating effects cannot be underestimated. Routine removal of silt from the drains especially during raining seasons will curtail the water overflowing the drains and hence flooding.

2.1.7 Flow regulations

Many people take advantage of non-perennial rivers and other water bodies which flow seasonally to develop such lands by putting up buildings and other structures in waterways and considering them as dry grounds, only for the rains to come and the river bodies bounce back to life again. Some even use them as dumping sites with the erroneous idea that the rivers carry the waste into the sea during flooding. Instead, this practice causes eutrophication and in extreme cases pollution, thus and killing fauna in water bodies especially during raining season. Flow regulations should be developed to prevent people from building on waterways and dumping rubbish in water bodies during both drought and rainy seasons.

2.2 Challenges, opportunities and lessons learned

In addition, the following the challenges are associated with the suggested methods of controlling extreme water conditions of drought:

Subsidence: Over extraction of underground water can cause land subsidence and even cause collapse of buildings when there is differential settlement as a result of over mining of underground water.

Education of the public on the effect of over exploitations of groundwater: Adjustment of building codes requires major education of stakeholders in the building and construction sector. This sometimes poses a challenge since conventional methods of construction and design will change.

3 Recommendations and conclusions

Government through the Water Resources Commission should embark on more advocacy to address some of these challenges. However, more effort needs to be put in place to enforce all the laws on the environment. There should also be more education through media, either print or electronic, on some of the solutions that address extreme water conditions in Ghana. Achieving adaptation to extreme conditions of water is possible. Government needs to change its attitude towards how issues concerning water are managed. We, as a people, need to change our attitudes in order to reduce the extreme water conditions in Ghana. We need to believe that we can and we must act now.

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7 | UGANDA

Towards gender equality in decision-making in the WASH sector in Uganda

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1 Introduction

According to recent statistics, access to efficient water supplies in rural and urban areas of Uganda has experienced significant improvement over the years (UBOS, 2012). There are considerable efforts towards improving water quality, water-use efficiency and access to safe, affordable drinking water across the country through projects and other development initiatives. However, the water and sanitation sub-sector still faces challenges, such as increasing population growth and the resulting need for new safe water sources, relatively low prioritization of sanitation and hygiene, and poor protection of water sources resulting in decreasing water quality.

Climate change, a major concern for the global community, has led to extreme conditions such as frequent floods and prolonged droughts with impacts such as water stress and food insecurity. The Uganda National Climate Change Policy highlights an average temperature increase of 0.37°C per decade and increased variability of rainfall, with current records showing an increase of approximately 1,500 mm of precipitation during the December to January rainy season for Eastern Uganda (MWE, 2015).

Although these changes are predicted to adversely affect water resources and water-dependent sectors in Ugandan economy, such as agriculture and energy, they are already being felt in extensive parts of the country (MWE, 2015), and have brought about economic and employment challenges (WWAP, 2016).

Good governance and specifically-inclusive participation in decision-making, as illustrated in Figure 1, remains a key tool for addressing water, sanitation and hygiene (WASH) challenge. However, women are still underrepresented in decision-making spaces, compared to their male counterparts, including in the water and environment sector in Uganda. This has been attributed to culture, attitudes and a largely patriarchal society, including differences in gender roles and responsibilities (Muheebwa et al., 2015). The implications are that women's practical and strategic needs for water and sanitation development are not being adequately met. Hence, this paper addresses the gender gaps in Uganda through an analysis of public participation practices in WASH-related decision-making and planning.

1.1 Methodology

The methodology used was a review of relevant documentation and literature, observations and key informant interviews. Overall the paper addresses water governance in Uganda and draws from the ongoing study by the Association of Uganda Professional Women in Agriculture and Environment (AUPWAE), entitled 'Analysis of public participation practices for environmental decision-making in Uganda'.

1.2 Key policy and legislative framework

Key policy and legislative framework currently in place that provide for gender mainstreaming in the water and sanitation sub-sector in Uganda include:

- Constitution of Uganda, 1995 – prescribes for gender balance, fair representation of marginalised groups and affirmative action in favour of women (Constitutional Assembly, 1995);
- Uganda Local Government Act, 1997 –contains a provision for increased women representation at local government level and for Local Councils to have 30% women representation;
- Uganda National Water Policy, 1999 – prescribes for full participation of men and women in the sector (MWLE, 1999);

- Uganda's Ministry of Water and Environment- Water Sector Gender Strategies (WSGS): I (2003-2008), II (2010-2015) – supports gender mainstreaming for the water and sanitation Sub-Sector (MWE, 2010);
- Uganda National Environmental Health Policy, 2005 – makes mandatory districts to establish active District Water and Sanitation Coordination Committees (Ministry of Health, 2005);
- Uganda Gender Policy, 2007 – I calls for gender equality and women's empowerment (MGLSD, 2007);
- Uganda National Health Policy, 2010 – encourages government to work with all health stakeholders including NGOs and traditional practitioners (Ministry of Health, 2010);
- National Development Plan II, 2015 (2015/2016-2019/2020) – provides support for participation of local communities for improving water and sanitation management (NPA, 2015); and
- The Ngor Declaration on Sanitation and Hygiene adopted at the African Conference on Sanitation and Hygiene in 2015 – calls for strong leadership and coordination at all levels to build and sustain governance for sanitation and hygiene across various sectors including water (AfricaSan, 2015).

At the international level, the United Nations Sustainable Development Goals calls for women's full and effective participation and equal opportunities for leadership at all levels of decision-making and strengthening of participation of local communities in improving water and sanitation management (UNGA, 2015).

The SDGs and all applicable targets have been integrated into Uganda's National Development Plan II and are to be translated into all appropriate sector and Local Government Plans for implementation (UNDP/NGO Forum, 2015).

2 Engaging communities in planning and decision-making

AUPWAE project seeks to promote public participation in decision-making for the water and environment sector through knowledge sharing and capacity building (see photos). Participation of women is particularly important due to their underrepresentation in decision-making platforms, including WASH. In Uganda, WASH issues affect men and women differently. For instance women and girls are the major water collectors, users and managers in homes, including promoting household and community sanitation activities, and yet they largely bear the impact of inadequate, deficient or inappropriate water and sanitation services (MWE, 2010). In Northern Uganda and other semi-arid districts, women and children have to travel long distances to collect water (MWE, 2010). Therefore, addressing gender gaps in the participation processes for WASH in Uganda is important for effective and efficient governance practices in the sector.

Public participation in decision-making as a tool for good governance

Source: Author.

Effective participation is characterized by three interrelated elements: i) access to information which allows for informed public opinion; ii) direct engagement which gives the public a chance to influence policy; and iii) oversight which allows the public to assess the implemented policies (Transparency International, 2011). The Aarhus Convention and its protocol are open for global accession to empower people with rights to access information and participate effectively in decision-making in environmental matters and opportunity to seek justice (UNECE, 1998).

For participation in the WASH sub-sector in Uganda to be successful, gender sensitivity in information flows and availability of engagement spaces should be prioritised, including monitoring of WASH activities. Some of the existing platforms for participation in decision-making for WASH in Uganda are:

- Water Source Committees or Water User Committees;
- Water Supply and Sanitation Boards;
- Uganda's Ministry of Water and Environment's committees and working groups approach which aim to deliver effective services delivery; and
- Parliament of Uganda's WASH forum.

It should be noted that the Water User Committees encourage full participation of both women and men (UWASNET, 2015), and all committees are required to have at least one woman holding a key position, thereby promoting women participation. Data from 30 district reports and 4,597 water sources for the financial year 2011-12 showed that 82% of these committees had at least one woman holding a key position (UBOS, 2012). However, women's influence in the water committees, specifically in making decisions such as location of water facilities, is still constrained due of women's socio-economic standing in society, where, for example, women do not own land and their views are generally not taken into consideration. Additionally, women's work burden particularly in rural areas limits their effective participation (MWE, 2010).

2.1 Uganda Parliamentary Forum on Water, Sanitation and Hygiene

The Uganda Parliamentary Forum on Water, Sanitation and Hygiene (UPF-WASH) was formed as a result of research carried out on the role of parliament in ensuring public access to clean water, sanitation and hygiene (Water Aid, 2011). UPF-WASH is non-partisan and provides the opportunity for over 80 current male and female Members of Parliament to form a consensus and collaborate on raising awareness and advocating for WASH.

The legislators sit on different Parliamentary Committees and come together to learn about WASH and then call on the government to take necessary actions to make WASH a political and financial priority. The forum which seeks to influence WASH policy and legislation in Uganda from an informed perspective is a platform where politicians, technocrats, civil society and the private sector can exchange information, knowledge and expertise on water, sanitation and hygiene.

Opportunities for addressing gender-related WASH issues through the Parliamentary forum are available through, for example, sharing of research findings by NGOs working on the ground in communities. In addition, the Parliamentarians engage in WASH-related monitoring where they engage with the public on water and sanitation issues affecting their communities.

2.1.1 Monitoring and sensitization

UPF-WASH's activity on monitoring and sensitization involves conducting field visits at district and sub-regional level (UPF-WASH, 2015), which are important spaces for the public to participate and interact with the policy-makers. During these visits, structured meetings are carried out where the Members of Parliament hold consultations with local leaders and community members on WASH issues. Both the men and women in the community have the opportunity to engage with the legislators and participate in airing their water-related concerns, initiatives, challenges and solutions.

Field visits for UPF-WASH's monitoring and sensitization exercises in 2014 took place in several districts, where consultations were conducted with local leaders, district leaders and community members, among others. Issues that came up included limited access to clean water and pollution of water sources, and accounting for water-borne diseases such as typhoid. In Nebbi district, for example, communities expressed appreciation of the government and NGO-initiated WASH interventions that led to reduction in unsafe water-related diseases. And in the case of Bududa district, the area was experiencing water stress due to occurrence of landslides and resultant water contamination.

Challenges documented during the visits included few functioning boreholes due to lack of maintenance at community level and the burden on women and children who are the primary water collectors in both rural and urban areas of Uganda. A number of districts had water scarcity issues which led to people buying water at relatively high costs; and there were also scenarios where district officials advocated for prioritization of water tanks for the elderly and disabled persons in the community. Overall there were gaps on awareness of roles and responsibilities for WASH initiatives such as misconceptions that deterred people from contributing to related operation and maintenance activities.

2.1.2 NGO collaboration

NGOs, such as Water Aid and Uganda Water and Sanitation NGO Network (UWASNET),[13] continue to share research findings on WASH together with the parliamentarians on UPF-WASH. UWASNET members consist of organizations working with communities across different parts of the country, including those representing women and other marginalised groups. Legislators are adequately equipped with researched information for engagement and debates during parliamentary sessions. UWASNET and the Civil Society Budget Advocacy Group (CSBAG)[14] have also, in recent times, shared experiences with UPF-WASH on development of a pro-poor national and gender-sensitive budget.

2.2 Challenges, opportunities and lessons learned

One of the significant challenges that came up in a number of the districts visited, including Nebbi was the wide perception among both men and women in communities that WASH issues were the government's responsibility and hence few functioning boreholes were reported in the district due to low operation and maintenance of these facilities. Low numbers of skilled WASH personnel in health centres and water departments were also reported in districts such as Zombo and yet trained staff are important in sensitizing communities on water, sanitation and hygiene issues. Sensitization is therefore important in addressing these challenges so that ownership can be taken-up by locals and increased involvement in operation, maintenance and general management of WASH facilities including related decision-making can be realised. The Government, through the Ministry of Water and Environment needs to prioritize and increase funding towards raising awareness of WASH.

The UPF-WASH has, nevertheless, continued to provide opportunities for NGOs and other civil society organizations, including those representing women's interests, to share their research findings for strengthening WASH policy and legislation. For example, legislators, using informed positions, were able to advocate for toilets in all households and public settings such as schools, including passing a motion on provision of emergency pads for menstrual hygiene management for girls in schools. (Parliament of Uganda, 2014).

Although female MPs are fewer than their male counterparts, the current chairperson of the forum is female, which further strengthens the advancement of women participation in WASH related decision-making in Uganda.

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13 For more information on UWASNET, please visit http://www.uwasnet.org/Elgg/

14 For more information on CSBAG, please visit http://csbag.org/

2.2.1 Lessons learnt from activities of the Uganda Parliamentary Forum on WASH

- The importance of decision-making from informed perspectives – hence stakeholders should share knowledge and research findings on the impact of WASH developments that impact on both men and women; and
- The need for local leaders to sensitize men, women and youth so as to strengthen ownership of WASH initiatives at community level.

2.2.2 Opportunities highlighted as a result of the Parliamentary forum's activities are

- Communities should lobby their local district leaders and participate in passing local by-laws for issues such as open defecation which is common along shores in fish landing site districts; and
- Shared decision-making should be encouraged at all levels for WASH

2.2.3 Emerging issues

- Need for training and personnel at district level: Opportunities exist for the government and NGOs like UWASNET, including AUPWAE to train both men and women leaders with necessary WASH skills to improve participation in decision-making;
- Insufficient gender data for WASH: The Ngor Declaration on Sanitation and Hygiene (2015) (AfricaSan, 2015) calls for the establishment of government-led monitoring, reporting, evaluation, learning and review systems. Sufficient data is required for gender mainstreaming at all levels; and
- Appropriate technology for WASH: Gender and technology issues need to be taken into consideration in WASH planning, such as the ability of women to access and use water-related technology. As cited in Ghana's Community Participation Strategy 2012 (MWRWH/MLGRD, 2012), designs of infrastructure should be gender and disability sensitive.

3 Conclusion

Uganda's approach for affirmative action is an excellent initiative in addressing the cultural and historic gender bias that exists. It provides opportunities for inclusive public engagement in the WASH sector, although more can still be done to bridge existing gaps and promote gender equality in decision-making. Some of the recommendations for the way forward include ensuring, the government's commitment to gender policy implementation at all levels; promoting informed and inclusive decision-making for both men and women through knowledge sharing on water, sanitation and hygiene; and building the capacity of local governments and communities to collectively engage in participatory monitoring activities.

