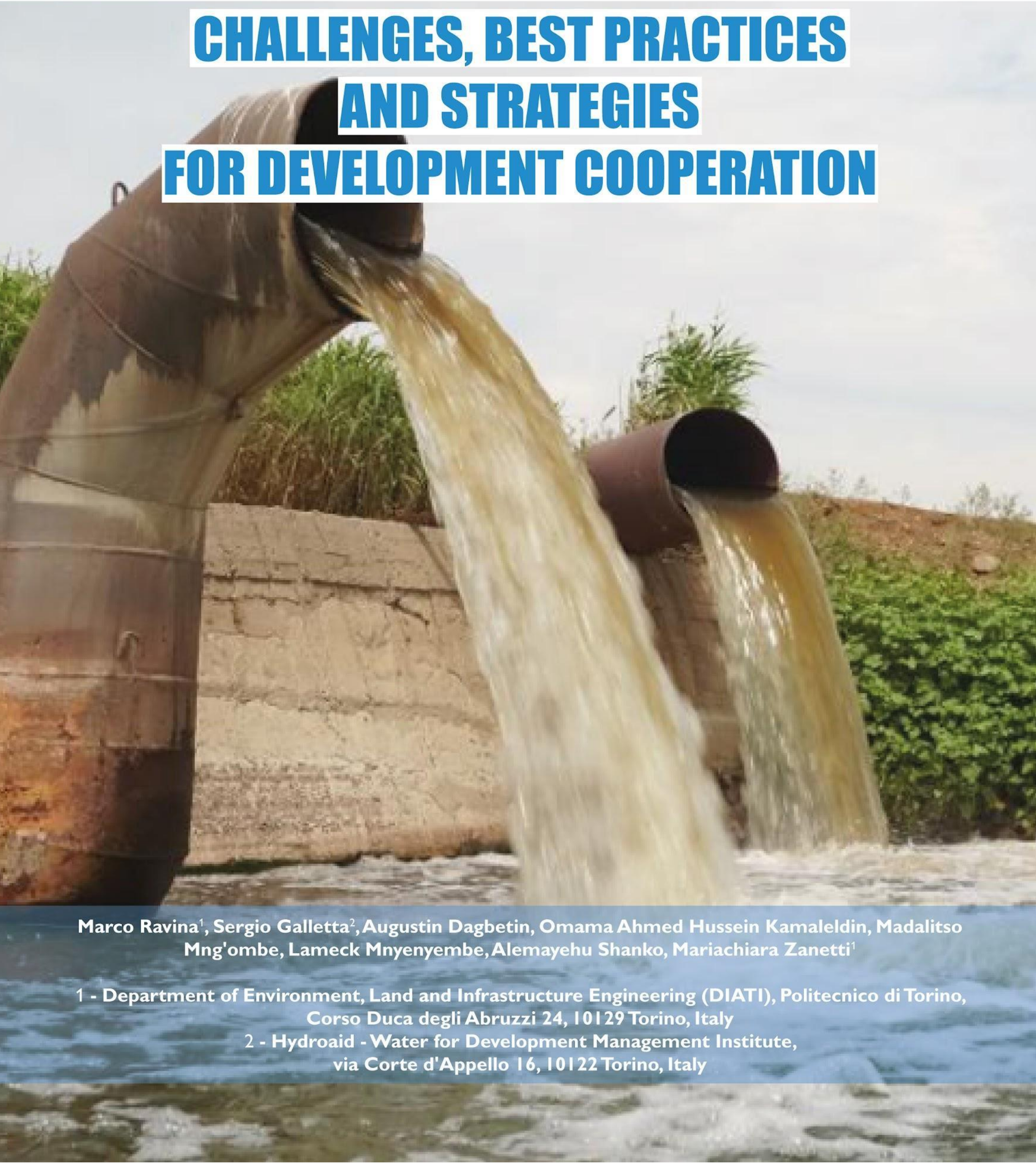
SANITATION IN AFRICA:
CHALLENGES, BEST PRACTICES AND STRATEGIES FOR DEVELOPMENT COOPERATION



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Abstract

This study is based on the evidences collected during the UAP Sanitation Project, developed in 2020 by the Hydroaid Association, in collaboration with Turin Polytechnic (Politecnico di Torino). The objective is to produce a comparative analysis of the most suitable strategies and technological solutions that, in the broad field of snitation, relate to wastewater management and treatment in African countries. Conducting such an analysis in different countries makes it possible to identify the best practices and the most recurrent problems linked to the various African contexts, which need to be considered for a complete definition of the planning strategy for accessible, efficient and sustainable sanitation infrastructures from an economic, social and environmental point of view. The research object of the project intends to exploit the information collected in the field by the participants of the 2020 edition of the "Technical e-Learning Course on Wastewater Treatment" organised by Hydroaid with the scientific collaboration of Politecnico di Torino. Four African countries - Benin, Egypt, Ethiopia and Malawi - have been considered and two relevant case studies among those proposed by the participants are presented. Both the analysis of their status, features and issues, and the evidences extracted from the project, raise important points of discussion about the topic.

Keywords: Wastewater treatment, Africa, Sanitation

1. Introduction

1.1 General context on sanitation

Global water demand will tend to increase significantly in the next few decades. Agriculture is responsible for 70% of total freshwater consumption worldwide (90% in Least Developed Countries), while energy and industry are responsible for 20%. The remaining 10% is used for drinking water, sanitation, hygiene and other domestic purposes [1].

The causes for this increase are mainly the population growth, the rapid urbanization to which is added the development of water supply and sanitation systems and the improvement of lifestyles. In fact, the world's population is expected to inevitably increase; in particular, it is estimated that the earth will be inhabited by 8.6 billion people in 2030, 9.8 billion in 2050 and 11.2 billion in 2100 [2]. Four billion people (almost two thirds of the world's population) currently live in areas affected by water scarcity for at least one month each year. Lack of non-renewable resources, such as fossil groundwater, will force to transfer water from areas rich in water or to displace people in case of severe water scarcity. Climate change will aggravate the scarcity of water issues because the variations of the water cycle increase the gap between water demand and water supply, exacerbating at local level the extreme events (floods and droughts) [1].

The availability of water resources is strictly linked to water quality, because increase of agricultural runoff and untreated wastewater from industry or domestic use lead to the degradation of the environment and the water sources, deteriorating the water quality in the world. If this trend remains unchanged over the next few decades, especially in countries in arid areas, water quality degradation will further contribute to water scarcity, endangering human health and ecosystems and holding back sustainable development.

Therefore, wastewater is a crucial component of water resources management. Nevertheless, treating wastewater is not often considered a necessity but rather a burden or nuisance. The results of this approach are clear: neglecting wastewater issues generates high negative impacts on the environment, waterborne diseases due to the use of contaminated water sources, and well-being of communities.

Underestimating the impacts related to wastewater means seriously compromising the achievement of the SDGs of 2030 Agenda. In particular, the SDG Target 6.3 states: "*By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.*" The achievement of this target is critical for achieving the entire 2030 Agenda and in particular for SDGs concerning health, education, cities and industry.

Wastewater is produced by human activities. The more the overall water demand grows, the more the quantity of wastewater and the degree of pollution increase. Freshwater withdrawn for human activity is nearly 4,000 km^3/year in the world. 56% of it is discharged as wastewater from urban and industrial activities or drainage from irrigation water. High-income countries collect and treat the majority of wastewater worldwide - in these countries on average 70% of urban and industrial wastewater is treated. Upper-middle-income countries treat only 38%, for lower-middle-income countries the ratio is 28%, while low-income countries release the wastewater to the environment mostly without any kind of treatment (only 8% is treated), with serious consequences on human health, ecosystems and local economies. These estimates are consistent with the overall ratio of 80% often used at global level.

The use of advanced wastewater treatment in high-income countries responds to the need to maintain water quality in the environment or have an alternative source of water available in case of water scarcity periods. On the other hand, in developing countries, the release of untreated wastewater remains common practice, due to lacking infrastructure, technical and institutional capacity, and financing. In particular, there is a lack of comprehensive and regular monitoring of wastewater treatment plants and surface water quality by the responsible authorities due to inadequate human capacity, low budgetary allocation to the sector and inadequate laboratory facilities [3]. Wastewater management services are generally inadequate. Sewage systems frequently break down at treatment plants and sewer lines blockages occur due to (i) poor maintenance and lack of spare parts; (ii) improper design of some sections and (iii) lack of public awareness on proper use of sewage systems. One of the main challenges is the governance and financial integrity of councils to appropriately manage the wastewater and other key services to the residents in the urban areas. Wastewater treatment and disposal is a matter of concern that needs to be addressed.

The MDG target for sanitation was not met: in 2015 68% of the global population had access to improved sanitation services (the ratio to be achieved was 77%, which corresponds to 700 million more people; the 1990 baseline was 54%). Nevertheless, some progress has been achieved: 2.1 billion people have gained access to an improved sanitation facility since 1990. In 2015, 2.4 billion people still did not have access to improved sanitation facilities, including 946 million still practicing open defecation [4].

Concerning the 2030 Agenda and the progress of the SDG 6, people who has still no access to safely managed sanitation services increase (3.6 billion in 2020 against 2.4 billion in 2015), while open defecation has been significantly decreased, passing from 946 million in 2015 to 494 million people in 2020 [5].

Considering the figures related to Africa, the situation is still more serious. Africa is the second driest continent after Oceania and less than 9% of the global renewable water resources (3,930 km^3) are located there. Moreover, there is also a huge disparity across African countries, ranging from 25 m^3/inhabitant/year of renewable water in Egypt to 121,000 m^3/inhabitant/year in Gabon. Only a few of the 54 African countries - and almost all located in the North region - met the MDG target for sanitation. Nearly 750 million people (69% of African population) - mostly in sub-Saharan countries - did not have access to improved sanitation services in 2017 [6].

Faced with this situation, the achievement of SDG 6 represents a great challenge for the world and in particular for Africa. It is time that wastewater is no longer considered just a burden and a cost. Investing in wastewater in terms of governance, infrastructure, technology and capacity building is necessary to achieve the objectives of the 2030 Agenda, contributing significantly to the fight against water scarcity, to the health of local communities, to the conservation of environment and to a sustainable society. Furthermore, in the spirit of the circular economy, inherent in the 2030 Agenda, wastewater represents a value, as if properly treated it can be a source of energy (e.g. biogas), a source for irrigation (reuse of water) and for agriculture (sludge as fertilizer). Finally, proper wastewater management also generates positive effects for climate change mitigation, food and energy security.

1.2 Objective of the research

The research intends to address the environmental issue of sanitation in various African countries, which the world of international cooperation has been looking at in recent years with growing interest. The objective is the comparative analysis of the most suitable strategies and technological solutions which, in the vast sphere of sanitation, refer to the management and treatment of wastewater in African countries. Conducting such an analysis in different countries makes it possible to identify the best practices and the most recurrent problems linked to the various African contexts, which need to be considered for a complete definition of the planning strategy for accessible, efficient and sustainable sanitation infrastructures from an economic, social and environmental point of view.

The research project intends to contribute to the improvement of the area of sanitation that is wastewater management, by promoting an approach based on "learning from the roots", through the knowledge and analysis of the social context, and the comparison of the various experiences in the different realities of many African countries. The research object of the project intends to exploit the information collected in the field by the participants of the e-Learning course “Technical course on Wastewater treatment - 2020 edition” delivered in partnership with Politecnico di Torino.

This report is organized as follows. First, the Hydroaid association and the Politecnico di Torino University, i.e. the project developers, are briefly presented. Subsequently, the structure of the project and the data collection is reported. Finally, data and case studies analysis is presented.

1.3 Hydroaid

Hydroaid - Water for Development Management Institute is a non-profit association founded in 1999 in Turin with the mission to contribute to the strengthening of knowledge, skills and competences for the sustainable management of water resources in developing and emerging countries. Since 2001, Hydroaid has promoted and implemented training and capacity development activities on the issues related to the water resources management for the benefit of 89 countries, building an international network of about 5,000 experts composed of technicians, managers, decision makers, trainers and students. In 2011, Hydroaid was granted the special consultative status with the United Nations Economic and Social Council (UN ECOSOC), an important recognition of the contribution given in the field of training and education of water management issues. As a consultative member, Hydroaid participates in periodical consultations on specific topics related to development.

The association structure is made up of permanent members - Piedmont Region, Metropolitan City of Turin, Municipality of Turin, the local water authority Autorità d’Ambito n. 3 “Torinese”, Politecnico di Torino, the local water utility SMAT S.p.A. and the private companies Hydrodata and Ai Engineering - who operate in support of the institutional activities and actively contribute to the implementation of the various initiatives. Since 2001 the Ministry of Foreign Affairs and International Cooperation has supported Hydroaid’s international activities and participates in the Steering Committee.

Training courses implemented by Hydroaid - in an e-learning, face-to-face or in blended learning mode - concern multiple aspects of water resources: design and management of water supply and sanitation systems, governance, planning, economic regulation and climate change. These training activities can be integrated in broader capacity development initiatives aimed at supporting and reinforcing the institutional and technical local partners in international cooperation projects in developing and emerging countries, in collaboration with its members, NGOs and partners. Concerning the activities for the benefit of the local population in Italy, Hydroaid carries out environmental education activities in primary and secondary schools, involving public institutions and local associations, with the aim of promoting and spreading a sustainable water and environment culture among the younger generations.

Through training courses, capacity development activities for the improvement and sustainability of local services, Hydroaid's commitment aims at pursuing long-term goals and accompanying local policy transformation processes in the beneficiary countries. Since its establishment, the Hydroaid Association has had Politecnico di Torino as one of its main supporting members. The membership of Politecnico di Torino has made it possible to transfer the didactic and scientific skills of the Institution into the training initiatives implemented by Hydroaid.

1.4 Politecnico di Torino

The Politecnico di Torino was founded in 1859 as Scuola di Applicazione per gli Ingegneri (Technical School for Engineers), and it became Regio Politecnico di Torino in 1906. A long history, which bore out the University as a reference point for education and research in Italy and in Europe, a research university of international level which attracts students from more than 100 countries and which activates about 800 collaborations per year with industries, public institutions and local organizations.

The attention to theoretical and applied research, the knowledge and development of cutting edge technologies, the concreteness and realism concerning the management of a manufacturing process or the organization of a service, the care of functionality without ignoring design, the analysis and proposition of solutions to the challenges of the society of today in order to plan a sustainable future: graduates from the Politecnico di Torino receive an education that goes far beyond technical knowledge. They are able to manage the interdisciplinary nature of the scientific world of today without forgetting social, ethical, economic and environmental implications.

Excellent results in education and research fields, positive judgments from students, education processes of quality and the ability in winning national and European grants brought the Politecnico di Torino to an excellent place in the assessment drawn up by the Italian Ministry of Education, Universities and Research (MIUR): since 2010, when the MIUR began to award the public funding of the Fondo di Finanziamento Ordinario according to a table on Universities performances, the Politecnico has always been the first University in Italy. A positioning proved by the good results of the University at the European level.

1.5 Description of the UAP Sanitation project

This research started from the results of the Hydroaid "Technical e-Learning Course on Wastewater Treatment", edition 2020, delivered in May 2020 for a 5-month duration and in collaboration with Politecnico di Torino. The course provided the key elements for the design, management and maintenance of wastewater treatment plants and for the reuse of water for industrial, agricultural and domestic purposes, presenting the possible and most effective technologies, from the most advanced treatments to those technically simpler than natural systems. The training was delivered in English and asynchronously through the Moodle platform, allowing each participant to access the didactic units and interact with each other in thematic forums even in the event of a low internet connection.

It was open to 102 participants from 33 countries. The breakdown of the number of participants by country is represented in Figure 1. 71 participants came from 20 African countries. The first 3 countries with the highest number of participants are African countries: Ethiopia (11), Tanzania (10) and Malawi (8).

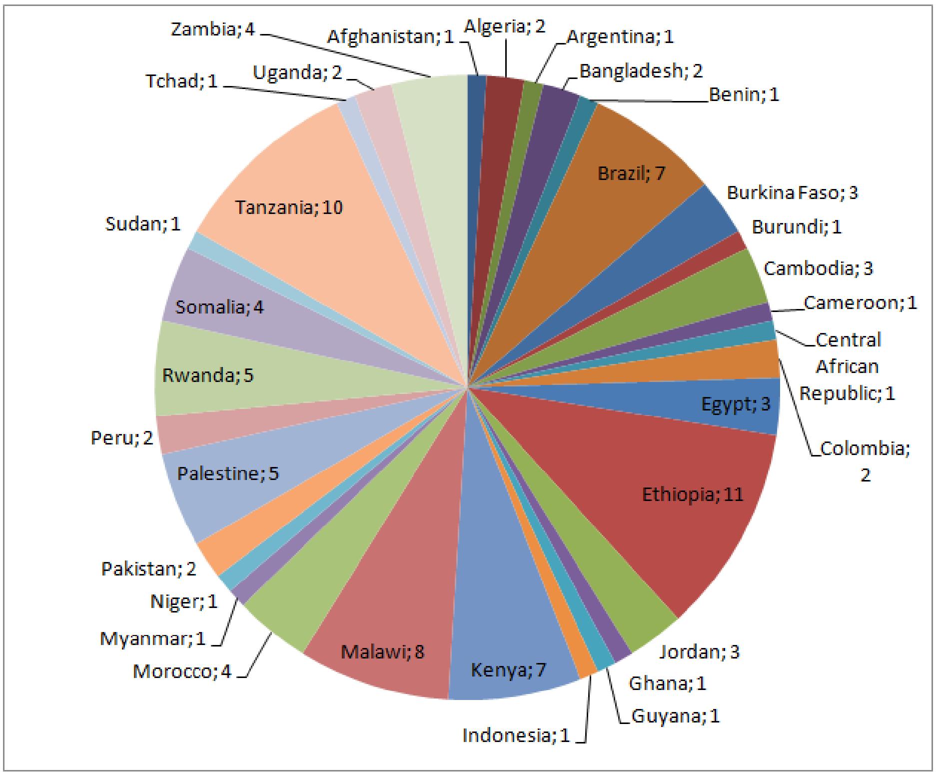

Figure 1 Breakdown of the number of participants by country

The training was structured in the following phases:

- first assignment
- 8 didactic units (weekly provided)
- final assignment

The interaction between the participants and the teacher/tutor and between the participants themselves was possible thanks to the provision of thematic forums or discussions on the platform. The first assignment consisted of a description of the wastewater governance in their own country and in particular the participants were asked:

- to mention the main references documents, such as principles, policy, strategies, etc.
- to point out the main stakeholders, such as regulatory body, service provider, local and national authorities involved, including their roles and responsibilities
- to provide an overview of the wastewater system management, introducing the situation about sewer and treatment plants, weaknesses and challenges to be faced.

The 8 didactic units, weekly provided, deal with basic knowledge on wastewater treatment: features of municipal wastewater; physical and biological treatments; treatment methods for developing countries; fundamental elements of planning, compatibility criteria and management of wastewater treatment plants; sludge formation and management; reuse of treated wastewater and water saving.

Concerning the final assignment, participants had to describe a specific wastewater plant in their own country, including:

- Technical data of the plant
- Main environmental impacts caused by the plant
- Financial data of the plant
- Social impacts on the community
- Common technologies used in their own country

The technical data of the plant included mainly the geographic information, plant size - in terms of equivalent inhabitants, water demand and organic load -, wastewater typology (domestic, industrial, runoff, etc.), kind of preliminary, primary, secondary and tertiary treatments, final destination of treated wastewater, sludge treatments and disposal.