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8 | ETHIOPIA

Water quality survey on improved community supply units in the southern region of Ethiopia

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1 Introduction

Improving the access of water in terms of quantity, quality and availability improves public health and promotes socio-economic development. Yet, waterborne disease is the main cause of morbidity and mortality in developing countries (Fawell and Nieuwenhuijsen, 2003). In Ethiopia, about 60% of communicable disease is due to lack of safe and adequate water and sanitation (Admasu et al., 2004).

In developing countries, water supply systems were introduced only in those villages with easily accessible water sources (Kanmony, 2003). This can lead to the proliferation of informal vendors, with high costs, or the use of available source such as rivers, groundwater and ponds that are not always safe for consumption. In some places, drinking water may not be available near the villages. This affects particularly women and girls who have to walk long distance to fetch water for daily water need (Reimann et al., 2003), which is a reality particularly in rural areas lacking improved water sources.

Water collection from protected spring

Source: Photo taken by Tsigereda Assefa during data collection in the SNNPR (2016)

There were many challenges for girls associated with collecting water: students drop out from school to collect water for the family consumption, girls abducted during water collection and exposed for early marriage and sometimes attacked by animals.

In order to tackle those problems, the Ethiopian government has been focusing to a great extent to supply adequate and safe water by installing improved water sources. In the Southern Nations Nationalities Peoples Regional State (SNNPR) of Ethiopia, the community is using improved water sources that meet the WHO definition of improved water, such as, protected springs, deep boreholes and covered shallow wells. But, the resulting water quality is not necessarily safe from pathogenic organisms and chemicals which are harmful for human health. The quality of water can be impacted by different factors, such as, lack of proper sanitation, absence of periodic maintenance of water sources (Cronin et al., 2006), collapse of many pit latrines, reduction of the sanitation coverage by heavy rainfall thereby contaminating the water bodies (Pritchard et al., 2009). Therefore, the main objective of this paper is to assess the physico-chemical characteristics of community supply improved water sources, from boreholes, covered shallow wells and caped springs in the SNNPR.

2 Materials and methods

2.1 Study area

Ethiopia is currently divided in to nine regions and two city administrations. The SNNPR is one of the four largest regions in Ethiopia with an area of 110,932 km2. It is located in the southern and south-western part of Ethiopia and lies between 40.43-80.58 North latitude and 340.88-390.14 East longitude. It contains some of the most remote and wettest parts of Ethiopia. The rain fall intensity and duration varies in different geographical areas where it decreases from West and North-West to South-Eastwards. The mean annual rain fall data ranges from 400 mm and 2,200 mm. In this region most of the people are using improved water sources for drinking and other household purposes.

2.2 Sample collection

The study was conducted in the SNNPR from August 2013 to June 2014. Stratified random sampling method was followed to collect representative samples. Three hundred and 62 samples were randomly collected from improved water sources of which 89 from boreholes, 132 from shallow wells and 141 from protected springs (see photos of different water sources taken during sampling). The list of improved water sources was obtained from the SNNPR and Energy Bureau. A training program was performed by environmental health researchers of Ethiopian Public Health Institute to the water quality survey team about sampling and sample handling during transportation prior to sampling. Plastic bottles were used to collect water samples. For the analysis of iron, manganese, copper and lead the water samples were collected in separate acid-preserved bottles. Samples that had to be analysed in the laboratory were stored in cold boxes and transported to the Environmental Health Laboratory of Ethiopian Public Health Institute.

The photo from left top, right top and in the bottom are boreholes, protected shallow well and protected spring

Source: Photo taken by Tsigereda Assefa during data collection in the SNNPR (2014).

2.3 Laboratory analysis

The (pH),electric conductivity (EC) and turbidity were measured on site immediately after samples were collected using portable pH meter (model AD111), turbidity meter (model AL450T-IR) and conductivity Cond/TDS/Sal/Res meter (model SX713). The concentration of Chloride (Cl−) in the water sample was determined by Argentometric method. The concentration of F- was determined by Colorimetric SPADNS method based on the reaction between fluoride and zirconium dye-lake. NO3- was performed by colorimetric method and NO2, using ultraviolet spectrophotometric screening method, by using uv spectrophotemter model (SHIMADZU UV-180) respectively. For the presence of Fe, Mn, Cu, Pb in the water, samples were analysed by Atomic Absorption Spectrometer model (AAS, novAA 400P). All analyses were performed following standard method of water and waste water analysis (Eaton et al., 1995) (Table 8.1).

Table 8.1 – Physico-chemical water quality parameters in water samples

Acidity (pH),	Chloride (Cl−)	Nitrite (NO2-)	Copper (Cu)
Electric conductivity (EC)	Fluoride (F-)	Iron (Fe)	Lead (Pb)
Turbidity	Nitrate (NO3−)	Manganese (Mn)	

2.4 Challenges, opportunities and lessons learned

2.4.1 Challenges

The following are some of the challenges encountered during the study:

- Water sources from which samples were collected were not easily accessible due to remote geographical locations, mountainous topography, flooding due to heavy rainfall, rough and muddy roads obstructed (see photos);
- In some places as there were no roads for driving vehicles we had to walk long distance for long hours to access the sample sites;
- In some areas, due to unavailability of petrol (fuel) it was necessary to wait hours to refill the tank;
- In some sampling areas, electric power failure disrupted pumping of samples from water sources; and
- Some improved water sources were non-functional and others dried out during sampling time. As a result we had to change sampling sites intern took longer time to find the substitute source. All these situations have delayed completion date of the study project.

The situation of the roads during sampling time

Source: Photos taken by Tsigereda Assefa during data collection in the SNNPR (2014).

2.4.2 Opportunities

We were allowed to present the finding of the study to local authorities therefore they become well aware about the status of the quality of the water sources. They understand that they need to protect water sources from contaminations, such as allocation of resources for continuous water quality monitoring, fencing to prevent access of animals in to the vicinity of water sources, assigning guards, development and maintenance of water sources.

2.4.3 Lessons learned

The study team has learned that future similar study projects planning phase should consider the weather condition of geographical regions to be included in the scope of the study and the composition of the study team in terms of knowledge and local languages to ensure effective communications.

3 Results and discussion

The minimum, maximum and median values of physico-chemical characteristics of water samples collected from 362 improved water sources in the Southern Nations Nationalities People's Region of Ethiopia are presented in Table 8.2. The analysis result of samples for the different water source types borehole, shallow well and spring are presented Tables 8.3, 8.4 and 8.5, respectively. The results of the analysis were compared with the World Health Organization (WHO) guideline values (WHO, 2004). Some parameters such as pH, electric conductivity, turbidity, iron, manganese, and cupper have no health based guidelines available; however, non-health based guidelines are incorporated in the table because the presence of excess contaminants indicates the pollution status of the water.

Table 8.2 – Physico-chemical parameters from the total 362 water samples

Parameters	Unit	Minimum	Maximum	Median	WHO Guidelines	Percentage of samples exceed WHO guidelines
PH	-	5.1	9.5	6.7	6.5-8.0	32.6
Turbidity	NTU	BDL	290.0	0.9	5.0	17.1
EC	µS/cm	4.2	1 580.0	213.0	-	34.8
Cl-	mg/L	BDL	299.9	3.0	250.0	0.3
F-	mg/L	BDL	7.2	0.5	1.5	10.8
NO2-	mg/L	BDL	4.8	0.1	0.3	1.9
NO3-	mg/L	BDL	236.3	2.3	50.0	1.4
Fe	mg/L	BDL	29.6	1.6	0.3	89.8
Mn	µg/l	BDL	1 101.0	0.5	400.0	1.1
Cu	µg/l	BDL	2 617.0	0.1	2 000.0	0.3
Pb	µg/l	BDL	553.0	0.8	10.0	13.8

BDL: Below the detection limit

Source: Compiled by Tsigereda Assefa based on the data collected in SNNPR (2016).

3.1 pH, turbidity and electric conductivity

One hundred eighteen samples (32.6%) of the total samples had pH levels outside the range of the guideline value. From these results, the highest proportion of water points, 112 samples (30.9%) exhibited acidic property below pH 6.5 and six (1.7%) above pH8. According to the WHO Guidelines for Drinking Water Quality (WHO, 2004), the pH of drinking water must lie between 6.5 and 8.0. The pH value for different water sources indicated that 15.7% boreholes, 26.5% shallow wells and 48.9% springs are outside the guideline limit. From the different water source types, there is a significant association ($p < 0.001$) between the water source type and pH of the water sample. Some researchers indicated that lower pH of groundwater may be due to the presence of granite-based rocks with low buffering capacity in the water table (Rossiter et al., 2010). Others argued that the concentration of oxygen in the groundwater is very low. The reduction of organic compound may take place and this can lead to the saturation of carbon dioxide in the water source, which is responsible for the low pH of the water. With a low pH, water can be corrosive and cause damage to water pipes (Hoko, 2005).

The values of turbidity in all water technology groups ranged from below detection limit to highest 290 nephelometric turbidity unit (NTU). Sixty-two (17.1%) of the water samples exceeded the WHO guidelines (WHO, 2004) value for turbidity (5 NTU), which was generally higher in shallow wells. Even though there is no health-based guideline value for turbidity, the presence of turbidity in water supports pathogenic microorganisms to grow in the water system. It also makes the disinfection process ineffective and exerts a high disinfection chemical demand (Pritchardet al., 2009).

The electric conductivity of water samples showed with a minimum 4.2 to a maximum value of 1580 μS/cm. Electric conductivity has no health based guideline value. The presence of high electric conductivity is responsible for the conductivity nature of water and is an excellent indicator for the presence of total dissolved solids that give the taste of water (Memon, 2011; Werkneh et al., 2015). In a study of drinking water quality performed by Hoko, (2005) in Mwenezi districts Zimbabwe, the perception of high objectionable taste was observed in areas having highest electric conductivity in the water.

Table 8.3 – Physico-chemical parameters 89 water samples taken from boreholes

Parameters	Unit	Minimum	Maximum	Median	WHO Guidelines	Percentage of samples exceed WHO guidelines
PH	-	5.50	9.40	7.40	6.5-8.0	15.7
Turbidity	NTU	BDL	210.00	0.61	5.0	10.1
EC	μS/cm	5.70	1 580.00	294.00	-	49.4
Cl-	mg/L	BDL	59.98	2.00	250.0	0.0
F-	mg/L	BDL	5.71	0.74	1.50	21.3
NO2-	mg/L	BDL	1.90	0.01	0.3	2.2
NO3-	mg/L	BDL	31.58	1.01	50.0	0.0
Fe	mg/L	BDL	16.43	1.24	0.30	86.5
Mn	μg/l	BDL	508.00	0.50	400.0	1.1
Cu	μg/l	BDL	346.00	0.17	2 000.0	0.0
Pb	μg/l	BDL	475.30	0.72	10.0	7.8

BDL: Below the detection limit

Source: Compiled by Tsigereda Assefa based on the date collected in SNNPR (2016).

Table 8.4 – Physico-chemical parameters 132 water samples taken from shallow wells

Parameters	Unit	Minimum	Maximum	Median	WHO Guidelines	Percentage of samples exceed WHO guidelines
PH	-	5.1	8.5	7.0	6.5-8.0	26.5
Turbidity	NTU	BDL	290.0	1.0	5	22.2
EC	µS/cm	4.2	1 511.0	287.0	-	49.2
Cl-	mg/L	BDL	299.9	4.6	250	0.8
F-	mg/L	BDL	7.2	0.6	1.5	12.9
NO2-	mg/L	BDL	4.8	0.0	0.3	1.5
NO3-	mg/L	BDL	80.3	1.1	50	2.3
Fe	mg/L	BDL	29.6	2.0	0.3	91.7
Mn	µg/L	BDL	1 101.0	0.5	400	2.3
Cu	µg/L	BDL	2 617.0	0.1	2 000	0.8
Pb	µg/L	BDL	477.6	0.7	10	15.2

BDL: Below the detection limit

Source: Compiled by Tsigereda Assefa based on the date collected in SNNPR (2016).

Table 8.5 – Physico-chemical parameters from 141 water samples taken from springs

Parameters	Unit	Minimum	Maximum	Median	WHO Guidelines	Percentage of samples exceed WHO guidelines
PH	-	5.27	7.8	6.53	6.5-8.0	48.9
Turbidity	NTU	BDL	147.00	0.89	5	17.00
EC	µS/cm	18.30	1 545.00	120.50	300	12.10
Cl-	mg/L	BDL	84.97	3.00	250	0.00
F-	mg/L	BDL	2.95	0.33	1.5	2.10
NO2-	mg/L	BDL	0.60	0.00	0.3	0.70
NO3-	mg/L	BDL	236.30	3.61	50	2.80
FE	mg/L	BDL	7.61	1.54	0.3	90.10
Mn	µg/l	BDL	108.55	0.41	400	0.00
Cu	µg/l	BDL	839.70	0.20	2 000	0.00
Pb	µg/l	BDL	665.60	0.87	10	16.30

BDL: Below the detection limit

Source: Compiled by Tsigereda Assefa based on the date collected in SNNPR (2016).

3.2 Fluoride and chloride

Thirty nine (10.83%) water points exhibited higher fluoride concentration than WHO guideline value (1.5 mg/l) (WHO, 2004). The higher concentration detected was 7.7 mg/L. Generally from the three different water technology types 21.3%, from borehole samples, 12.9% from shallow wells and 2.1% from springs had elevated concentration of fluoride than the guideline limit. The water sample obtained from well waters (boreholes and shallow wells) is significantly ($P < 0.001$) associated with higher fluoride concentration. From the analysis result high fluoride concentration in groundwater in the Southern region of Ethiopia is in agreement with previous study performed by (Alemu et al., 2015) on fluoride distribution in Ethiopian drinking water sources. The average concentration of fluoride was 4.9 mg/l with a maximum value of 24 mg/l (WHO, 2004). Many studies showed that high concentration of fluoride from 11 to 20 mg/l was found in groundwater in Ethiopia especially in the rift valley area (Rango et al., 2009; Reimann et al., 2003). High intake of fluoride can lead to dental and skeletal fluorosis (Rango et al., 2009). The presence of a higher concentration of fluoride in the groundwater is related to leaching of fluoride bearing rocks (Moghaddam and Fijani, 2008).

The chloride content of almost all samples were found to be less than the minimum allowable limit of drinking water (250 mg/L) only one sample (0.3%) of the water had high concentration. High concentration of chloride in drinking water is an indicator of the contamination of water with the residual chlorine found in urine (Ramirez et al., 2010). Chloride is corrosive and responsible for the salty taste of water (Rossiter et al., 2010). The concentration chloride taken from the three water technology types shown to be within the allowable limit of drinking water (250 mg/L) issued by WHO guidelines (WHO, 2004).

3.3 Nitrite and nitrate

The nitrite and nitrate concentration in water ranged from below the detection limit of the instrument to a maximum 4.8 mg/l and 236.3 mg/l respectively. For nitrite, five (1.4%) of the total samples were out of the recommended limited (0.3 mg/l) and for nitrate, seven (1.9%) of the samples were beyond the recommended limit (50 mg/l) (WHO, 2004). The highest concentration of nitrite, 4.8 mg/l, was observed from shallow wells. Boreholes and springs also had higher concentration of 1.9 and 0.6 mg/L nitrite. The assessment revealed that no elevated amount of nitrate contaminations was found in boreholes. Whereas, three (2.3%) shallow wells and four (2.8%) spring points had a nitrate concentration of above the standard limits, with the high concentration of nitrate 80.3 and 236.3 mg/l respectively.

The high level of nitrate observed in this study could be a result of contamination from agricultural runoff, human and animal waste, and leaching near pit latrines (Mekonnen et al., 2014). During the sampling undertaken in the water sources, the sanitary condition of the water sources was weak. Residents in the water sampling area are engaged in agriculture including animal farming; animals have easy access to the vicinity of the water sources, where contamination can be very apparent. Nitrate and nitrite are believed to be noncumulative toxin chemicals for human beings; however, higher concentrations of nitrate could pose health problem to infants for the occurrence of methmoglobinemia or blue-baby syndrome (Nkansah et al., 2010). It must also be noted that nitrite has to be taken into account, since it is about 10 times as potent a methaemoglobinaemic agent as nitrate (British Medical Bulletin, 2003).

3.4 Iron, manganese, copper and lead

High concentrations of Iron (Fe) above the WHO guideline value (0.3mg/l) (WHO, 2004) were found in the samples with a maximum level of 29.64mg/l. Some 325 (89.8%) of the total samples do not comply with the guideline value. Iron is the common constituent of groundwater resulted from water and Iron bearing rock interaction (Sorlini, et al, 2013). It has an essential role in our body as a constituent of enzymes (Vuori, 1995). Even though iron is not considered as health concern, elevated concentrations above the guideline value may create objectionable impression due to aesthetic reason of coloured and metallic taste. Water system piping and fixtures could also become obstructed (Krachler and Shotyk, 2009; Vuori, 1995; Ramola and Singh, 2013; Sarin et al., 2004).

The presence of manganese above the recommended level has a similar effect as iron. In particular, black deposits in laundry equipment show the presence of high manganese in water. Moreover, 1.15% of the samples were found to contain manganese (Mn) concentration above the permissible limit (400 μg/l) (WHO, 2004).

The permissible limit of copper (Cu) in drinking water is 2000 μg/l (WHO, 2004); however, only one sample from shallow well (0.3 %) of the sample found to be above the permissible limit 2617.0 μg/l. High concentration of copper in drinking water can cause mental disease such as Alzheimer's (Muhammad et al., 2014). Copper in a drinking water supply typically arises from the corrosion of pipes when the water pH is less than 7 (Chakrabarty and Sarma, 2011).

Lead (Pb) level was higher in some samples with a maximum concentration of 665.6 μg/l. Fifty (13.8%) samples shown to have higher amount of lead than the WHO guideline value (10 μg/l) (WHO, 2004). The samples from each technology types have a very high concentration of lead 475.3, 477.6 and 665.6 μg/l for borehole, shallow well and spring water sources, respectively. Initially, lead accumulates in agricultural soils from application of agrochemicals that contain toxic metals and leached to water sources during rainy season. Lead is one of the most known toxic and carcinogenic metals that may cause chronic health risks, if it is absorbed in elevated amounts (Muhammad et al., 2011).

4 Conclusion

Water quality assessment surveys on 362 improved water sources on 11 water quality parameters were conducted, analysed and evaluated by comparing with the requirements of WHO guidelines (WHO, 2004). The assessment results revealed that:

- 13.8% of the water sources were found to contain excessive lead (Pb);
- 10.8% of the water sources were found to contain excessive fluoride (F-);
- 89.8% of the water sources were found to contain excessive iron (Fe);
- 1.4 and 1.9% of the water sources were found to contain excess nitrates(NO3-) and nitrites (NO2-).

Based on the assessment summarized above it can be concluded that the improved water sources covered by the scope of the study were found to have poor quality for drinking purposes. Using this water for drinking in its present form without adequate treatment may have significant health risk to the consumers.

5 Recommendation

To rehabilitate the water sources and insure the supply of safe and adequate water to the community of the Southern Nations Nationalities Peoples Region of Ethiopia, the following recommendations have been proposed:

1. Ensure appropriate site selection of water sources in order to prevent the water from natural and anthropogenic contaminants;
2. Construction and maintenance of water sources should be with durable materials, regular maintenance of the water schemes, and ensure adequate fencing to prevent accessing of domestic and wild animals;
3. Training of the community on water source management at planned intervals.

4. Cost effective and available household water treatment technology will be vital for the communities;
5. In order to avoid dalliance of tests on samples and enhance the reliability of test reports strengthen testing laboratories at regional level.
6. Establish national water surveillance and monitoring system and centralized water quality database to verify that the water being supplied to the consumer remains to be safe and adequate; and
7. Establish "Water Fund" in order to allocate adequate fund for the supply of safe and adequate water in rural areas.

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9 | CAMEROON

Community–led total sanitation as one of the best strategy to achieve sustainable development goal in sanitation in low-income communities

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1 Introduction

Cameroon is located on the Atlantic coast in central Africa between latitude 2° and 13° North (Figure 9.1). Its rate growing population is around 2.6% per year. It has 208 km3 of renewable water resources and only 1 km3 is used for drinking water. Its huge and diversified water resource potential places Cameroon at the second potential water resources in Africa after the Democratic Republic of Congo (Freie Universität Berlin, n.d.).

In 2011, it was estimated that 30% of about 20 million of Cameroon's total population had access to an improved sanitation facility and about 47% have a rudimentary traditional sanitation, among them 7% had no option other than open defecation (INS, 2011). While the rate (83.2%) of access to improved sanitation facilities is relatively high in the cities of Yaoundé and Douala, it is much less in secondary cities (78%) and rural areas (33.4%) (INS, 2011). Between 2002 and 2012, epidemiological surveillance of cholera has reported 46,416 cases with 1,861 deaths (WHO, n.d.). Aware of the challenges, Cameroon aims to increase the rate of access to basic sanitation facilities from 15% to 60% by 2020, through the construction of 1.2 million latrines (MINEPAT, 2010).

The concept of community-led total sanitation (CLTS) was launched in the Eastern region of Cameroon in March 2009) by the Minister of Water Resources and Energy. The government, with the financial and technical support of UNICEF, has expanded and promoted the approach mainly in four out of 10 regions (East, Adamawa, North and Far North). The CLTS's approach promotes the construction of latrines by community members without any financial support. The government has adopted the CLTS approach and included it in its strategic documents as the strategy paper for growth and employment (MINEPAT, 2010) and the national sewerage strategy (MINEE, 2011).

Figure 9.1 – Map of Cameroon

Source: UN (2015, Map no. 4227 rev. 2 http://www.un.org/Depts/Cartographic/map/profile/cameroon.pdf).

The implementation of CLTS activities since 2009 shows that about 38,500 latrines were built by 678 communities without any financial support from government (estimation by authors based on internal documents). Given that the national sewerage strategy recommends that the government allow subsidies of CFA 95,000 (US$190) per simple pit latrine constructed by households in rural areas (MINEE, 2011), it meant that the construction of the latrines allowed the government an additional savings of more than CFA 3.6 billion (US$7.2 million) during this period.

This amount, if it were mobilized, could have been invested in other sectors such as the sanitation sector. Thus, by contributing in achieving results in sanitation while allowing government to save money, CLTS appears as a best strategy compare to the other subsidy strategies.

This paper aims to demonstrate how Cameroon is committed to the challenge of increasing access to basic sanitation for low-income communities.

2 Project description

The methodology is based on data gathered from all stakeholders involved in the implementation of the CLTS approach in four concerned regions. The regions involved are Adamaoua East , Far North and North regions. The costs invested by households are deducted based on the average cost of building a household latrine. The fraction of the alleged "subsidies" suggested in the national sewerage strategy is then evaluated to determine the induced financial gain of the contribution of low-income populations in the state budget. In rural areas, a simple pit type Sanplat[15] average price is CFA 110,000 (US$220) and the government is supposed to allow subsidies of CFA 95,000 (US$190) to each household to construct its pit latrine (MINEE, 2011). Once it is subsidized, the cost of simple pit latrine represents 10% of average monthly household expenditures (MINEE, 2011).

In addition of the construction of household latrine, CLTS has facilitated hygiene promotion through installation of handwashing devices (see photo). The device cited is made up of rudimentary equipment, including a container, a weir and a pedal board connected to the can by a simple rope. For washing hands, the user of the latrine stomps the pedal which allows the container to pour its contents on his hands and the waste water is conducted in the rudimentary weir. When the user lifts the foot, container regains its stable equilibrium position.

Innovative handwashing device

Photo: F. Mbida. (2015).*

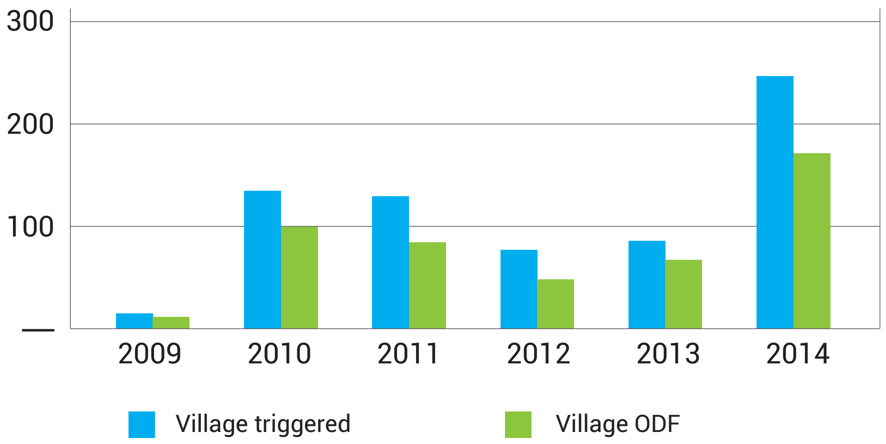
[15] SanPlat is the abbreviation of Sanitary Platform, which is the common name given to the simple pit latrine covered by slab with 60 cm x 1 m size. It use locations for feet and it makes cleaning easier.
* All photos in this case study were taken by F. Mbida during CLTS survey 2015 in the east region of Cameroon.

2.1 Development

The intervention approach consists of identifying villages with low and less than 50% access to basic sanitation services. After being identified, facilitators mobilize communities using different tools around sanitation and hygiene issues. The potential facilitators presented by local civil societies or local government staff involved in the implementation of CLTS approach are then invited to attend a workshop with a view to acquiring required skills. After the workshop, potential facilitators are evaluated during 'triggering' exercises which lead to the selection of competent facilitators.

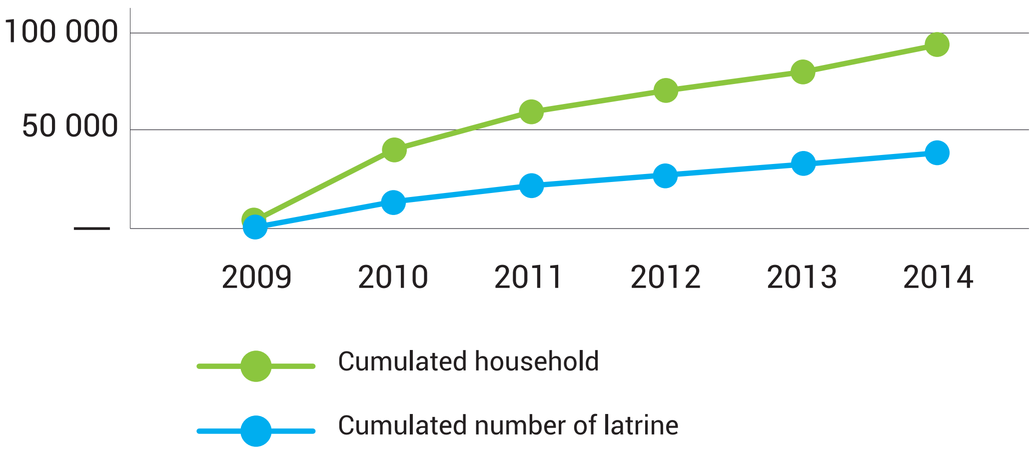
Figure 9.2 shows the number of 'triggered' villages versus the number of villages which reached the open defecation status. Figure 9.3 shows the evolution of latrines constructed by household without any subsidies from government or partners. The type of latrines built by households are shown in the photo below.