The environmental impacts caused by the plant had to be analyzed mainly with respect to 1) final quality of the treated wastewater that is discharged into water bodies; 2) possible residual pollutants and/or pathogens contained in the reused wastewater (if wastewater is reused); 3) possible residual pollutants and/or pathogens in the treated wastewater sludge; 4) possible emissions into the atmosphere of hazardous pollutants, odours or greenhouse gases deriving from the process; 5) possible impacts of side-products generated by the process (e.g. use of chemicals).

The financial data of the plant concerned the payment or not of taxes or fee by citizens or companies for the sanitation service; the identification of the main stakeholders involved; the economic sustainability or otherwise of the plant; the description of economic revenues or savings due to the recovery of energy (e.g. biogas) and material (e.g. reused water or sludge).

The social impacts on the local community meant to identify aspects, related to religion or habits, in conflict with the operation and aims of the plant, and the impacts of the plant on local population in terms of advantages for the access to sanitation service, generation and remuneration of jobs.

Finally, participants had to describe the technologies commonly used in their own country, the design and performance of the case studied with respect to the technical standards and possible changes which could be occurred in the future.

First and final assignments were particularly useful for the present paper because they can be considered the primary sources of the data and the direct link to the local African contexts, which are continuously in progress.

The first assignments collected were 72, while the final assignments were 65. The assignments came from 26 countries, including 15 African countries. The breakdown of the different assignments received by country is represented in Figure 2.

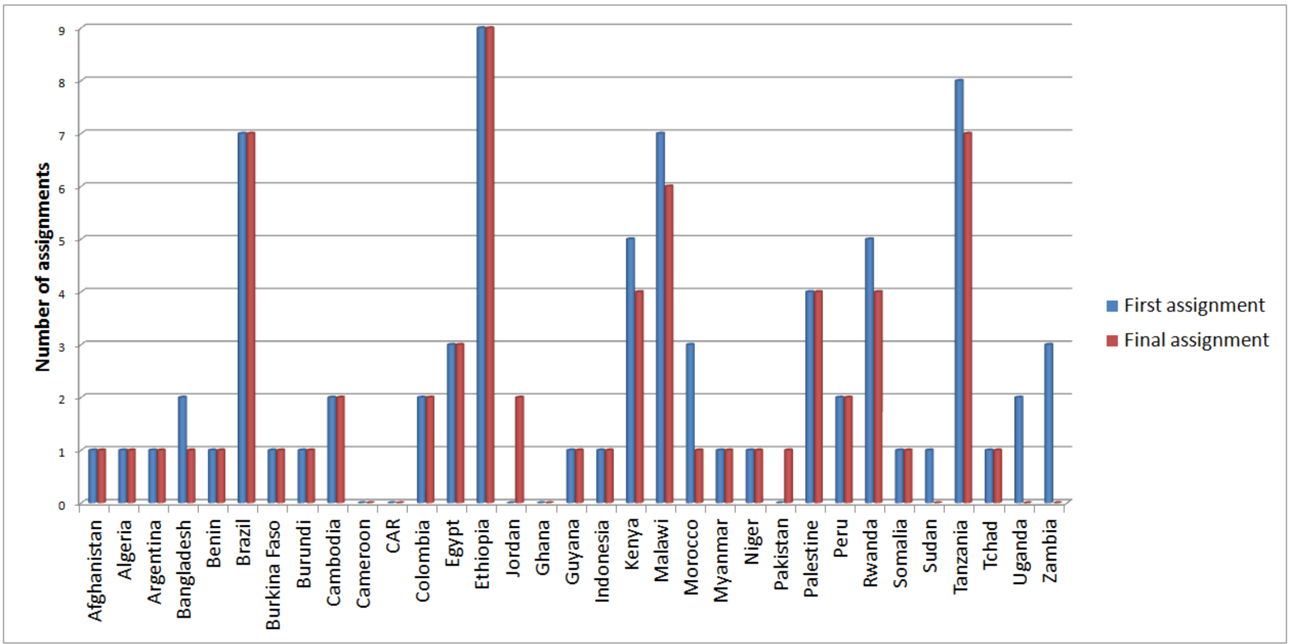

Figure 2. Breakdown of the number of assignments by country

2. Methodology

As above mentioned, the departure point of the drafting of this research is the assessment of the data contained in the first and final assignments received by the participants to the "Technical e-Learning Course on Wastewater Treatment", edition 2020, delivered by Hydroaid in collaboration with Politecnico di Torino.

Firstly, a selection was done among the 15 African countries involved in the training, mainly following the adoption of some criteria listed below:

- geographic area
- quality and quantity of the assignments

The geographic area criterion consisted of representing as much as possible the different African regions (North, West, East, Central and South Africa), in order to take into account, the diversity of the contexts in the continent. Then, the geographic area selected had to be consistent with the Hydroaid strategy, which favours the African countries where the Association has been operating or intend to operate in the near future in the context of the international cooperation projects.

The quality of work is also relevant because it was necessary to have the most significant data on the country's sanitation facilities available. Generally, it is not always easy to have complete and accurate data on sanitation management in African countries. The possibility of obtaining data directly from experts in the sector has been an important advantage that has made it possible to acquire detailed and specific information, otherwise hardly available. Furthermore, it was preferable to have more than an assignment available for each country, as it allows to acquire more information about a country and make redundant data verification easier.

Based on the adoption of these criteria, 4 African countries were selected for this comparative analyse: Egypt, Benin, Ethiopia and Malawi, which cover, as can be seen in Figure 3, most of the different regions identified above.

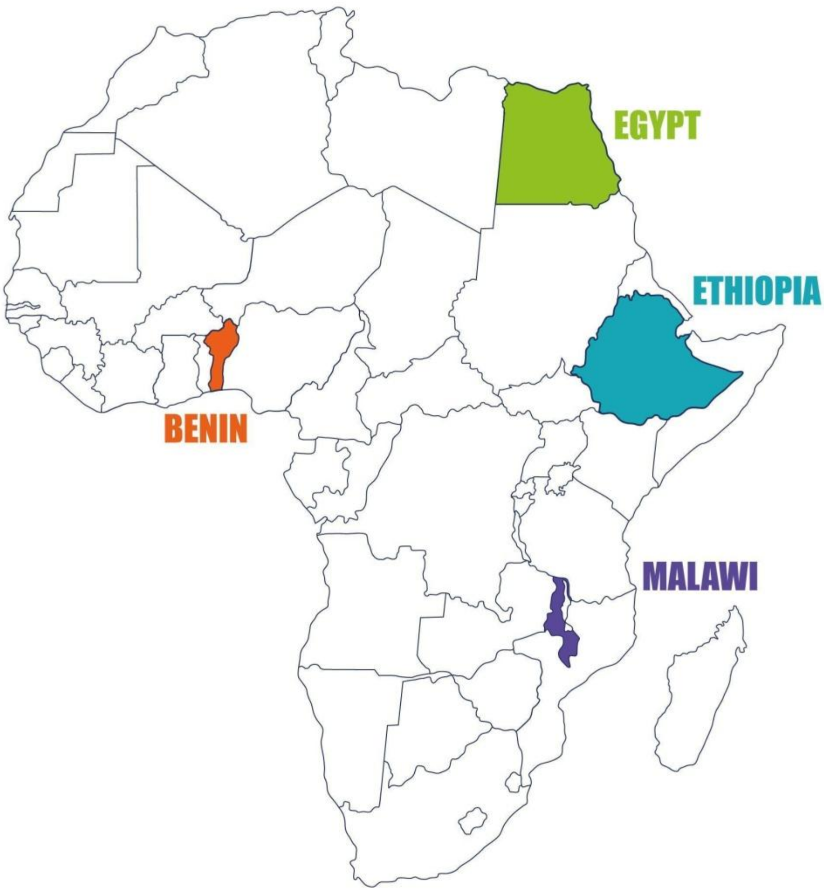

Figure 3. African countries selected for the comparative analyse

The following step consisted in assessing the entire information on each of these 4 countries and collecting it in a single document, a sort of country sheet on sanitation issues containing all the information requested from the participants in the first and final assignment.

Afterwards, this working document was sent to some of the participants of these countries with the aim of updating, verifying and integrating with new information or adding new reference documents (laws, policies, government or local reports, etc.). The participants recipients of this request were the most motivated and active during the training course and rated with the highest scores.

The final phase was the assessment of the final version of the country sheets, elaborating on the one hand the aspects of governance and the national context in the field of sanitation and, on the other hand, the technical, managerial, economic and social aspects of the case studies that have been taken into account.

Among the case studies presented by the students the most complete and interesting in terms of technological solutions are presented. In particular, a wastewater treatment plant of Addis Ababa in Ethiopia and of Lilongwe in Malawi are described.

This research is financed by the Ministry of Foreign Affairs and International Cooperation of Italy - Analysis, Programming Statistical and Historic Documentation Unit in the context of the call for proposals 2020.

3. Status and coverage of WW management

In the present section, main information about status, coverage and challenges of WWT in the selected African countries is reported.

3.1 Egypt

In Egypt, the total length of sewage networks amounts around 45,000 km. Around 60% of the total population is served by sewage system, mostly in big urban areas. Of the rest, 35% has indirect access to sanitation, and nearly 5% have no access. Non-served people may have a private system by the help from community organizations, usually a septic tank. Policies related to the Egyptian water sector are set by several ministries. The Ministry of Water Supply and Sewerage Facilities, established in 2012, assumed the functions of the Ministry of Housing and Urban Communities, which was previously responsible for this sector. The Ministry of Water Resources and Irrigation is responsible for the management of water resources and irrigation and supervises all institutions responsible for providing water and sanitation services. The Ministry of Health and Population is responsible for analyzing the water quality. The Holding Company for Drinking Water and Wastewater, which was established in 2004, is responsible for the financial and technical sustainability of the existing governorate. The Egyptian Water Regulatory Agency, which was established in 2006, is responsible for economic and technical regulation in public utilities. The three institutions that are responsible for planning and overseeing infrastructure construction are the Cairo and Alexandria Potable Water Organization (CAPWO) for the country's two largest cities, and the National Organization for Drinking Water and Sanitation (NOPWASD) is for the rest of the country except for the new urban communities. The New Urban Communities Authority is responsible for water supply and sanitation investments in new societies, through which 29 drinking water stations have been built that serve 5 million residents of those communities, 10,000 km of water pipelines, and 7,000 km of pipelines sewerage, and 26 wastewater treatment plants. The HCWW Holding Company and its 26 subsidiary companies are responsible for the operation and maintenance of water and wastewater. In Egypt, the main reference that controls the wastewater management process is the Egyptian Code for Sanitary Drainage Networks [7].