Figure 9.2 – Situation of 'triggered' village per year



Source: MINEE/MINSANTE/UNICEF (2015).

Figure 9.3 – Evolution of construction of latrine by household



Source: MINEE/MINSANTE/UNICEF Cameroon (2015).

Latrine built by a household without subsidies

Photo: F. Mbida. (2015).

The implementation of CLTS activities since 2013 shows that about 38,500 latrines have been built in 678 communities.[16] Each household fully financed the latrine construction using mostly local material.

2.2 Challenges, opportunities and lessons learned

2.2.1 The current challenges in the implementation of CLTS are political, strategic and operational:

- Political: The budget of CLTS in the Public Investment Budget mainly financed through a donor.
- Strategic: The integration of CLTS in municipal development plans and its implementation by municipalities.
- Operational: The sustainability of villages, which will put an end to open defecation.

2.2.2 Opportunities

Pressure from international commitments, particularly the Sustainable Development Goals (SDGs), which include the issue of open defecation[17] is positive, insofar as the government engages itself to meet the targets for sanitation and therefore will mobilize the necessary resources, including mobilization of technical and financial partners to achieve related goals.

The government's **commitment regarding the decentralization** implies the accountability of sanitation to Decentralisation Local Authorities (DLA) so that they can take ownership of CLTS in their respective municipalities. The low cost of CLTS approach will facilitate its implementation and boost results as far as concern access to basic sanitation is concerned. The availability of a national strategy and a methodological guide on CLTS represents a great opportunity to involve more partners in the implementation of the approach. In the context of decentralization, the guide will be also be useful to DLA, NGOs and other relevant ministries as partners in the implementation of CLTS.

- Support for traditional and potential technical and financial partners (UNICEF, ADB, World Bank, EU, etc.) in the implementation of CLTS is a great opportunity for the country. With the adoption of SDG 6 which has a focus on ending open defecation, technical and financial partners will invest in addressing issues. As CLTS has given results, those who have not yet supported this approach should invest in it. For other partners, such as UNICEF, it may increase its support.

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16 Estimation by authors based on internal documents.

17 SDG 6 – Target 6: Ensure availability and sustainable management of water and sanitation for all (UNGA, 2015).

- The implementation of the sanitation market is an opportunity to improve sanitation and make it a promising sector and mobilizing resources. This could also help boost the local economy.
- The involvement of teachers and primary school students, through their participation in outreach activities conducted in the various localities and the lessons on hygiene are elements that will contribute to the achievement of the end of open defecation (ODF) and enhance the sustainability of state interventions.

2.2.3 Lessons learned

This experience shows that considerable efforts are needed to achieve acceptable levels of sanitation.

To fill existing gaps, a scale-up is required and a national strategy accompanied by a methodological guide are being drafted and implemented in 2016. To maintain the end of ODF, it would be better to lay down the implementation of a mechanism for monitoring communities after the celebration of the end of ODF and the need to promote local materials in the construction of improved latrines. These mechanisms will help government to save more than CFA 3.6 billion (US$7.2 billion) required for subsidies.

3 Conclusions

Access to basic sanitation remains an issue in Cameroon. One of strategies adopted by the government to address the issue in low incomes community is CLTS. The implementation of this approach in Cameroon has enabled to country to increase the access to basic sanitation for this vulnerable population while saving money. Thus, the government should then invest further in CLTS, which appears as a best strategy to achieve sustainable development goal in sanitation.

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11 | SUDAN

Strategy to operationalize transboundary water quality monitoring station – The case of the Blue Nile River

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1 Introduction

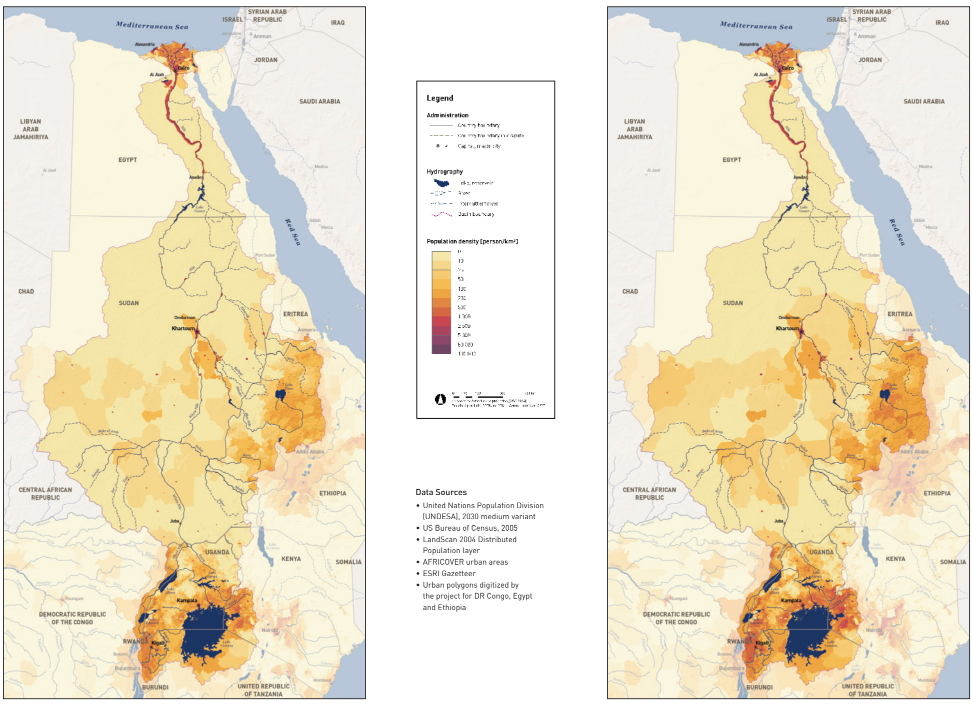
The Nile Basin covers an area of about three million km2, with a population that is estimated to reach 654 million in 2030 from 372 million in 2005 (FAO, 2011) (Figure 11.1). More than half of the total population currently live within the basin. As a vital source for sustainable socio-economic development in most of the riparian, it is important to ensure good environmental conditions and maximize its natural resources. Accordingly, its water quality together with other environmental aspects should be monitored to determine trends and magnitude of change, which will determine the appropriate measures for management and protection. In this regard, the water quality component of the Nile Basin Initiative Shared Vision Programme (NBI SVP, 2001) aims to build capacity, confidence and enhance cooperation among Nile Basin countries, creating an environment and the required momentum for further cooperation and joint investment in the Nile Basin.

The Water Quality Baseline Report – Sudan (NTEAP, 2005) states that as population increases and water demands for industry and food production rise, there is a threat to the status quo and pollution from agro-chemical, industrial and domestic wastes will attain transboundary significance in the future. The strategy to operationalize the Nile Transboundary Water Quality Monitoring Stations (2007) describes how the water quality in the Nile River and its tributaries shall be accessed through regular transboundary water quality monitoring. Forty-four (44) geo-references and transboundary water quality monitoring stations have been agreed on and established by the Regional Water Quality Working Group (RWQWG).

Figure 11.1 – Population prospects in the Nile Basin

2005 Estimates

2030 Projections



Source: FAO (2011). ©FAO, http://www.fao.org/nr/water/faonile/.

2 Project description

2.1 Area of study

The Nile Basin in Sudan is composed of five sub-basins: the White Nile, the Sobat, the Blue Nile, the Atbara and the main Nile (Figure 11.2).

Figure 11.2 – Map of countries of the Nile River Basin

Source: World Bank Group (2000).

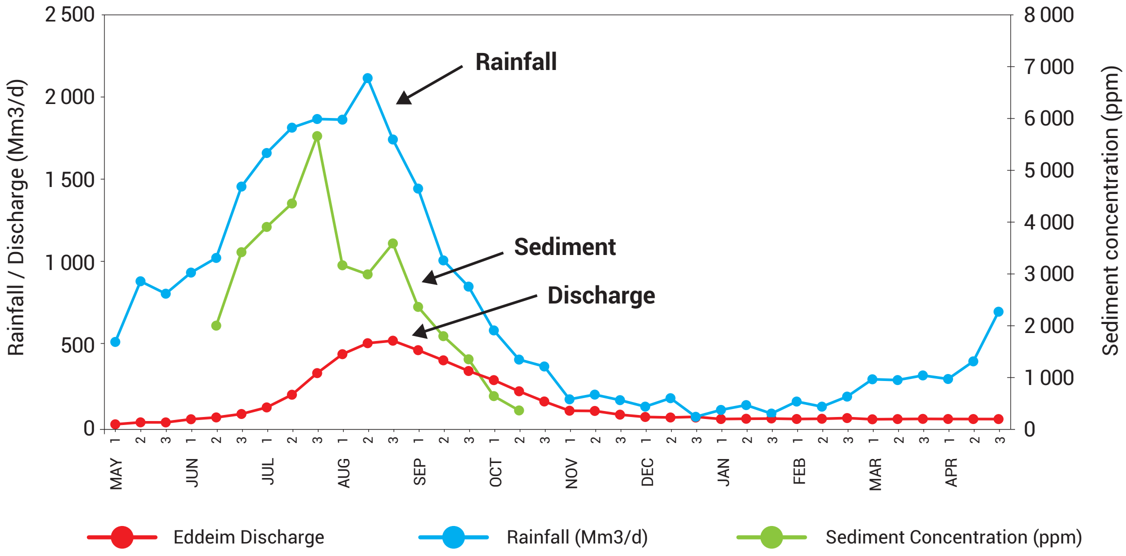
The Blue Nile has an average annual flow of 50 billion m3, with high flow variations during the year. The flow of the river rises steeply from June to August with a peak during August/September, followed by a sharp decline before it peaks again in May. The Blue Nile carries large quantities of silt as a result of its steep gradient and heavy seasonal rainfall in its upper catchments area, and transports high sediment concentrations during July and August.

The comparison between the discharge, sediment concentration and average rainfall in the eastern highlands, as well as the catchment of the river, shows that the sediment peak occurs before the peak of the flow by about two weeks. This is due to the fact that rainfall in Ethiopian highlands falls on bare lands at the beginning of the rainy season in July, and brings high sedimentation load before the maximum runoff occurs in the area. The runoff coefficient is estimated to range between 20-30% (Figure 3).

2.2 Objectives

The main objective of this study is to assess the sediment status in the Blue Nile, in particular the factors leading to sedimentation with a view to develop suggestions for its monitoring and management (Figure 11.3). The specific objectives are: i) to study the sediment threat and the role of monitoring, laboratory and information management; and ii) to provide an overview of transboundary monitoring stations of the sedimentation process in the Nile. This last objective is an important issue in the study of reservoir sedimentation, catchments erosion and river morphology information.

Figure 11.3 – Comparison of rainfall, discharge and sediment yield in the Blue Nile Basin



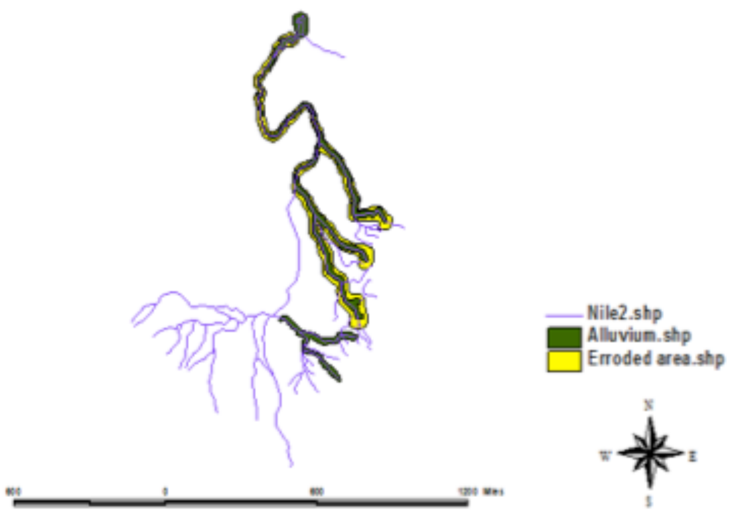
Source: Ahmed and Ismail (2008, Fig. 19, p. 31).

2.3 Justification of the sedimentation threat

The Nile River system is vulnerable to sedimentation risks from several sources (Figure 11.4). The most evident are siltation, urbanization and agricultural activities.

The monitoring of Nile's water quality was mainly focused on sediment load, which is a serious problem costing Sudan's increasing loss of strategic water storage and conveyance capacity, as well as the cost for water treatment for domestic used, and blockage of the turbines. In addition, the sedimentation process creates a bottom layer of sediment Oxygen Demand (SOD) and encourages formation of nitrogen compounds, which affects the ecology of the river, and acts as a shield for micro-organisms and toxic substances. The aquatic weeds growth is a serious problem in irrigated schemes, especially during the winter time, when the irrigated water is clean and without sediment. The growth of aquatic weeds aggravates the sedimentation rate, while the sediment depositions furnish good environment for weeds to grow.

Figure 11.4 – Erosion and sedimentation along the Blue Nile



Source: Author.

2.4 Monitoring, laboratory work and information management

Sediment monitoring is carried out by the Nile Water Directorate, assisted by the Hydraulic Research Station (HRS); which took over most of the activities as part of a programme started in 1988. Sixteen stations (Table 11.1) were established along the Nile River system to monitor the sedimentation process. Out of 16 measuring stations in the Nile River system and the irrigation canal networks, four are in the Blue Nile, namely Roseiris, Wad Elais, Sennar and Wad Medani.