3.2 Benin

According to a survey conducted in Benin in 2018 by the National Institute of Statistic and Economic Analysis (INSAE), only 12.8% of Benin citizens have access to a suitable sewage system [8]. The majority of the population use the self-built sewage systems, or have access to community latrines. Wastewater is largely disposed of in courtyards or streets. In Benin, sanitation is relatively young and became prominent in 2003. The central government saw the need to decentralize sanitation to the municipality level. Results from this strategy saw the development of sanitation and sewerage facilities in the big towns. In the rural areas, the use of toilets and the practice of basic hygiene at home and schools was encouraged. Benin republic has its own legal framework regarding wastewater management. This is contained in the following reference strategic documents: National Strategy for Wastewater Sanitation in Urban Areas (2008-2015) [9], National Health Development Plan (2009-2018) [10], Benin Blue Book [11], National Water Policy [12] and Decree 2001-109 of 4 April 2001, fixing the quality standards of residual water in the republic of Benin [13].

Regarding the main actors in wastewater management, the Ministry of Mines, Energy and Water develops and coordinates the implementation of the government's policy in the water sector. The Health Ministry develops and coordinates the implementation of the government's policy in the hygiene and basic sanitation sector. The National Directorate of Public Health (DNSP), attached to the Ministry of Health promotes hygiene and basic sanitation in rural areas, relayed locally by the SHABs (Departmental Hygiene and Basic Sanitation Services). The National Water Society of Benin (SONEB) is in charge of drinking water supply, sewage disposal and treatment in urban areas. Municipalities are the owners of water and sanitation utilities and those responsible for planning, financing, building and operating drinking water supply and sanitation infrastructures in rural and urban areas. Finally, local and collective NGOs elaborate and coordinate projects, ensure their management as a support operator for municipal project management, often in partnership with decentralized and non-governmental cooperation actors.

3.3 Ethiopia

According to the 2014 WHO/UNICEF Joint Monitoring Program for Water report [4], 73% of Ethiopia's urban and 77% of its rural population used unimproved sanitation facilities, with 8% in urban and 43% in rural communities practicing open defecation. In general, sanitation systems are present in larger urban areas like Addis Ababa (capital city), and State/Regional capital cities. In the rest of the country, community sanitation is poor. In recent decades, urban sanitation interventions have focused on increasing access to improved toilet facilities, with little attention paid to ensuring that wastewater is adequately collected and treated prior to discharge into the environment. Despite the availability of Health Extension Workers (HEW) in all Ethiopian towns, more than 60% of households in urban areas use traditional pit latrines and about 6% of urban residents are still practicing open defecation. Faecal sludge is often accumulated in poorly designed and built pits, and then discharged directly into storm drains, open water bodies, seep into the ground or is manually removed from the pit and dumped into the environment. Addis Ababa is the only urban centre with sewer connection in Ethiopia, that serves about 10% of the population.

In Ethiopia, the Ministry of Water Irrigation and Electricity (MoWIE), Ministry of Urban Development and Construction (MoUDC), and Ministry of Health (MOH) share responsibilities for monitoring and oversight of the hygiene and sanitation services at the national level. Water and Sewerage Authorities in each municipality are legally mandated to provide sanitation services in the large cities. In most of the cities, municipalities are responsible for managing wastewater management. The regional Water Bureau mainly supervises the construction of water supply utilities. They also supervise the activities of water supply and sanitation projects undertaken by private agencies, like NGOs. The constructed facilities will be then handled by the town administration. Town water utilities are accountable to Water Boards. The Water Boards act on behalf of the town administration [14]. While Utilities are directly accountable to an autonomous Water Board, which are in turn partly regulated by the Regional Water Bureaus. The MoUDC, in its effort to exercise its mandate of monitoring standards of municipal services, also plays a part in monitoring the performance of utilities.

Main regulatory policies include the Environmental Pollution Control Proclamation n° 300/2002, developed by Ministry of Environment, Forest and Climate Change (formerly EPA); the Ethiopian Public Health Proclamation n° 200/2000, developed by Ministry of health; the Proclamation n° 661/2009 developed by the Food, Medicine and Health Care Administration and Control Authority; and the National Strategy for Improved Hygiene and Sanitation [15].

3.4 Malawi

Malawi is one of the most densely populated countries in Africa, with a population density of 129 persons/km^2 [16]. As reported by Msilimba and Wanda (2014) [17], about 15% of the population is connected to waterborne sewerage and 15% to septic tanks. It is estimated that only 5.4% use flush toilets (to sewer and septic tanks), 1.4% use Eco-san toilets and the remaining 93.2% relies on pit latrines [18]. The main centralized treatment plants are located in the cities of Blantyre, Zomba, Lilongwe, and Mzuzu. For instance, wastewater flow diagrams reported in Figure 4 and Figure 5 for Blantyre City and Kasungu municipalities reveal that 34% and 66% of liquid waste generated in Blantyre and Kasungu respectively is safely managed. For offsite sanitation, only 1% out of 10% wastewater contained is treated, 8% of wastewater is not delivered to treatment, remaining 1% is not treated for Blantyre city. In Kasungu, in terms of offsite sanitation, only 1% out of 5% wastewater contained is treated. 3% of wastewater is not delivered to treatment while remaining 1% is not treated [19] [20].

The majority of inhabitants in the municipality just discharge the untreated wastewater in the storm drains and natural waterways. A minor part discharges the wastewater in their household septic tanks which discharge into the soils or is collected by the City councils. Mostly, when the latrine is full, they abandon it and dig another. Effluents from septic tanks are collected and discharged into sewerage systems by either city councils or private operators who operate emptying business. Mr. Clean Malawi is a good example of business of emptying the septic tanks and pit latrines in Mzuzu City.

In Malawi, wastewater generation has increased due to an increase in population, urbanization and industrialization [17]. Key policies and legislation guiding management and operations of wastewater in Malawi include Guidelines for the Design, Operations and Maintenance of Waste Stabilization Ponds in Malawi (2012), Waterworks Act (1995) [21], Water Resources Act (2013) [22], National Sanitation Policy (2006) [23], Local Government Act (1998) [24], Public Health Act (1948), and quality standards guided nationally by the Malawi Bureau of Standards (MBS MS539:2002 and MS691:2005) [25]. International and regional standards and guidelines such as World Health Organisation (WHO) may also apply to complement the national standards. The legislation and policy mandate ministries and departments responsible for water affairs, sanitation and public health to manage, monitor the development of water resources, utilization and safe disposal of liquid waste among others in order to protect the environment.

In Malawi, the process of treating water and managing wastewater is done by the government with support from private entrepreneurs, Non Governmental Organizations and Donors. The National Water Resources Authority (NWRA) regulates and protects water resources quality from adverse impacts; issues water abstraction and effluent discharge rights; monitors and enforces conditions attached to permits for water use. District assemblies oversee the implementation of decentralization policies, including for water resources management, and implement water and sanitation goals under decentralization reforms. City and regional water boards (i.e. Southern Region Water Board; Blantyre Water Board; Central Region Water Board; Northern Region Water Board) are responsible for water supply to regions, and work with governments and community agencies to implement water and sanitation goals. Private entrepreneurs are mainly in the construction of latrines, septic tanks, pit emptying and transportation of waste to the wastewater treatment Plants. NGOs and community-based organizations provide support to the construction of sanitation facilities, mainly in rural areas. Donors, mainly the World Bank and the European Investment Bank provide financial supports and loans to the government.

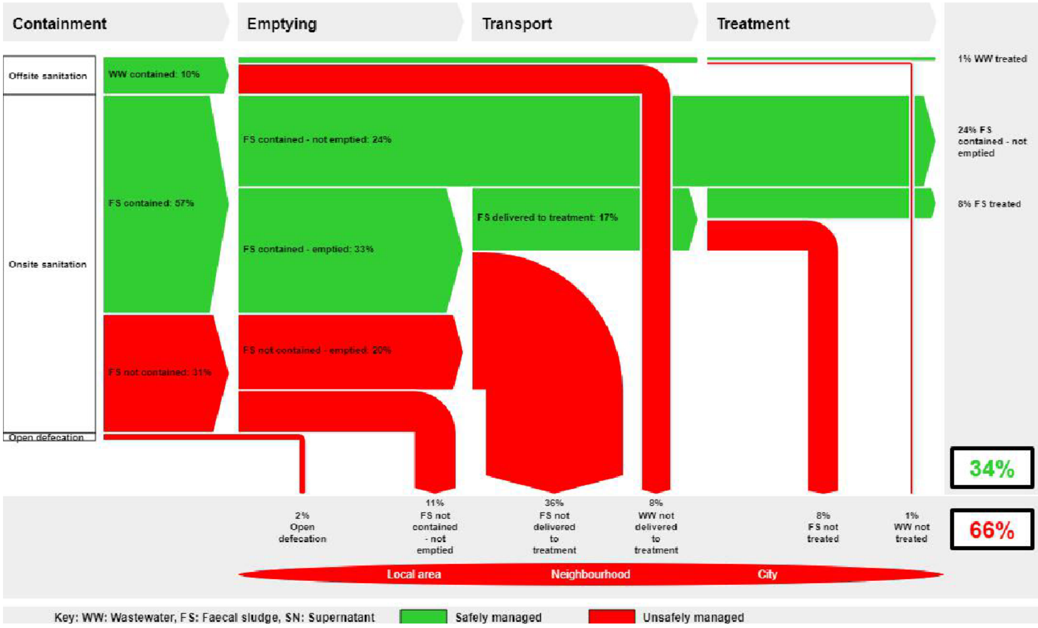

Figure 4. WW flow diagram of Blantyre city, Malawi [19]