Table 11.1 – Monitoring sediment of the Nile in Sudan

No.	Station	River	Starting date	Data collection	Laboratory analysis
1	Eddeim	Blue Nile	1970	Nile Water	HRS
2	Wad El-Ayes	Blue Nile	1970	Nile Water	HRS
3	D/S Sennar Dam	Blue Nile	1970	Nile Water	HRS
4	Hawata	Rahad	1991	Nile Water	HRS
5	Giwaisi	Dindir	1991	Nile Water	HRS
6	Gezira and Managel Canals		1991	HRS	HRS
7	Soba	Blue Nile	2000	Egyptian Irrigation Department	GW & Wadis + HRS
8	Khartoum	White Nile		Egyptian Irrigation Department	
9	Malakal	White Nile	2000	Egyptian Irrigation Department	GW & Wadis + HRS
10	Tamaniat	Main Nile	2000	Egyptian Irrigation Department	GW & Wadis + HRS
11	Atbara K3	Atbara River	2000	Egyptian Irrigation Department	HRS
12	Hudeiba + Hassanab	Main Nile	2000	Egyptian Irrigation Department	HRS
13	Dongola	Main Nile	2000	Egyptian Irrigation Department	GW & Wadis + HRS
14	El Karro (South Abu-Hamad)	Main Nile	1990	Nile Water	Merwi Dam Laboratory
15	Wad El Bahi	Main Nile	2004	Merwi Dam	Merwi Dam Laboratory
16	El-Bagaria	Main Nile	2004	Merwi Dam	Merwi Dam Laboratory
17	El-Jebel	Main Nile	2004	Merwi Dam	Merwi Dam Laboratory
18	El-Hosh + Abu Saleem	Main Nile	2004	Merwi Dam	Merwi Dam Laboratory
19	Gash	River Gash			HRS

Source: Based on Mona (2006).

The role of monitoring is summarized as follows:

- Strengthen national and international capacity to provide reliable information on surface water flows and the quality of waters, including sediments in the Nile River basin;
- Develop compatible information management systems for the exchange of information at the international level;
- Operationalize the transboundary stations, and operate the National Reference Laboratory Network (NRLN), with equal technical (equipment) and methodological capabilities (practices for sampling and analysing); and
- Improve the comparability of sampling techniques and laboratory analysis.

In Sudan, the selected key stations (Figure 11.5) of transboundary water quality monitoring downstream the Nile River system include:

- Eddeim on the Blue Nile (TBS[18] 1);
- Wad-el-Hiliew on Setit River (TBS 6);
- Kubur on Atbara River (TBS 5);
- Giwaisi on Dindir (TBS 3);
- Hawata on Rahad River (TBS 4);
- Hillet Dolieb on Sobat River (TBS 2); and
- Dongola on the main Nile River (TBS 7).

Figure 11.5 – Key transboundary stations along the Nile River System

Source: Author (2016).

Hydrological data

Hydrological data records started in 1920; however, most stations (see Figure 11.6) under Sudanese administration started in the 1960s. The available records are of widely varying types, ranging from fully rated stations where reliable records for many years are available or have been maintained with few or no gaps, to stations where there are no stage records but the flow values have been estimated from occasional discharge measurements.

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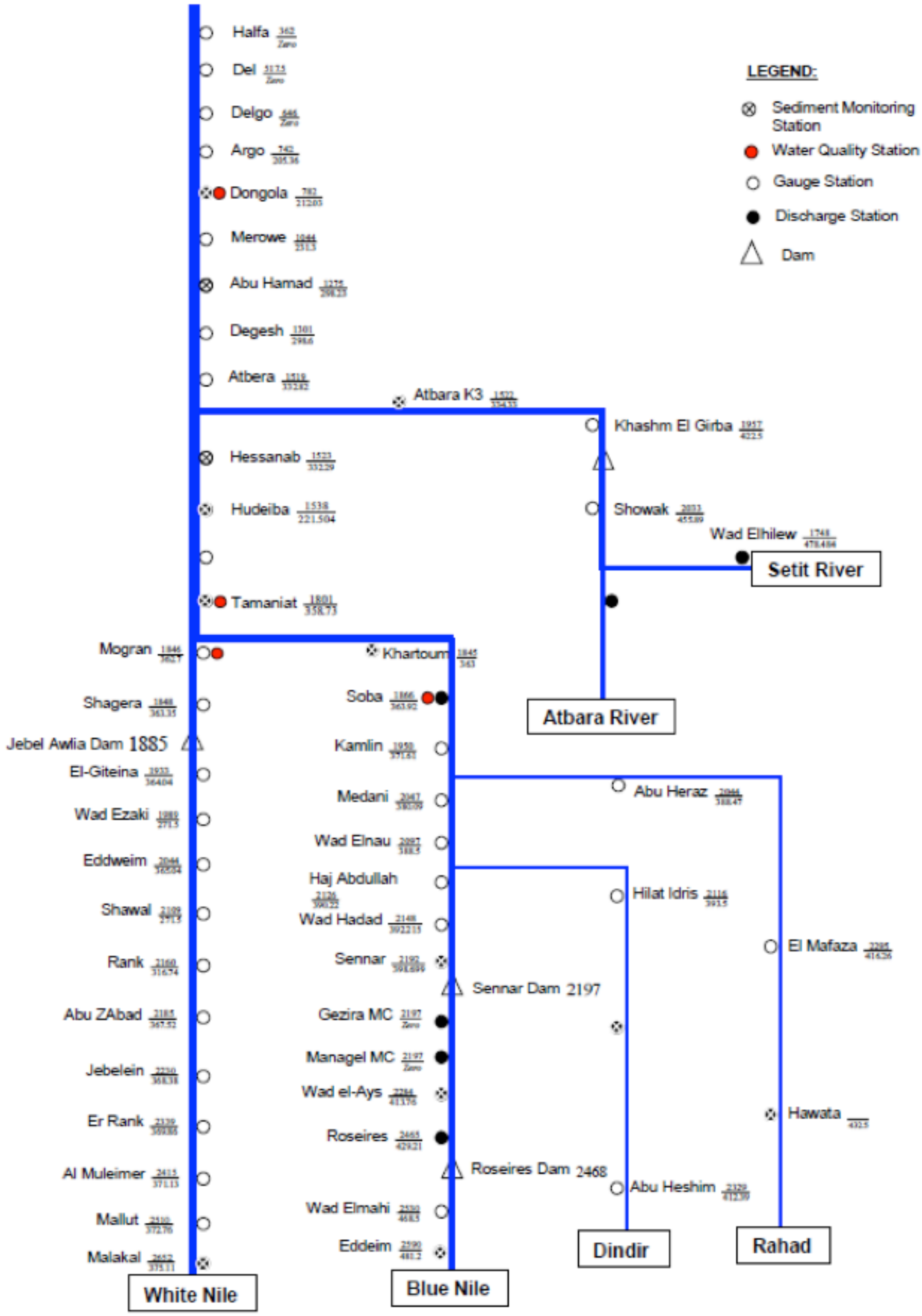
[18] TBS: Transboundary station – NS: National station – WN: xx – RN: xx

The monitoring network is comprised of more than 200 stations for gauge readings, discharge and sediment load measurements. However, most of these stations are not operating now for different reasons.

Figure 11.6 – Existing monitoring locations under by the MOIWR* on Nile River system in Sudan



*Ministry of Irrigation and Water Resources, Sudan

Note: The upper numbers indicate the measured distance between the river and nearest station, lower number indicate the measured distance between the two stations

Source: Based on Mona (2006).

3 Methodologies

This study, as well as some of the figures, is principally based on literature review and existing data from different water institution. The data for the chemical analysis was collected from laboratories and adapted accordingly. Currently, the only sediment database is established at Hydraulic Research Station (HRS) in Wad Medani. The HRS database is stored as an Excel spreadsheet consisting of long-term monitoring data on suspended load of the Nile at fixed location (Figure 6 above)

3.1 Criteria for the selection of monitoring stations

The following criteria were used to select both the general area of a water body from where samples are taken (sometimes called "macro-location") and the specific place from where the sample is taken (commonly referred to as a "sampling station"):

- Nature and types of land use activities in the upstream and downstream catchments
- Drainage pattern or characteristics
- Nature and movement patterns of sediment and pollutants
- Accessibility of station during sampling
- Importance of selected point to the surrounding community
- The total number of stations should covers the entire rivers basin
- Sampling sites and stations selected with Geo-reference position and location coordinates

3.2 Sampling strategies

To establish background levels of particulate matter composition, samples of bottom sediment were taken in the upper reaches of the river basin. The effects of tributaries on the main river should be covered by sampling tributaries close to their Junction with the main river.

The possible effects of point sources can be estimated from a sample taken from the point source (effluent or tributary), whereas the impact on the river is determined by taking samples immediately upstream and downstream of the source. These samples must be taken from the same side of the river as the effluent input, since the river flow will maintain an influx to the bank of origin for many kilometres downstream.

The impact of land-use (diffuse sources) and the influence of a city should be covered by sampling both upstream and downstream of the city or land-use area. Single bottom sediment samples are adequate provided the objective is to assess only the qualitative impact on the composition of the sediment.

3.3 Sampling

The suspended sediment concentration is sampled on a daily basis (for the period June 1988-October 1989) during the flood period. Data normally obtained in the determination of suspended-sediment discharge consists of:

- Suspended sediment mean concentration;
- Particle size;
- Specific gravity of the suspended sediment;
- Temperature of the water-sediment mixture;
- Water discharge and distribution of flow in the stream cross section;
- Settling velocity of suspended solid (SS); and
- Density measured of recently deposited sediment.

3.3.1 Types of samples used

The concentration data are usually obtained according to one of the following schemes:

1. depth-integrated samples collected at stream verticals representing areas of equal water discharge in the cross section;
2. depth-integrated samples collected at equally spaced stream verticals in the cross section; and
3. point-integrated samples collected at selected depths at stream verticals representing areas of equal water discharge

Records of sediment discharge are generally computed on a daily basis (between June and October) or on an annual basis using current metering. The method used for computing daily or annual values depends upon the data collected, the frequency of the field observations and the size of the river-bed material in transport.

The sediment grain size is determined in the laboratory using sieve analyses for D > 75 microns and hydrometric test for D < 75 microns.

3.3.2 Samplers

There are three types of samplers available:

1. Dissolved oxygen sampler, which is used to collect samples for dissolved oxygen in the river;
2. Depth integrated sampler; and
3. Multipurpose sampler.

Measured parameters include the concentration of the coarser fractions of suspended sediment increases towards the bottom of the river channel. The segregation of material by particle size requires that, for the purposes of measuring quantity of suspended sediment, a depth integrating sampling technique is used to obtain a sample that accounts for different sediment concentrations throughout the vertical profile of a water body .It is often necessary to use methods which concentrate the suspended material from a large volume of water.

The major parameters used to calculate the suspended load can be summarize as following:

1. Discharges that are computed using various methods. The standard velocity-area method is followed for flow computation. The mid-section technique is used to calculate the mean velocity and cross sectional area.
2. Water levels are read from staff gauges of standard type (masonry structure with marble scale), with a frequency varying from the daily in the dry season to two hourly during the flood peak.

Hydrological data records started in 1920; however, most stations (Figure 11.6) under the Sudanese administration started in the 1960s. The available records are of widely varying types, ranging from fully-rated stations, where reliable records for many years are available or have been maintained with few or no gaps, to stations where there are no stage records but the flow values have been estimated from occasional discharge measurements.

3.4 Sediment information

Available sediment information gathered from the Blue Nile system is summarized in Table 11.2, while Table 11.3 summarizes sediment information downstream at Dongola station.

Table 11.2 – Mean of 10 days sediment concentration for the Blue Nile at different locations

Month	Period	Eddeim transboundary station	Wad Alais national station	Sennar national station
June	II III	1 856	1 172	-
July	I II III	3 361 3 895 4 335	2 454 2 724 3 274	3 200 4 072 3 612
August	I II III	5 660 3 095 2 948	2 772 2 859 2 654	2 790 2 415 2 154
September	I II III	3 589 2 305 1 755	2 588 1 669 1 028	1 887 1 500 1 442
October	I II III	1 294 591 317	990 946 -	900 - -

Source: Author.