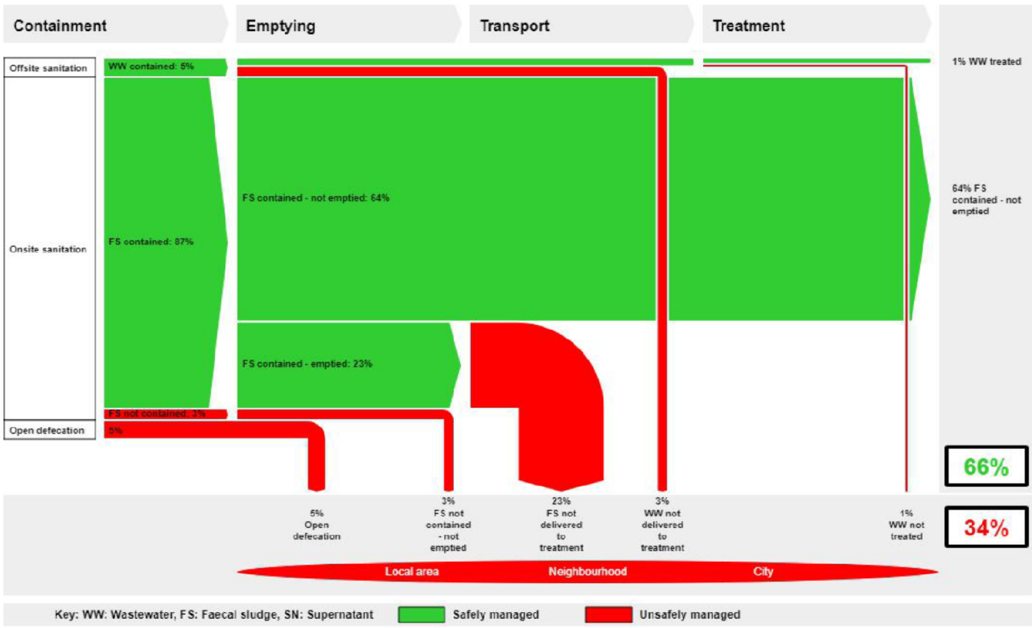

Figure 5. WW flow diagram of Kasungu city, Malawi [20]

4. Case studies

The case studies reported in this study are two centralized WWTPs serving highly populated urban areas. The first is the Kaliti WWTP, located in Addis Ababa, Ethiopia. The second is the Kauma WWTP, located in Lilongwe, Malawi. The technical configuration of the process of each case study is reported in Table 1. Single cases will be analyzed in the following.

Table 1. Main features of the processes

Plant name	**Kaliti WWTP**	**Kauma WWTP**
Location	Addis Ababa, Ethiopia	Lilongwe, Malawi
Altitude (m. above sea level)	2,200	1018
Geographical area	Flat land with hilly areas	Flat land
Climate type:	Humid subtropical	Sub-tropical
Territorial constraints:	No territorial constraints are present	Environmentally protected area; Landscape protected area; Hydrogeological risk area.
Equivalent inhabitants:	2,270,000	55,000
Average daily water demand per inhabitant (l/hab/d)	n.d.	40
Average organic load only for domestic wastewater (gBOD5/hab/d)	32	26
Wastewater typology	Chemical industry; Textile industry; Meat and sausage industry	Domestic
Type of wastewater treatment plant	Anaerobic plant	Both
Other input data		Physical and biological treatments take place at the WWTP through stabilization ponds
Preliminary treatments	Grit chambers and screens	Screening; Grit tank; Equalization tank
Primary sedimentation	Circular	Rectangular
Organic load treatment	Trickling filters	Maturation ponds
Nutrient abatement	No treatment	No treatment
Secondary sedimentation	Circular	Rectanguar (stabilization ponds)
Filtering	Constructed wetlands	No treatment

Disinfection	No treatment	No treatment
Indicate the final destination of treated wastewater	Irrigation and agricultural purposes	Discharge into Lilongwe River
Sludge thickening	Gravity thickening	No treatment
Sludge stabilisation	Anaerobic digestion	Aerobic digestion. The aerobic digestion takes place in the Facultative oxidation ponds for a maximum retention period of 21 days after which the wastewater is discharged into the receptor body.
Sludge hygienisation	No treatment	No treatment
Sludge drying	Sludge drying beds and lagoons	Sun dried. After sedimentation has taken place in both anaerobic and facultative ponds sludge is directed to drying ponds/beds through gravity.
Sludge Incineration	No treatment	No treatment

4.1 Kaliti WWTP (Addis Ababa, Ethiopia)

Addis Ababa is the capital and largest city in Ethiopia. It is located on a plateau in the centre of the country, at an elevation of 2,200 metres and forms part of the watershed for the Awash River. The city is the seat of government of Ethiopia and the country's financial, commercial, educational, and media centre. The population was estimated at 4.4 million in 2017.

The Addis Ababa Water Supply and Sewerage Authority (AAWSA) provides, among other services, water and wastewater (mainly human excreta) collection and disposal services. There are also other actors (such as the private sector and NGOs) involved in the area of wastewater collection and disposal activities. The major wastewater disposal system in Addis Ababa, as it is the case in other big cities and medium towns of the country, is by use of vacuum trucks. According to the recent data of AAWSA, wastewater practices in the metropolitan area are poor [26]. The estimated wastewater production in the area is 398,985 m^3/day. From the total wastewater which should be removed in the Metropolitan only 0.43% are disposed every day. It is estimated that in Addis Ababa city, only 7.2% of the liquid waste is disposed in appropriate way and the remaining 92.8% is disposed inappropriately in to rivers and rainwater channels. The Kaliti Catchment is the only one where a sewerage facility exists with a central wastewater treatment system. It is the North West part of the city covering an area of 210 km^2, including the centre of Addis Ababa. According to the 2007 census, 14.3% of the housing units in Addis Ababa had no toilet facility and 51% of the households use private and shared pit latrines [27].

The first design capacity of the Kaliti WWTP was about 7,500 m^3/day with a biochemical oxygen demand load of 3,500 kg/day. Currently, the inlet flow is up to 47,500 m^3/day, reaching the double during the rainy season. The Kaliti wastewater collection system was designed on the basis of average water consumption of 150 l/capita/day to serve an equivalent population of 200,000 people. The Kaliti WWTP is currently over loaded and new expansion and rehabilitation of the treatment plant is presently under construction.

The plant constructor claims that following construction of the WWTP and during the pre-commissioning and commissioning of the plant, AAWSA provided staff training to facilitate the take-over of operations and maintenance. The Contractor trained 35 of the client's staff members, however, when the time came for the takeover only 18 of the trained staff showed up. Meetings with AAWSA management were held to stress the importance of maintaining and operating the plant and emphasize the importance of having enough staff available 24/7.

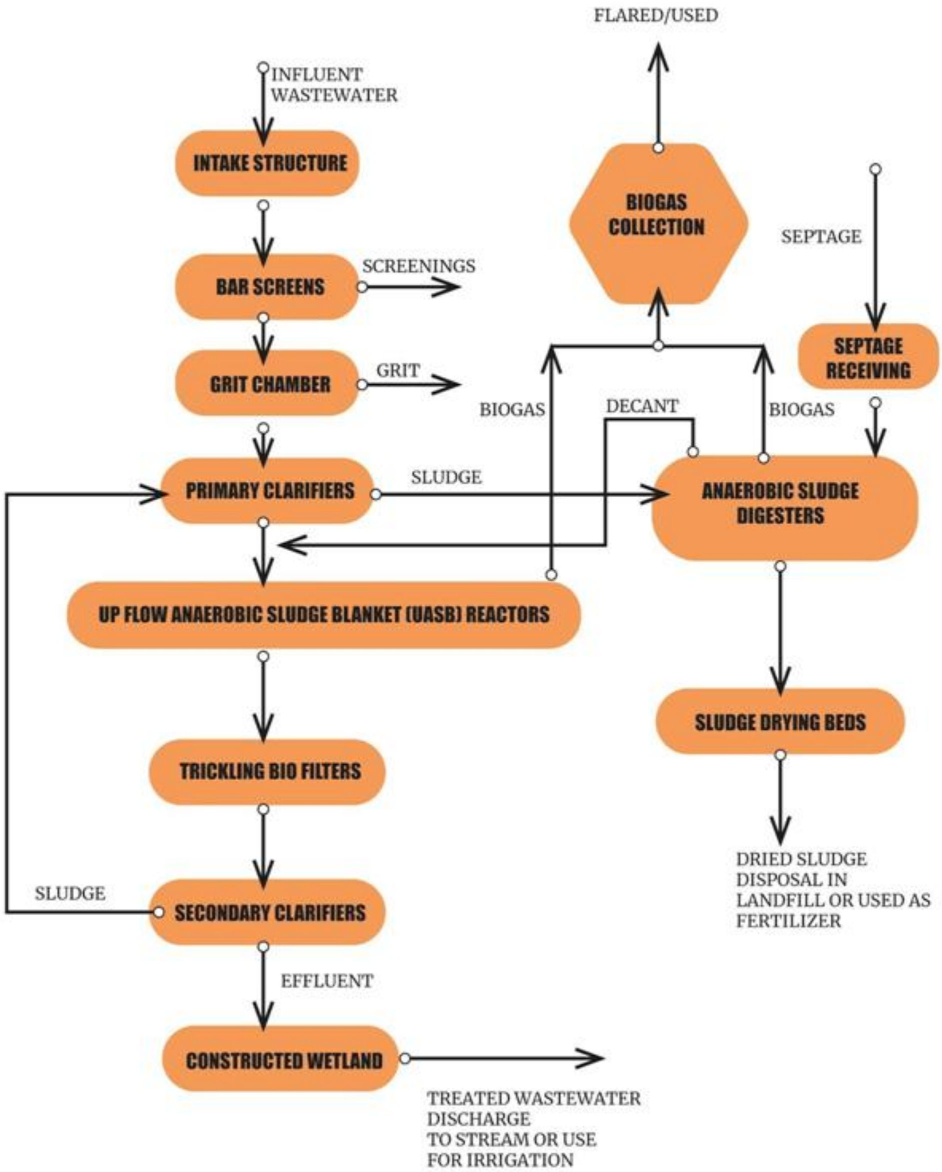

Figure 6. Kaliti WWTP process scheme

Grit chambers and screens are used as primary treatment. The choice of circular clarifiers was mostly the preference of the designer. For organic load removal, an UASB (Upflow Anaerobic Sludge Blanket) process and trickling filters are used. UASB reactors are attractive in tropical countries because they work better at mesophilic conditions. No additional treatment is present to reduce the nutrient load. After the UASB treatment, effluent is conveyed to secondary sedimentation, then to facultative and maturation ponds. Plant upgrading projects aim at transforming these ponds into engineered wetlands. Free Water Surface (FWS) wetlands are preferred because they are much simpler and less costly to adapt from an existing pond. Wetlands are generally effective in removing nutrients, metals and organics from wastewater [28] [29]. In addition, pollutants coming from industry activities - which could inhibit plant growth in agricultural fields or cause health problems – will be removed. The sludge produced by the process is treated by gravity thickening, then dewatered in drying beds and lagoons. Based on these data, the Kaliti wastewater treatment plant discharges the effluents difficult to reuse for irrigation.

Treated effluent is discharged into the Akaki river. The wastewater irrigation practices in Akaki River have got the attention of researchers due to its high economic benefit and adverse effects on farmers, public health, and the environment. Since the 1940s, a variety of vegetables have been produced within and around the city, mainly using water from the Akaki River. The irrigation is carried out informally by smallholders without conventional irrigation infrastructure. They provide about 60% of the vegetables on the cities' vegetable markets, which provides their main source of household income [30] as cited by Van Rooijen (2009) [31].

The effluent quality of Kaliti WWTP is reported in Table 2, compared with the WHO existing standards for irrigation purposes. Considering the overall data, the value of BOD concentration reported by Abiye et al. [32] seems not representative of the plant and therefore it is not considered. These data show that wastewater in Kaliti wastewater treatment plant does not fulfil the reference standards for irrigation. Total coliform content reported by Abiye et al (2009) is above ten times the limit value.

Table 2. Effluent quality of Kaliti WWTP

Parameter	Unit	WHO standard (2006) [33]	Gebresilassie (2020) [34]	Abiye et al. (2009) [32]
COD	mg/l	60	202	231
BOD	mg/l	20	133	23.3
TSS	mg/l	30	66	560
Helminthes	#eggs/l	1	No data	No data
	E. coli/l	105	No data	1,200

4.2 Kauma WWTP (Lilongwe, Malawi)

Lilongwe is the capital and most populated city of Malawi. It has a population of 989,318 as of the 2018 Census. The city area is 328 km^2. Lilongwe is located on a plateau in Central Malawi, forming part of the East African Rift Valley situated at an altitude of 1,050 m above sea level, along Lilongwe River. The area has a sub-tropical climate characterized by seasonal changing wet (November to April) and dry (may to October) conditions.

The area has an average annual temperature and rainfall of 21° C and 852 mm (2003–2012 averages), respectively, with a rainy season between November and April. The city has many zones defined by housing density (low, medium and high density zones) and industrial zones. The higher density housing zones correlate with medium and lower incomes and vice versa [35]. Water supply in Lilongwe is managed by the Lilongwe Water Board (LWB; as stipulated by Malawian legislation). Water is currently supplied to about 70% of city residents [36].

In terms of hydrogeology, during recent years Lilongwe city has experienced floods during rainy season. This is probably due to infrastructural development and poor drainage system within the city.

The plant is located in the city of Lilongwe and in selected areas. Specifically, the areas are Area 1, 15, 47, and 49. Figure 7 shows the network areas and the Kauma Treatment Plant area

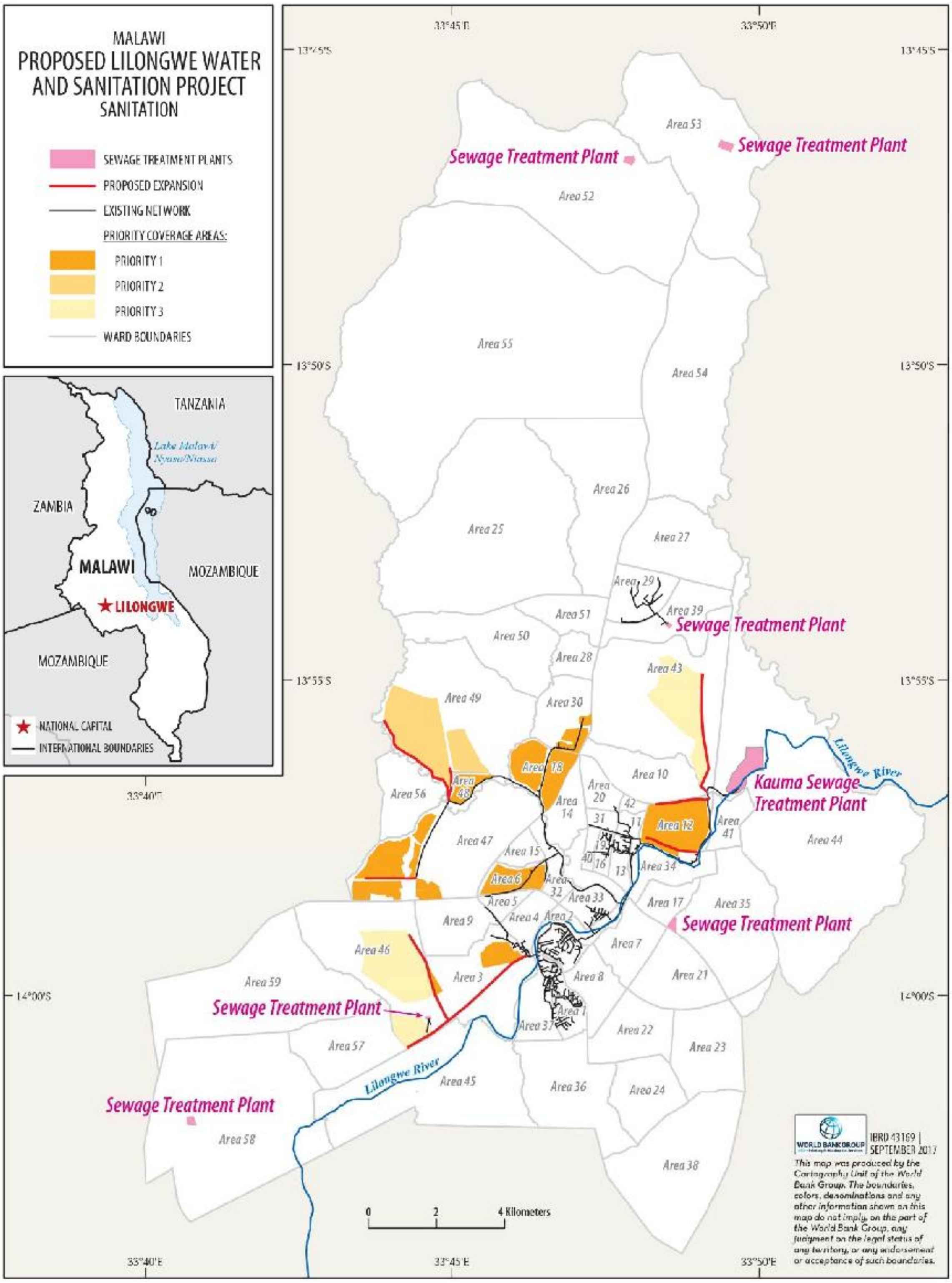

Figure 7. Map of the sewage network in Lingongwe and location of the Kauma WWTP [37] [38].

Physical and biological treatments take place at the WWTP through stabilization ponds (Figure 8 and Figure 9). Preliminary treatments are performed with screening bars, grit tanks and equalization tanks. Primary sedimentation takes place in rectangular tanks. Here the influent is treated anaerobically. Maturation ponds are the secondary and the final stages in the treatment process. The dissolved organic matter is allowed to settle at the bottom of the ponds and form sludge which is manually removed by trucks after drying up. Sub-tropical type of climate provides favourable condition for this type of secondary treatment, due to its simplicity in construction, flexibility with respect to degree of treatment, low maintenance requirements, low energy consumption and easiness to operate. The dissolved organic matter is allowed to settle and after 21 days the effluent is conveyed to three stabilization ponds for further same treatment process. No treatment is foreseen to reduce nutrient concentrations. No tertiary treatment is performed. This may also be attributed to costs for buying the chemicals, energy and the plants where to apply the process. Treated wastewater is finally discharged into the Lilongwe River.

There are no associated plants for sludge treatment in the WWTP. The costs for construction, energy and operation and maintenance of such plants are the main constraints. Sludge aerobic digestion takes place in the facultative oxidation ponds. Sludge is dewatered before it is removed in order to reduce water content. Sludge is dried for at least a month after draining the facultative ponds. After sedimentation has taken place in both anaerobic and facultative ponds, sludge is directed to drying ponds/beds through gravity. Here water content from the sludge is reduced through evaporation. The dried sludge is freely removed for various soil Agricultural improvements. People or farmers tend to use it as inorganic fertilizer or as soil improver. Dried sludge is provided for free.