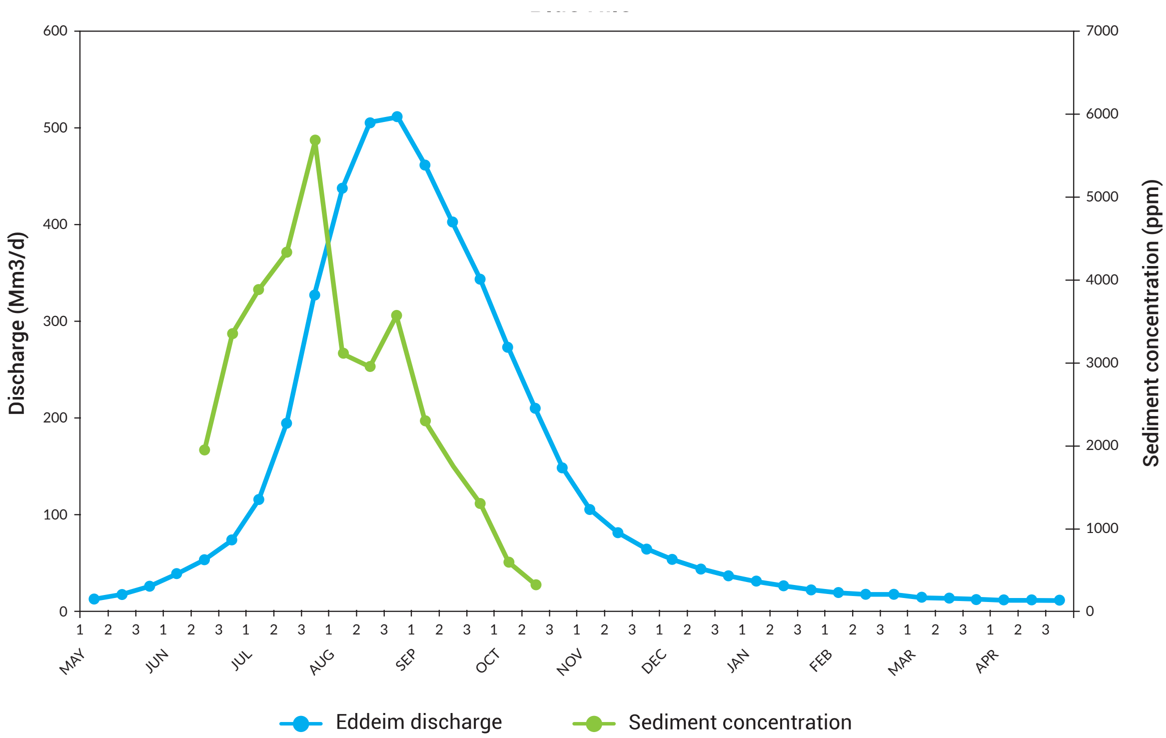
Table 11.3 – Water quality and sediment concentration for the Transboundary station (RN) on the main Nile River (Dongola station) and Blue Nile (BN) at Soba station, Khartoum State

No.	Location	Sample day/year 2012	S.S.	Turb.	TDS	E.C.	pH
1	BN	15/1	16.0	16.0	191.1	273.0	8.3
2	RN	21/1	28.0	34.0	158.2	226.0	8.3
3	BN	27/1	30.0	63.0	161.7	231.0	8.3
4	BN	19/2	24.0	35.0	204.4	276.0	8.3
5	RN	28/3	16.0	25.0	149.24	213.2	8.3
6	BN	31/3	21.0	14.0	183.4	262.0	8.3
7	BN	13/4	53.0	77.0	191.8	274.0	7.9
8	RN	18/4	5.0	19.0	165.2	236.0	7.9
9	BN	14/5	15.0	284.0	185.5	265.0	8.3
10	RN	16/5	32.0	257.0	163.8	234.0	8.3
11	RN	13/6	30.0	25.78	14.07	210.0	7.8
12	BN	15/6	34.0	31.64	156.8	224.0	8.4
13	RN	15/7	35.0	12.83	211.4	302.0	7.7
14	BN	15/7	1 862.5	902.0	196.7	281.0	7.7
15	RN	15/8	920.0	2 240.0	229.6	328.0	7.7
16	BN	26/9	2 480.0	920.0	209.3	299.0	8.3
17	RN	27/9	75.0	87.5	209.3	299.0	8.3
18	BN	14/10	720.0	198.2	161.9	230.0	8.3
19	RN	14/10	42.0	26.35	184.1	263.0	8.0
20	BN	19/11	13.0	59.0	154.7	221.0	8.1
21	BN	14/12	11.0	53.0	143.0	205.0	7.98

Notes: SS - Suspended solid; TDS -Total dissolved solid; EC - Electrical conductivity; PH - Hydrogen ion concentration; Turb. - Turbidity
Source: Author (2012), Water samples analysis was carried in GWWR Laboratory.

The sediment carried annually by the Nile River used to average 110 million tonnes as measured in Aswan. However, since the 1990s, the average increased to about 140 million tonnes (HRS, n.d.). Furthermore, according to HRS (1996), average sediment concentration is estimated at 4,000 ppm with maximum values sometimes reaching 6,000 ppm. However, during the last 10 years, the maximum sediment concentration increased to about 8,500 ppm (45% sand, 15% silt and 40% clay) (Figure 11.7).

Figure 11.7 – Sediment yield and average flow hydrograph in the Blue Nile at Eddeim Station



Source: Mona (2006).

The annual estimated sediments load in Sudan Medani is 120 million tonnes resulting in high turbidity values: maximum 7,275 (Blue Nile), 115 (White Nile) and 6,575 (Main Nile), respectively. The main sediment load contributor to the White Nile is Sobat River, while Atbara River sediments contribution to the main Nile is notable at north Atbara town.

4 Project development

4.1 Nile database

Currently, the only sediment database is established at HRS, where it is stored as an Excel spreadsheet consisting of long-term monitoring data on suspended load of the Nile at fixed locations. These data were under stringent quality assurance and quality control. Data checking takes place in many stages including laboratory data collection, data entry and statistical summary of data.

4.2 Challenges and opportunities

All sediment laboratories used to work under the Nile Water Directorate at Wad-Medani, Aljazeera State, Dongola, Roseires and Atbara. However, they have ceased working due to weak capacities to carry out analyses – the samples are currently sent to the HRS laboratories or at the Rosaries Dam laboratory, and later at GWW laboratories in Khartoum. This situation affects not only the frequency of sampling, but also the capacity of laboratories to carry out the sediment analysis due to equipment not working and dead sets. The monitoring activities are currently undertaken by HRS, in collaboration with the field staff of Nile Water Directorate for sampling.

The main challenges can be summarized as follows:

- Weak legal and institutional frameworks, including policies and strategies;
- Weak national water quality monitoring programmes and network;
- Lack of modern laboratory facilities; and
- Varying data management practices and low level of awareness on water quality issues.

4.3 Hydrological data challenges

The monitoring network is comprised of more than 200 stations for gauge readings, discharge and sediment load measurements, most of which are no longer functioning for different reasons. Moreover, at some locations (e.g. at some confluences and downstream dams of the Blue Nile), the discharge is measured at two different locations according to the volume of flow, which lead to an increase to error on the following grounds:

- Different sources of data;
- Deterioration of monitoring network;
- Data archiving;
- Different record length for each station;
- Missing data; and
- Unknown geographic coordinates of the gauges and spatial distribution of location.

4.4 Opportunities

The Nile hydrological database presents good opportunities where the data is formatted and available, such as:

- Water levels, and discharges (daily and 10-days average);
- Stage discharge data (velocity area measurements);
- Decision support system model (DSS) was created by Nile Basin countries to share data which were calibrated and used by the network of countries; and
- New technology introduced using sensor and remote sensing (data from space) to monitor and establish in some of the existing network stations.

5 Sustainable development

The SVP statement ensured the good quality of the Nile Basin water resources for its different competing uses, the preservation of different ecosystems, and the pursuit of sustainable development objectives and peace.

The goal of this study was to provide a preliminary assessment of the transboundary water quality, mainly the range of sediment concentrations encountered in River Nile system in Sudan, and a baseline to which comparisons could be made in future. The most important factor that would ensure sustainability at the national level is the inclusion of the activities in the national plans, improvement of water quality monitoring network through regular sediment monitoring, reducing pollution, and eliminating dumping and minimizing release of hazardous chemicals and materials. Often, the problems of sedimentation leads to water shortage and non-utilization of reservoirs this, then leads to scarcity of water which there by affects the livelihood of common man and in certain cases, leading to conflicts, Implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

6 Conclusion

Currently, water quality management in the Nile Basin is purely managed within the confines of the national boundaries, but a holistic basin-wide approach is desirable. The widespread scarcity of water resources in the Nile Basin can be aggravated, if water quality deterioration from the many environmental threats is not checked. Transboundary water resources use and management are of paramount importance to riparian states.

The Nile Basin is shared and integrated efforts for transboundary water quality monitoring should be exerted. Sedimentations studies are carried out intensively, management practices are quite weak and do not answer critical problems. The size of the watershed and basins also plays a decisive role in sediment management. Policy initiatives taken to afforest catchments have always proved right in controlling erosion and thus managing sediments.

Part of the sediment problem can be solved through joint efforts between Sudan and Ethiopia. The sediment creates many difficulties and problems to Sudan, at the same time, it has its negative impact on the Ethiopian Highlands, from where it originates, degraded the land by erosion and reducing its productivity

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12 | MAURITIUS

Improvement of wastewater infrastructure at Sir Seewoosagur Ramgoolam National Hospital (SSRNH)

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1 Introduction

With the present trend, it is expected that Mauritius might experience water stress conditions by 2025 (MoE/NDU, 2006). Water availability can be a severe constraint to development if effective water resources management and sustainable water development are not pursued. The quality of water resources is also under threat due to industrial pollution, agricultural, urban runoff and sewage disposal and, if not properly managed and disposed of, also causes water pollution.

In Mauritius, the following measures are adopted to control water pollution:

- providing sewerage infrastructure and solid waste management system to prevent pollution at source;
- requiring industries to pre-treat their effluent to prescribed standards before discharge into the sewerage system; and
- Prohibiting industries which use or store large quantities of chemicals to be sited within water catchments.

Accordingly, with the pressures of climate change, increased pollution, sea water intrusion and population growth, water resources will become even scarcer and will require further treatment to render it safe for consumption.

2 Project description

Prior to the improvement of the wastewater infrastructure in June 2015, the wastewater at the Sir Seewoosagur Ramgoolam National Hospital (SSRNH) was being channelled through an internal sewer network to a wastewater treatment plant. From there, the treated effluent is then discharged into the nearby Canal de La Ville Bague and afterwards into Citrons River. The performance of the existing wastewater treatment plant was poor (Ministry of Health and Quality of Life, 2005) and it was discharging treated effluent with characteristics well above the permissible limits. The non-compliant parameters included total suspended solids, ammonia, nitrate, phosphorus and the microbiological parameters, total coliform and E-coli organisms.

2.1 Baseline environment

The environment in which the wastewater treatment plant is located is dominated by the existence of the nearby SSRNH. This hospital was built in the late 1960s in midst of sugarcane fields and today, the hospital zone is still surrounded by cane fields. The wastewater treatment plant is in an enclosure juxtaposing the Haemodialysis unit which is separate from the main hospital buildings. Around these two infrastructures is a man-made forest. The infrastructures are shielded from the main road by a three-meter high stone wall and are not visible from the entry to the SSRNH.

2.2 Current situation (prior to upgrading)

The existing wastewater structure comprises mostly pitched fibre and asbestos cement pipes for the gravity sewers. The pitch fibre pipes have reached end of life, some of them having been observed to have collapsed and are therefore in an advanced stage of deterioration, resulting in frequent blockages and overflows of wastewater within the premises of the hospital.

The existing wastewater treatment plant (WWTP) at SSRNH was designed for a treatment capacity ranging from 180-220 m3 per day, but was receiving lower flows (Ministry of Health and Quality of Life, 2005). The existing wastewater plant is an activated sludge type with minimal pre-treatment facilities, two aeration tanks, a static secondary clarifier and a chlorine contact tank for disinfection with chlorine prior to discharge into the canal.

An examination of the treated effluent characteristics indicates that the plant efficiency is poor (Ministry of Health and Quality of Life, 2005), although it has been designed to receive higher flows. In general, the wastewater treatment infrastructure is not performing according to standard and is subject to frequent operational problems which represent potential threats to the environment and to human health. Thus, there is an urgent need for a complete refurbishment of the existing wastewater infrastructures.

2.3 Improvement works

An assessment of the existing wastewater treatment plant performance was undertaken. It evaluated the adequacy of the current wastewater collection network, the existing facilities which were not connected to the existing WWTP, the effluent discharge standards and the projected flows following implementation of the Master Plan for development of the SSRNH. Consequently, the following improvement works have been recommended (Ministry of Health and Quality of Life, 2005):

- Replacement of the existing sewer network by new sewers with diameters ranging from 110 mm to 300 mm. The extent of the works amount to pipe laying of 3.3 km of sewers;
- Refurbishment of the existing treatment plant to ensure that the treated effluent will meet the effluent discharge standards prescribed by the local environmental regulations; and
- Construction of a new pumping station to collect the wastewater from the staff quarters and from all other existing facilities of the hospital, which are not currently draining their wastewater to the treatment plant.

2.4 Development of the project

2.4.1 Replacement of the sewerage network

The existing wastewater network comprises mainly of 75 mm, 100 mm and 150 mm diameters. However, some of the sewers at the downstream end of the drainage area are 225 mm and above in diameter. The existing sewer network has been replaced by new sewers with diameters ranging from 110 mm to 300 mm. The extent of the works consists of laying 3.3 km of sewers. Moreover, since the existing system is buried under the existing buildings and crosses many corridors, the new system has been constructed along a completely new alignment in order to avoid breaking off floors through existing corridors and buildings and also to avoid any unduly long disruption of the hospital activities during execution of the works. Furthermore, the new network will subsequently be accessible for maintenance and for any future repairs/remedial works.

2.5 Assessment of existing treatment plant

2.5.1 Existing treatment plant

The existing treatment plant consists basically of an influent channel, two aeration basins, one collection chamber, a clarifier, a sludge sump, a chlorine contact tank and a sludge drying bed.

2.5.2 Inlet works

The wastewater flow reaches the treatment plant through a 200 mm diameter pipe. The raw influent passes only through a coarse screen. Large solids are removed by this process. The manual coarse screen has exceeded its operational life and is not fulfilling effectively its intended purpose. There is also no flow measurement device at the inlet of the works.

2.5.3 Aeration tanks

After the screening process, the influent passes through a tee joint whereby the flow is divided and enters the respective aeration tanks. The biological treatment unit consists of two aeration tanks of 12 m x 5 m x 3.5 m each, which are operated in parallel blowers. Oxygen is provided by diffusers found at the bottom of each tank. This method aims a complete mixing of the sludge and raw wastewater. The treated wastewater overflows to a collection chamber through a 200 mm pipe and gravitates to the clarifier for solids and water separation. Sludge from the clarifier is returned to the aeration tanks when the sludge well, immediately downstream of the clarifier, fills up.

The parameters, such as hydraulic retention time, food/microorganisms ratio, sludge retention, dissolved oxygen ratio and oxygen ratio, were measured and analysed during the design phase and it was concluded that the aeration tanks were not operating efficiently and were rather operating in an extended aeration mode rather than a conventional aeration one.

2.5.4 Clarifier

A circular clarifier of 26 m2 surface area is actually available on site. The clarifier allows for solids water separation and thickening of sludge. The thickened sludge flows to sludge well of about 6 m3 capacity from where it is then recirculated to the aeration tanks. Provision was made for sludge wasting from the sludge well to sludge drying beds in the past. These were observed to be no longer in operation.