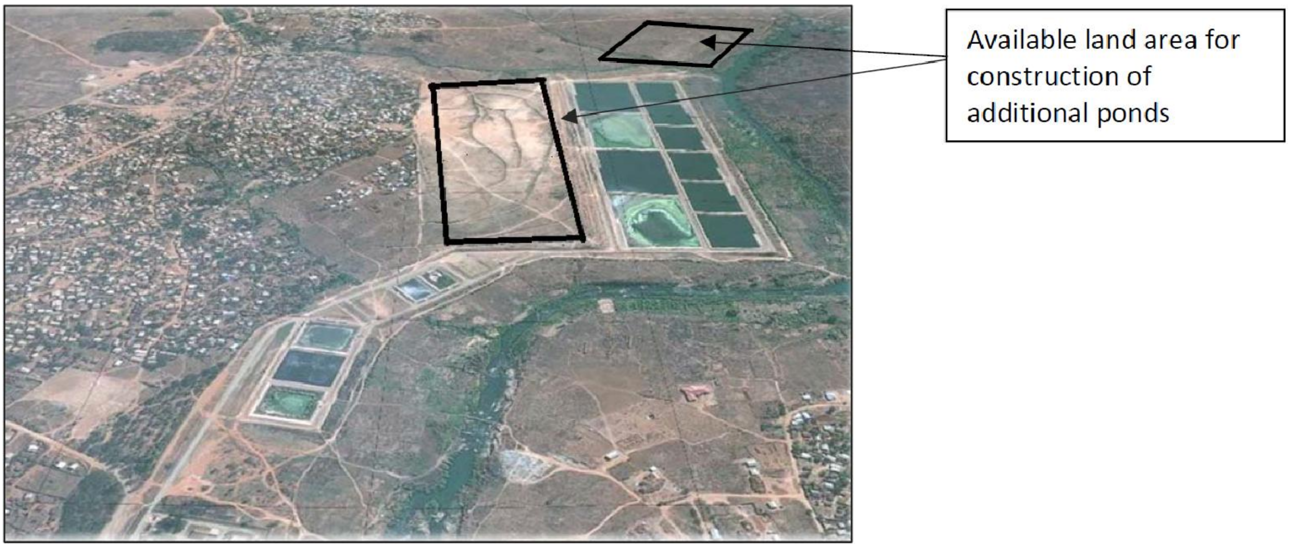

Figure 8. Existing Kauma Sewage Ponds and Expansion Area [38].

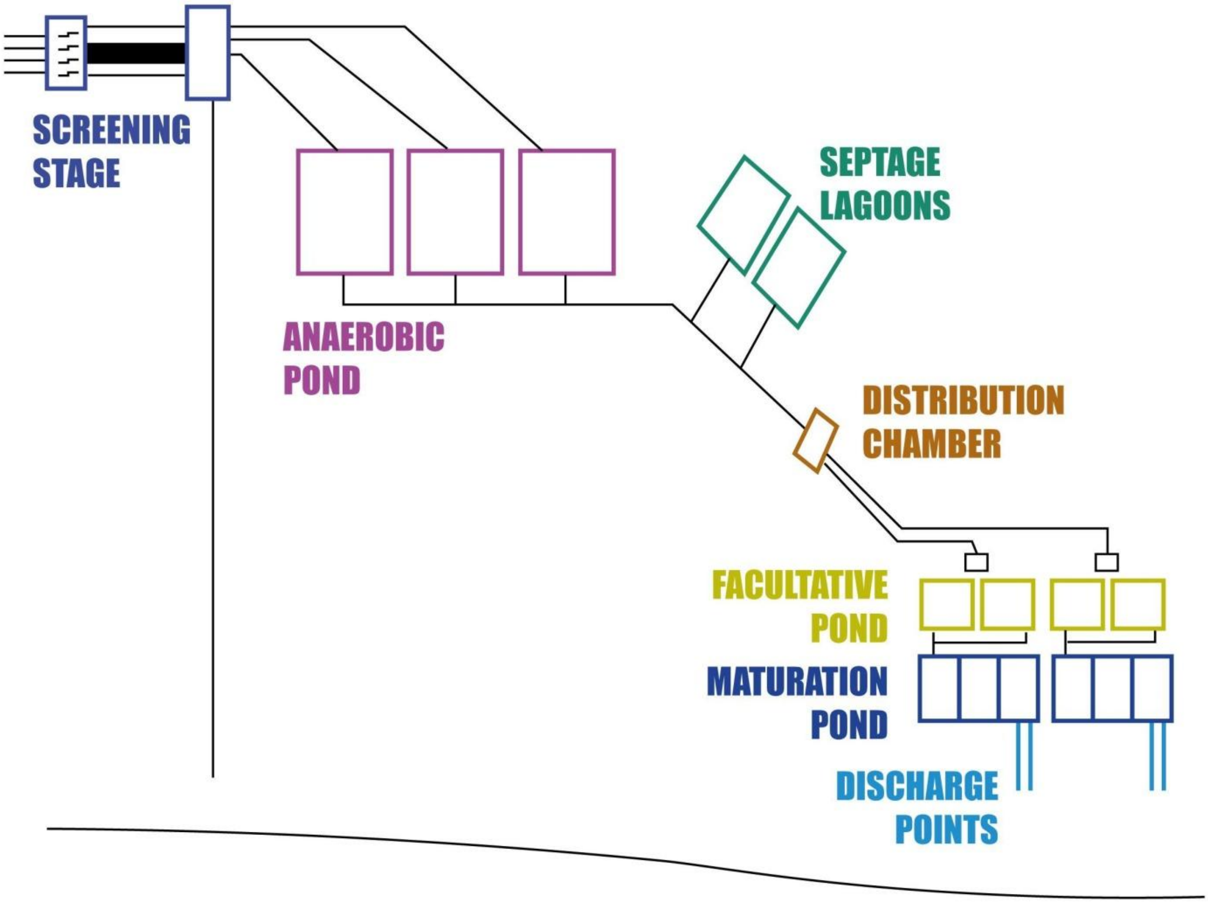

Figure 9. Sketch for Kauma Sewage Treatment plant. Not drawn to scale [39].

Project implementation was governed by a set of four agreements. The World Bank signed a financing agreement with the Ministry of Finance, Economic Planning and Development (MoFEPD) as the recipient of the credit/grant. MoFEPD in turn, signed a subsidiary financing agreement with Lilongwe Water Board (LWB) with terms and conditions acceptable to the World Bank. All project operational modalities were detailed in a Project Implementation Manual [38].

Donors such as European Investment Bank support the government in operations and maintenance whenever necessary. Citizen pays for water bills which contribute to maintenance and operation of the treatment plant.

Sewer network expansion is limited to those areas of the city that are within the vicinity of an existing trunk sewer. Priority of sewer expansion areas identified include Area 3, 6, 12, 18, 30, 47 and 48 in the Lilongwe City (Figure 7). However, most of the locations in the City have been left out of the sewer line. Some communities are connected to sewage systems while majority of population use septic tanks. In some areas, there is no running water and people use pit latrines. The WWTP is gravity fed by the pipe network system. So, the communities that are on higher elevation are connected to the network unlike those that are on the lower elevation, otherwise they would have to use pumping.

The plant construction and management provided job opportunities to various skilled and technical levels. During construction, for example, plant operators and builders had an opportunity to get employment. The plant also generates jobs for private companies for pit emptying and transportation of wastes to the treatment plant. Currently, the plant personnel consist of 6 skilled and 10 unskilled units.

Concerning the quality of the effluent, recently an analysis of samples taken from the maturation ponds indicated a high level of faecal coliforms, meaning that the quality of effluent does not meet required standards (Table 3).

Table 3. Effluent quality of Kauma WWTP.

Parameter	Ref. [40]	Ref. [41]	MBS	WHO
COD	39 – 97	21 – 55.1	60	60
BOD_5	13 – 19	14.2 – 35.8	20	20
TSS	21 – 84	93 – 118	30	30

The following issues were reported on the plant, that possibly contribute to the low reported efficiency of the plant:

- Grit chambers and distribution chambers were cleaned less frequently than desired
- Effluent discharge pipes were not cleaned at all
- Greasing of gate valves and movable weir spindle shafts was not done
- Monitoring of effluent quality was not done
- Desludging of anaerobic ponds was done once every two years
- Filling of a pond maintenance record sheet was not done
- Equipment and materials for Operation & Maintenance works were reported not working
- Lack of resources was reported as the main cause for not carrying out some O & M activities

Recently, the LWB announced a rehabilitation and upgrading project of the Kauma WWTP, that should include the following actions:

- Desludge and rehabilitate the existing ponds;
- Construction of additional facilitative and maturation ponds to increase the treatment capacity from estimated 6,000m^3 to about 8,700m^3 per day;
- Flow measurement equipment installation

The sub project under Priority Sanitation Improvements will finance rehabilitation and expansion of about 92 km of sewerage network and connecting approximately 5000 new households to the sewer network and upgrading of the Kauma WWTP.

5. Sustainability aspects

The information collected throughout this research project, as well as the analysis of the case studies proposed by the participants, rise important point of discussion with respect to the current sustainability of sanitation practices in African countries. Following the project structure, the evidences collected were separated into environmental, economic, social and technical aspects. The main findings are resumed in the following.

5.1 Environmental and sanitary sustainability

The evidences collected confirm a significant lack of water sanitation in all the African countries. The analysis of case studies reveals that few centralized WWTPS are present and, in principle, their design respected the common standards. Nevertheless, the available data show that the treatment facilities do not fully treat the wastewater to the standard, as evidenced by effluents with high concentration of BOD, coliform bacteria, total phosphorus, total nitrogen and turbidity [42] [40]. The concentration of these parameters does not comply with country (if present) and WHO standards. In addition, operations errors in the water distributions systems were reported, for which population was exposed to unclean water. This causes the pollution of superficial water bodies posing environmental and health threats to the entire river basin ecosystem. In addition, bad functioning causes gaseous emissions that pose a threat to human settlements surrounding the WWTPs.

The potential impacts and the sanitary risk are not really taken into account. In Egypt, the mismanagement of the by-products of wastewater treatment from unofficial suppliers lead to mixing sewer with water that finally lead to health issues like diarrhoea in children and hepatitis C virus, that affects 35 million people in the country. In Benin, common waterborne diseases include Malaria, diarrhoea, typhoid fever and abdominal pain. In Ethiopia, up to 60 percent of the current disease burden is attributable to poor wastewater management and sanitation systems, whereas 15% of total death are from diarrhoea, mainly among children under five. In Malawi, the most common waterborne diseases include diarrhoea and cholera (but also typhoid and bilharzia). Treating of such diseases has a great impact on economy of the countries.