Observations on site show that not infrequently, sludge detaches from the bottom to float above the surface with some of it overflowing into the channel leading to the contact tank. This obviously impacts on the amount of suspension that is carried over with the effluent.

2.5.5 Disinfection

Disinfection is currently being carried out in a 2.3 m x 1.8 m chlorine contact tank. Sodium hypochlorite is added regularly using a chlorine injection pump.

2.5.6 Desludging

Currently, the only facilities on site are two small drying beds of 4.3 m x 3.3 m occupying a total area of 14 m2. It is not known whether the drainage pipes within the drying beds are still operational.

2.6 Wastewater treatment after upgrading

2.6.1 Inlet channel

The inlet channel comprises a Venturi flume. The flume has been installed to record the flow. Downstream the Venturi flume, a 22 mm spacing bar screen has been installed. The function of this bar screen is to trap solids larger than 22 mm, such as rags, bandages and similar coarse solids. The trapped solids are regularly removed manually and stored in a watertight bin for eventual disposal.

The inlet channel is also equipped with an online pH meter for recording pH of the inlet wastewater.

2.6.2 Distribution channel

Raw wastewater from the inlet channel flows to distribution chamber. The distribution chamber flow splits the inflow equally into two streams which flow to the primary sedimentation tanks.

2.6.3 Primary sedimentation tanks (PSTs)

Wastewater from the distribution channel passes through the sluice valve chambers and is diverted to the primary sedimentation tanks. The primary sedimentation tank is a rectangular reinforced concrete tank with slanting walls with a sump at the bottom.

Clear wastewater overflows through the V-notch and flows to the Aeration Tanks. Solids collected at the bottom of the tanks are pumped by the sludge draw off pumps to the sludge holding tank.

2.6.4 Aeration tanks

The overflow from the PSTs is directed towards the aeration tanks. There are two aeration tanks in the WWTP. The volume of each aeration tank is 156 m3 and thereby allows for a retention time of 19 hours at the actual flow of 400 m3 per day (Ministry of Health and Quality of Life, 2005). Each aeration tank has two distinct zones namely the anoxic zone for denitrification and aeration zone for organic breakdown and nitrification.

Influent to the aeration tanks enters at the anoxic zone. A baffle wall in the anoxic zone ensures maximum retention time in the anoxic zone and provides for minimum turbulence. Return activated sludge (RAS) from the RAS pumping station enters the anoxic zone. The wastewater overflows in the aeration wastewater is treated aerobically.

Treated wastewater overflows to the collection chamber and flows to the final settlement tank.

2.6.5 Final settlement tank (FST)

Water flows from the collection chamber to the final settlement tank, FST. Sludge is normally carried over from the aeration tanks to the FST. The role of the FST is to separate the sludge from the liquid such that the liquid overflowing from the FST is clear and free from solids. Sludge settles at the bottom of the clarifier.

Settled sludge is continuously recirculated to the anoxic zone of the aeration tank. This is done by the RAS pump located in the RAS/SAS pumping station. During the biological treatment, new cells are generated continuously such that there is a surplus activated sludge (SAS) regularly. Excess sludge needs to be removed from the system. SAS pump transfers the excess sludge to the sludge holding tank. Operation of the SAS pump is controlled by the sludge level detectors installed in the FST.

2.6.6 Pressure filtration

Water from the FST flows to the chlorine contact tank. Calcium hypochlorite is injected in the chlorine contact tank by two dosing pumps such that residual chlorine of 0.5 mg/l is achieved.

After disinfection, water is pumped by two filtration pumps to three pressure filters. The pressure filter media is silica sand and activated carbon for removal of odour.

The pressure filters are equipped with automatic valves and control units which automatically start the backwash sequence of filters. Backwash of filters is automatically controlled by the pressure difference.

2.6.7 Outlet channel

Filtered water from the pressure filters enters the backwash tanks and overflows to the outlet channel. Monitoring equipment, such as the outlet flume and pH sensor, is installed in the outlet channel to monitor flow and pH of the final treated wastewater.

2.6.8 Sludge treatment

Primary sludge from the PSTs and surplus activated sludge from the FST is pumped to the sludge holding tank. A submersible mixer is installed in the sludge holding tank to keep the sludge always in suspension. An ultrasonic level sensor continuously monitors the level of sludge in the sludge holding tank and raises an alarm at high sludge level. Two sludge transfer pumps are used to transfer the sludge into wastewater carriers.

3 Challenges, opportunities and lessons learned

Difficulties were encountered during the construction of the works because the plans for the alignment of the existing services and the extension of buildings construction are not available.

New corridors to lay sewer pipes on some areas were not available. The contractor had to carry out the pipe works into the existing lines. The contractor had to divert the flow or pump the sewage water from upstream manholes and work downstream.

There was some corridor’s crossing to be carried within the hospital compound. The width of the corridor was approximately 2 m with extensive mass concrete. Excavation works across the corridor could not be carried out at one go since access to public, patients and hospital staff had to be maintained. The contractor carried out the excavation across the corridor half width at one time with all the necessary safety measures such as providing hard enclosures within the working areas.

Moreover, during the construction phase, dust pollution became a concern. To mitigate the pollution, the contractor organized to place workers at specific points within the hospital compound to clean the dust during construction works. The corridors within the hospital compound were also being subject to mud during rainy weather. The contractor took the necessary steps to wash and clean the corridors.

Roads within the hospital compound and near the treatment plant were sprinkled with water. Temporary double bituminous surface treatment reinstatement was carried out along main roads where pipe laying work had been completed to improve traffic and mitigate dust pollution pending permanent reinstatement.

Noise due to excavation works with mechanical means was also causing disturbance to the hospital staff, especially to the doctors at the Outpatient Department, main Operation Department and at the Maternity. This aspect was given a special attention. Excavation works were carried out manually and sometimes during restricted hours with mechanical means to minimize noise pollution. Moreover, in general the contractor was not allowed to work at night during the hospital compound.

4 Conclusions

The improvement of the wastewater infrastructure at SSRNH is a project which was badly needed for quite some time. the new WWTP's performance with regard to treated effluent quality now qualifies the SSRNH WWTP as one of the most efficient WWTPs in Mauritius in terms of treating effluent to permissible standards.

The Maurice Ile Durable Project and the Millennium Development Goals were the principal enabling environment factors that allowed this project to be funded by the government and completed, although the initial project planning was initiated during 2003. Moreover, strict monitoring and evaluation of the project was done throughout the construction, commissioning and defects liability phases. A project manager was appointed in this respect, who performed her duties very satisfactorily by ensuring that the project was completed at no additional cost.

The opportunities that are envisaged from the upgrading works for the future are the use of the treated effluent for irrigation of the hospital's landscape, washing of the pavement and flushing of toilets, and the use of stabilized sludge for production of compost.

The upgrading works of the wastewater infrastructure at SSRNH are also in line with Sustainable Development Goal (SDG) 6: Ensure availability and sustainable management of water and sanitation for all (UNGA, 2015).

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Annex 1 - Synoptic table of challenges and policy responses

Country	Title	Area description	Challenges	Policy responses (implemented/suggested)
Zambia	A step towards groundwater protection in Mtendere, Lusaka	Zambia is landlocked country located in Sub-Saharan Africa. On average, the yearly rainfall is more than 950 mm, lasting from November to March. The highest temperature is recorded in October, more than 25°C, while July is the coldest month with temperature of less than 18°C. The capital city is Lusaka, and Mtendere is a peri–urban area located in this city, with around 90,000 inhabitants.	• People's reaction and acceptance to the installation of the new technology, mainly by households. They had been using pit latrines also as solid waste disposal, almost free of charge. • The price of the construction works; lack of space for water-borne toilets meant it was necessary to demolish some structures, which lead to high compensation costs. • The installation of water- borne toilets will have costs, such as toilet paper, cleaning detergents, maintenance costs and water bills.	• The Government of Zambia together with the Millennium Challenge Account–Zambia is promoting the installation of off-site sewer systems and water – borne toilets in Mtendere, a peri-urban area of Lusaka. • The project will provide only sewer and water networks, while individual households will be in charge of proving water-borne toilets to connect to the off-site sewer systems. • The installation of offsite sewer systems and of water-borne toilets could reduce the threat of groundwater contamination. • An educational campaign was conceived in order to explain the health benefits of using such technology, as well as providing the necessary information on how to use and maintain it.
Kenya	Water resources management authority intervention on the quality of wastewater discharged in the river: a case study of North Kinangop Mission Hospital	Kenya lies in East equatorial Africa and it has a direct access to the Indian Ocean. On an average year, rainfall exceeds 650mm and the wettest months are April and November, while the driest are February and September. Throughout the year, temperatures are always higher than 23°C, with peaks of around 27°C in March, the warmest month.	• The quality of the effluent before the intervention was very low and it could not be discharged into the River Kitiri. • After the process of desludging, the ponds were tested and it was found that some of them were leaking, thus it was necessary to repair them. The repair process lasted more than 6 months. • The costs of desludging and meeting the Effluent Discharge Control Plan (EDCP) standards were high, so it was difficult to obtain the necessary funds. • The preparation of the working site and the construction of drying beds needed time, because it was necessary to take into consideration different elements, such as flood conditions, slope, odour risk and desludging. • The implementation of the EDCP requires a necessary time frame in order to allow the hospital to meet its required standards.	• The Water Resources Management Authority (WRMA) designed the EDCP for the hospital, to prevent the pollution and the contamination of water and soil. EDCP is a regulatory tool used in the enforcement of compliance with effluent discharge requirements. It allows discharge entities to follow guidelines, implementing waste management programmes and to practice self-audit in order to receive an Effluent Discharge permit by WRMA. The implementation of the EDCP improved the quality of the wastewater, so it could be then discharged directly into the river, allowing the use inside the community with fewer conflicts. • The solid part of the waste, collected from the pond and the sludge, is used to produce biogas, employed as source of fuel for the hospital.

Zimbabwe	The application of remote sensing in operational drought monitoring	Zimbabwe is a landlocked country located in South-East Africa. The rainy period lasts from November to March, with an average rainfall of more than 600 mm. Temperatures go from 16°C, in July, the coldest month, to an average of around 25°C during the warmest months, from November to February.	• The different regions of the country are frequently affected by droughts, varying in intensity and duration. • Recurrent droughts negatively influence food production and thus, food security; particularly for farmers (who rely on rainfall for the irrigation of their crops) and children. In Zimbabwe a third of children under five years old are chronically malnourished. • Groundwater has been used to mitigate surface water shortages as well as sustain livestock and people during severe droughts. The available information about groundwater in the country is very limited; there are few data about the reserves and the possibility to use them as emergency source. • Zimbabwe has a national policy on drought management, but the lack of preparedness in dealing with such events shows that it is not totally efficient.	• Development of capacity building in the management of surface and groundwater resources should be enhanced. • Installation of more hydro-meteorological observation networks and improvement of an efficient information dissemination network should be taken into consideration in further policy actions. • The Normalised Difference Vegetation Index (NDVI) is influenced by the soil colour where vegetation canopies are sparse; thus the different soil background colour results in different values of NDVI. Hence, local knowledge is important to validate the result.
Nigeria	Persistent organic pollutants (POPs) and groundwater quality: A case study of contamination levels of POPs in groundwater within selected obsolete pesticide stores and electric power stations in Nigeria	Nigeria is a central-west African country on the Gulf of Guinea. The temperature throughout the year is always more than 25°C; the lowest temperatures are reached in January and December. The warmest period goes from March to May, when temperatures are around 30°C. On an average year the total recorded rainfall exceeds 1100mm and the wettest period is from July to September.	• Anthropogenic activities such as agriculture, industrial manufacturing, waste burning and energy production are activities responsible for releasing POPs into the environment. • The lack of application of waste management technologies means dumpsites can be potential POP hotspots. • There are scientific research gaps, infrastructural deficits and lack of human capacity in assessing and evaluating the POPs levels in groundwater, surface water and soil. • There is a lack of data for groundwater resources, and consequently there is a need to strengthen the existing coordinated monitoring. • Awareness on POPs is very low, thus there is a need to elaborate raising awareness activities, targeted at decision-makers.	• In order to achieve SDGs, referring particularly to reduce significantly the release of wastes and hazardous chemicals in the environment, the following actions are suggested: • Develop a coordinated monitoring of POPs in groundwater (as well as in other water resources). • Develop and update continuously of a database on levels of POPs in various media. • Build and strengthen human and infrastructure capacity for the analysis of POPs and other organic pollutants, including emerging pollutants. • Establish national standards describing the maximum permissible levels in different media and guidelines on POPs containing materials. • Enhance a national policy on sound management of POPs. • Create a regulatory framework, including an enforcement strategy for POPs-contaminated sites. • Formulate an awareness plan for POPs.

Zimbabwe	Accelerating the implementation of water-related Sustainable Development Goals in Zimbabwe	Zimbabwe is located in South-East Africa and has no direct access to the ocean. The rainy period lasts from November to March, with an average rainfall of more than 600 mm. Temperatures go from 16°C, in July, the coldest month, to an average of around 25°C during the warmest months, from November to February.	• Lack of adequate human resources to deal with the increasing demand of expert services in the main institutions for water resources management, such as the Zimbabwe National Water Authority (ZINWA), the Agricultural Research and Extension Services (AREX) and the Environmental Management Agency (EMA). • The lack of precise and accurate information and data regarding water demand and availability is weakening the role of communal farmers. This has negatively influenced their participation in water management issues, despite the creation of sub-catchment councils where they should be deeply involved. • Despite the legal framework enhancing stakeholder participation, the limited fiscal space does not allow them to travel to and attend sub-catchment council meetings. Stakeholders' perceptions and interests could cause a variation in their perspective, slowing the council meetings process. The effectiveness of future reforms is threatened by powerful stakeholders, who could pursue their own interests. Political influence could affect negatively the participation process, promoting particular decisions.	• In 1998 the government of Zimbabwe introduced the Water Act and the Zimbabwe National Water Authority Act (ZINWA); these acts introduced structural changes regarding the participation and the representation of water users in water management. • One of the goals of the Water Act was the promotion of representation and participation of previously excluded water users, such as communal, resettlement and small-scale farmers. It also aimed to improve institutional coordination to facilitate efficient water management. • In recent years, the country has been developing a different approach to water governance, from a top-down supply-driven to a bottom-up demand-driven method. This process tries to combine experience, knowledge and understanding of various local groups and people.
Ghana	Exploring solutions to resolve extreme water conditions in Ghana	Ghana lies in West Africa, on the Gulf of Guinea. It is characterized by a long wet period, from April to October, where on average the precipitation reach 1000 mm. Throughout the year temperatures are always higher than 25ºC; the warmest period is from February to May, with peaks of 30°C, while the coldest is from July to September.	• Poor management of water resources have intensified the impacts of extreme events, such as frequent floods, droughts and scarcity of water. • Floods and droughts in particular have strong impacts, causing loss of lives, damages to property, infrastructure, crops and animals. • There is an important gap between demand and water supply. The effective access to potable water supply covers around 70% of the total population; around 80% of urban population and slightly less than 20% of the rural population. • To address water scarcity cities should develop the extraction of groundwater. However, this approach could cause land subsidence and differential settlements of soil, damaging infrastructures. Furthermore, over-extraction could decrease the water table, as well as drying wells and rivers. • Drains in the capital city of Accra are highly exposed to misuse; people discharge solid and liquid waste into them. Some are not even designed to collect the volume of water during the rainy season, causing water overflow onto the streets. Siltation of water infrastructure is another cause of floods in the city. • Many people use the bed of non-perennial water bodies to construct buildings or as dumping sites	• The government should promote the creation of water storage facilities and rain harvesting structures in every household, through the cooperation of the Association of Engineers and the update of the existing building codes. • It should not be permitted to build on waterways and wetlands, or to use these areas as dumpsites. • Government should allow water treatment companies to invest in desalination of sea water. • Groundwater extraction should be regulated by a monitoring agency, which should assess extraction and recharge of groundwater. • Drain systems should be improved, based on the volume of water, and drains should be covered to prevent misuse. • Silt removal should become a routine, especially during rainy seasons. • Raising awareness campaign should be promoted, to educate citizens and stakeholders on sustainable and correct ways of using potable water. • Government should enforce laws and acts related to the environment.

Uganda	Towards gender equality in decision-making in the WASH sector in Uganda	Uganda is a landlocked country lying in East Africa. Rainfall is present throughout the year; the driest months are from December to February, with around 150 mm, while precipitation during the rest of the year is quite constant, exceeding, on average, 1100 mm annually. During the year, temperatures range from 22°C in July to around 25°C in February.	• There is the need for new safe water resources due to the population growth, prioritization of sanitation and hygiene practices, and poor protection of water sources. All of these issues impact negatively water-dependent sectors, such as agriculture, energy, employment and economy. • Women and girls are the responsible for water collection, use and management as well as promotion of WASH activities within households and communities. Women's influence in water committees is still constrained due to their socio-economic role in societies, where their opinions are generally not taken into account. • The population thinks WASH issues are entirely the responsibility of the government. • There is a lack of trained staff in health centres and water departments to raise awareness of WASH issues among the population. • The technology available for WASH needs to be improved; funds are necessary to undertake this process. • The government should better incorporate gender and technology issues in WASH planning. The Declaration on Sanitation and Hygiene (1995) prescribes the establishment of governmental systems involved in monitoring, reporting, evaluating and learning in the WASH sector.	• Association of Uganda Professional Women in Agriculture and Environment (AUPWAE) project aims at promoting the participation in decision-making for water and environment section through knowledge sharing and capacity building. • There are already existing platforms for participation in decision-making, such as Water Source Committees, Water User Committees, Water Supply and Sanitation Boards; Committees of the Ministry of Water and Environment and the Uganda's Parliament forum for WASH (UPF-WASH). • UPF-WASH is a non-partisan organ that allows Members of Parliament to form consensus and collaborate on raising awareness and advocating for WASH. Its activities include monitoring and sensitization on WASH through field visits at district and sub-regional level. Motions to promote drill boreholes in each school and menstrual hygiene management in schools were promoted to the parliament. • Stakeholders should share research findings and information connected to impacts of WASH developments on men and women. Local leaders should be more engaged in sensitisation communities about operation and maintenance of WASH facilities.
Ethiopia	Water quality survey on improved community supply units in the southern region of Ethiopia	Ethiopia is a landlocked country located in Eastern Africa. The wettest months are July and August, with a mean precipitation of around 250 mm, while the driest months are from November to February. Temperatures are around 22°C, in December and January, while in the warmest period they can reach 25°C. The Southern Nations, Nationalities and Peoples' Region (SNNPR) has an area of 110,932 km^2 and it is located in the southern and south-western part of Ethiopia. There, rainfall intensity and duration varies. The mean annual rainfall data ranges from 400 mm and 2,200 mm.	• The introduction of safe water supply systems only in those villages with easily accessible water sources has increased the proliferation of informal vendors, who sell water at very high cost, or the use of water sources that are not always safe for consumption. • Women and girls are in charge of fetching water, thus leading to dropping out from school, animal attacks, girls' abduction, and related exposition to early marriage. • Water quality is not always safe, even if the Ethiopian government has been involved in the installation of improved water supply. The quality of water is influenced by lack of proper sanitation. • Improved water sources are not always functional, sometimes they dry out or they are only accessible by foot.	• The results of the research were presented to local authorities; thus they are now well aware of the actual condition of the water sources in the SNNPR. • There is a need to promote actions in order to protect water resources from contaminations, as well as to allocate resources for continuous monitoring, fencing to prevent access of animals to water sources, and the development of a plan for their maintenance.

Cameroon	Community – led total sanitation as one of the best strategy to achieve sustainable development in sanitation in low income communities	Cameroon is located on the Atlantic coast in central Africa. On an average year, precipitation exceeds 1500 mm; during the wettest months, from July to October, the rainfall is about 900mm. Temperatures are higher than 24°C during all year long, and from February to May, the warmest months, they exceed 26°C.	• In 2011, 30% of the total population of the country, about 20 million people, had access to an improved sanitation facility, 47% had a rudimentary traditional sanitation, and 7% had no other option than open defecation. • The percentage of people accessing improved sanitation facilities is quite high at around 83% in big cities, such as Yaoundé and Douala, whilst in smaller dwellings it is less than 80%, and in rural areas it decreases to about 33%. • Between 2010 and 2015, Cameroon recorded more than 37,500 cases of cholera, and about 1,700 deaths. • The budget reserved for Community lead total sanitation (CLTS) projects is mainly financed by donors. • The integration between CLTS and municipal development plans is a strategic challenge due to the necessity to harmonize the CLTS method for national implementation.	• Cameroon aims at increasing the rate of access to basic sanitation facility from 15% to 60% by 2020 by constructing more than a million latrines. • The CLTS project was launched in 2009 by the Minister of Water Resources and Energy. It promotes the construction of latrines and handwashing devices by community members without any financial support. • The decentralisation of the government facilitates the ownership of CLTS activities by municipalities. The low cost of this project allows its implementation and its achievement of the goal of access to basic sanitation. • The presence of guidelines about the CLTS implementation would allow the replication of the project, and would be a useful tool for municipalities, NGOs and partners involved in the project. • Awareness raising campaigns in schools about sanitation and hygiene would contribute to the success and the sustainability of the project.

Sudan	Strategy to make operational the transboundary water quality monitoring stations in Sudan, a case study Blue Nile River	Sudan lies on Eastern Africa and has a short coastline on the Red Sea. Rainfall is very scarce during the year, on average less than 450mm. During the wettest period, from June to September, the total precipitation is slightly above 300 mm. Throughout the year, the temperature always exceeds 22°C; the warmest period goes from April to October, with average temperatures higher than 28°C and peaks of 31°C.	• Nowadays, water quality management in the Nile Basin is not transboundary managed, but it is controlled inside each country. Legal and institutional frameworks are weak and poor national water quality monitoring programs need to be enforced. The Blue Nile River faces several problems. • Population growth, increasing water demand for industry and food production and pollution due to higher use of agrochemicals, industrial and domestic waste threaten water resources. • Sediment transportation has caused loss of stored water, conveyance capacity, blockage of turbines and an increase in the cost of water treatment for domestic use. • Problems on sedimentation could cause water shortages leading to threaten human livelihoods that could create conflicts among users. • Regarding the management of data, the sources and management practices need to be harmonized. Information and knowledge about water quality issues must be improved in order to operate in a more effective way.	• The following are actions that should be integrated in the establishment of a transboundary institution/treaty: • Strengthen national and international ability to provide reliable information on surface water flows and quality of waters. • Improve the harmonization of sampling techniques and laboratory analysis. • Develop harmonized information management systems to facilitate the sharing of information among transboundary countries.
Mauritius	Improvement of wastewater infrastructure at Sir Seewoosagur Ramgoolam National Hospital (SSRNH)	The Republic of Mauritius is a group of islands in the Indian Ocean located north of Madagascar. On an average year, the total precipitation is around 1600 mm. During the year, temperatures are always higher than 20°C; the coldest months are July and August, while the warmest period goes from December to April. The studied hospital was built in the late sixties and today the hospital compounds are surrounded by sugarcane. The wastewater treatment plant is separated from the main buildings. Around the infrastructure, there is a man-made forest which is shielded from the main road by a 3-meter high stone wall and is not visible from the entry of the hospital.	• The wastewater treatment plant performance was poor; furthermore it discharged treated effluents not meeting the national standards. • The existing wastewater structure mostly consisted of pitched fibre and asbestos cement pipes. Some of the pitched fibre pipes reached the end of their life-cycle and it was observed their collapse and deterioration, causing frequent blockages and overflows in the hospital premises. It had also frequent maintenance problems, potentially threatening the environment and human health. • During the restructuring period, it was necessary to divert the flow or pump the sewage water from upstream manholes and work downstream; in most cases the corridor excavations had to be half-width in order to adhere to safety measures. • Mechanicals tools used during the working phase caused lot of noise, thus they were done manually and sometimes during restricted hours to minimize noise pollution. Generally, work during the night was not allowed.	• The Ministry of Health and Quality of Life financed the restructuring of the wastewater treatment of the hospital. • The new system was constructed along a new alignment in order to reduce the demolishment of floors and the consequent disruption of the normal activities. • The Maurice Ile Durable Project and Millennium Development Goals were the main enabling elements that forced the government to fund the project. • Careful monitoring and evaluation were performed during the whole project. • It is planned to reuse the treated water to irrigate the hospital lawns, clean pavements and flush toilets, and to use the stabilized sludge to produce compost.

Annex 2 - Programme of training workshop

	Monday, the 11th	Tuesday, the 12th	Wednesday, the 13th	Thursday, the 14th	Friday, the 15th
BREAKFAST (7:30 - 8:45)					
9:00 - 12:30 COFFEE BREAK 10:30/11:00	**OPENING CEREMONY** **9:15-10:00** Stefan Uhlenbrook and Franco Montalto opening remarks; Diego Zurli, Regione Umbria; Angela Ortigara: Presentation of the training **10:00-10:30** Tour de Table **LECTURE 1** **Water and Sustainable Development/Role play** *Angela Ortigara*	**LECTURE 3** **Water, Energy, Food, Environment Nexus including development and decent jobs** *Stefan Uhlenbrook*	**LECTURE 5** **Integrated Water Resources Management** *Pieter van der Zaag*	**LECTURE 7** **9:00 – 9.30** **Instruction for Case Studies Publication** *Valentina Abete* **9:30 – 13:00** **Adapting to Extreme Events for Resilient Urban Ecosystems** *Prof. Dr. Fernando Nardi*	Departures
LUNCH BREAK (12:30 - 14:00)					
14:00 - 17:30 COFFEE BREAK 15:30/16:00	**LECTURE 2** **Data and Information on Water** *Graham Jewitt* **17:00 Engendering water. WWAP Gender&Water Toolkit in view of the 2030 Agenda for Sustainable Development** *Michela Miletto and Paola Piccione*	**LECTURE 4** **Planning Sustainable Urban Water Infrastructure** *Franco Montalto*	**LECTURE 6** **Transboundary Water Management** *Pieter van der Zaag*	**14:30** Field trip	Departures
NIGHT ACTIVITIES	**Apericena** **19:30** *Resturant at Villa*	**Dinner** **19:30** *Restaurant at Villa* **Movie Night** “The Water Rooms” *Sala Lodovico I*	**Dinner** **19:30** *Restaurant at Villa*	**Evening in Bevagna** **20:00** Dinner	Departures

Regione Umbria

This book – the second of three volumes – contains a collection of case studies from nine African countries selected during the Training Workshop on Capacity Development on Water and Sustainable Development, organized by UN WWAP UNESCO in October 2015. This activity was realized under the project "Capacity Development of Workers in the Water Sector" funded by the Arab Gulf Development Fund (AGFUND).

The training programme was aimed at providing water professionals with tools for: identifying, maintaining and assessing data that may improve water management; managing water resources in a way that ensures a rational allocation of water among competing users; preserving ecosystems; mitigating the effects of extreme events such as floods and droughts on water supply and treatment; and facing the challenges associated with the achievement of an efficient, effective and equitable water resources management, transboundary water management and growing urban environments.

Each case study covers a different aspect of the path that will lead to sustainable management of water resources, highlighting challenges and solutions adopted by the country. The discussions that ensued were enriching for both participants and professors alike, which demonstrated the importance of exchanging information and comparing the challenges in diverse realities.

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