Owing to the information collected, all the considered countries have environmental impact assessment (EIA) regulations. In all the selected cases, plant construction and operation were subject to EIA. For the

Kaliti WWTP, the operation of the plant had a detailed environmental and social monitoring plan that was implemented in collaboration with stakeholders of various kinds. Such integrated management plan established a Project Steering Committee (PSC) that is composed of the Addis Ababa Water and Sewerage Authority (AAWSA), The ministry of Works and Urban Development (MoWUD), Addis Ababa Environmental Protection Agency (AAEPA), and representatives from affected Kebeles (administrative units). For the Kauma WWTP, plant construction was subject to EIA procedure as required by the Environmental Management Act of 1996. Nevertheless, the correct application of environmental standards is still lacking.

Besides wastewater, sludge management also represents a threat to the environment and public health. In the observed cases, sludge is commonly dried on large lagoons and drying beds and that may cause some form of groundwater pollution. In addition, if dried sludge contains heavy metals and aromatic hydrocarbons, these substances would not be removed by the treatment facility. Even if technically hard to be implemented, sludge anaerobic digestion with biogas production overcomes part of these issues. In Kaliti WWTP, 42,820 kg/d of solid are produced from the sludge digesters, which will be dewatered, stored on site and used as fertilizer. An estimated amount of 2,000 m^3/d of methane can be produced from the proposed sludge digesters.

The operation of WWTPs should be improved so that the following measures are put in place against environmental pollution:

- Leakages of wastewater to groundwater should be avoided;
- Sludge drying beds should be impermeable;
- Efficient drainage system for leachate and flood protection structures must be constructed
- Temporary sludge disposal sites should be impermeable and protected from flood

Also, as African urban areas are continuously evolving, there should be a territorial protection for human settlements to limit population exposure, which should be enforced by local administrations.

5.2 Economic sustainability

The major actors that participate in waste water management in the context of the selected African countries are Governments (Ministries of water, irrigation, environment and health), regional water Boards and municipalities of cities. Central administrations issue the general urban wastewater management strategy and water resource policies that regulate the handling, collection, treatment and effluent release. The case studies presented were both financed by the World Bank through the signing of a set of agreements with local authorities. The operation and maintenance of WWTPs are under the supervision of such national and local authorities, for example the Holding Company of Water and Wastewater in Egypt, the AAWSA in Ethiopia or the LWB in Malawi.

In general, plant management is not economically sustainable. The main observed failures in O&M may be due to financial constraints. Plants require regular maintenance activities in the ponds, pipes and distribution structures. In Malawi, the Kauma plant has been receiving funds from City council to carter for operation cost, still with support from the World Bank, but the system is not self-sustainable. Other sources of funds (a small amount) may come from sewer connection fees and disposal fees which come from septic tanks and pit latrines. Also, due to lack of funds, plants are not expanded in order to satisfy the population growth. Nor upgrading works are possible, in order to achieve a higher quality at discharge. The reuse of reclaimed water or sludge cannot provide any significant economic revenues to be distributed among the community. Sludge is recovered but it does not generate economic revenues as it is provided freely to the individuals or companies as one way of getting rid of the material. The only exception, as seen for the Ethiopian case, is represented by anaerobic digestion of the sludge, were sludge is recovered for soil reconditioning and biogas is used for electricity generation. However, the revenues collected from sludge treatment do not fully cover the expenses for running the plant. Another major problem is that citizens are not willing to pay for wastewater treatment. Majority of citizens can pay for pit emptying and transportation of wastewater but may not pay for wastewater treatment. This means that the government and the donors have almost no income from sanitation taxes and fees.

5.3 Social sustainability

According to the information collected, there was complete agreement among all participants in that WWTPS are socially accepted as there are no aspects related to religion or habits that are possibly in conflict with the operation and aims of these plants. The project reported in the case studies received support both by the community and the different stakeholders involved. According to the data reported by the participants, all district and sub-city authorities and experts of the different sectorial offices fully supported the projects. There were no people or groups excluded due to religion, custom, or habit. In Kaliti, the construction of the plant created temporary jobs and the emergence of small business activities around the plant, that are beneficial socio-economic impacts.

5.4 Technical sustainability

Currently, the practice of wastewater management in African countries is at an infant stage. Despite the regulations, there is low enforceability. In some countries like Benin, there is neither industrial nor municipal wastewater treatment. A part of waste waters generated by industrial, commercial and domestic activities is collected by sewage systems without any further treatment and the other part is directly disposed of in courtyards and streets. In Egypt, Ethiopia, and Malawi, the common treatment methods are lagoons and drying beds. Especially in rural areas, most of the time the community uses decentralized sanitation systems such as pit latrines, ventilated pit latrines and septic tanks. These facilities are mainly concerned with reducing the sediment load rather than removing most of the harmful chemicals and pathogens. These dominant treatment types mainly remove just about 30% of the organic wastes and 50% of suspended solids and bacteria [39]. The quality target of the effluent is set to use the water for agricultural practices. Since secondary and tertiary treatment are not performed, nutrients such as nitrogen and phosphorous as well as pathogens like E. coli remain in the effluent. Also, heavy metals and organic contaminants may remain in the wastewater or sludge.

Wastewater generation has tremendously increased due to increase in population, urbanisation and industrialisation. Centralized WWTPs need to be designed in order to foresee their future expansion, to accommodate more flow. In several cases, the sewer system is not properly working due to e.g. sewage system breakdown, sewer lines blockages occur due to poor maintenance, improper design of some sections, and also lack of public awareness on use of the sewerage systems. A case study presented of a pilot WWTP in the University of Abomey-Calavi, Benin, showed that pond systems, if well managed, can reach reasonable performance levels. The plant is made of an anaerobic pond, a facultative pond and two series of maturation ponds. The effluent from the series is conveyed to two separate fish ponds for aquaculture. The effluent from the fish ponds is then used on site for crop farming. The performance of the plant was evaluated through the monitoring of physico-chemical parameters such as pH, turbidity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand at 20°C after 5 days incubation (BOD5), nitrate, nitrite and phosphate. From the laboratory analysis, the removal efficiencies observed are: 93% and 90% for COD, 97% and 93% for BOD5 respectively for the duckweed based system and algae based system; the percentage of removal of suspended solids is approximately 98% for the two systems [43].

Wastewater and sludge reuse are promising options to alleviate water shortage challenges, but its feasibility must be carefully assessed in order to avoid human health issues. Restrictions and guidance need to be provided for the reuse of the wastewater or sludge that has been removed from the process.

6. Discussion and concluding remarks

The case studies presented, as well as the other evidences drawn by the project activity, confirm that sanitation in African countries is still lacking and/or facing enormous problems. The inappropriate disposal of municipal wastewater and the absence of adequate sanitation facilities pose a great threat to the environment and public health. If present, WWTPs are not managed properly, thus the effluent fails to reach the required quality standards. The design and performance of the respective plants were, in most cases, properly done, but utilisation is a challenge due to the following reasons:

- mismanagement of resources.
- low capacity/knowledge in plant utilisation.

- poor monitoring and supervision of these plant.
- undefined guidelines for various stakeholders who are affiliated to the plant
- lack of awareness among the community

In order to cope with SDGs, treating capacity of WWTP should be rapidly increased. As already discussed in previous studies [44], the choice of decision makers must rely on the integration between centralized and decentralized systems. Regarding centralized systems, the options are between simple facilities relying on facultative and maturation ponds (as the Kauma WWTP), or more technically advanced plants (as the Kaliti WWTP). These latter are in general recommendable in developed countries, but their utilisation must be carefully assessed in low-income countries.

Besides the selected approach, these is a general need of improving secondary and tertiary treatments, in order to preserve human health by possible pathogen impacts. Introducing mechanical aeration is one possible option. Also, sludge treatment should be improved in order to minimize negative impacts and possibly introduce a source of income. Anaerobic digestion, mechanical de-watering and sludge incineration are, in principle, feasible solutions. WWTP managers should implement minimum monitoring equipment, to provide appropriate testing before discharge. Concentrations of BOD, COD, TSS and pathogens in the effluent should be periodically measured. Another upgrading could also be introduced by constructing free surface wetlands. Soil or sediment organic matters which have accumulated in the wetland pond could be absorbed, degraded and dried regularly.

Regarding the economic conditions, it must be said that the management of centralized WWTPs is not, at present, economically sustainable. This is evidenced by problems such as leakages of sewer pipes and inadequate monitoring of the plant, possibly due to financial constraints. WWTPs require regular maintenance activities in the ponds, pipes and distribution structures. WWT sludge is recovered but it does not generate economic revenues. In addition, restrictions and guidance need to be provided for the reuse of the wastewater or sludge that has been removed from the process as these may have health impacts on the population.

This research intended to attract the interest of sanitation experts on the necessity to start collecting data on wastewater treatment and management in African countries. As mentioned, considering water demand increase, due to population growth, urban settlements development and access to drinking water improvement, the challenges to be faced in African countries are huge and more and more urgent. Starting from data collection on sanitation issues, it will allow to develop a knowledge of the different contexts, in order to focus on the main weakness and needs in terms of sanitation, hygiene and health, evaluate the most adapted solutions from a technical, economic, environmental and social point of view and, finally, motivate decision makers to implement the best strategy to reverse the course.

African urban areas are expanding at a tremendous rate. With an increase in population of urban areas, there will be more demand for water and sanitation facilities. Thus, it is imperative to further increase the treatment capacity in the coming years. There is a need for human capacity to generate data on quantity and quality of wastewater and plan for an efficient wastewater management system which can help to reduce the potential public health risks associated with wastewater management. Human capacity development is required for identifying a combination of treatment and crop restrictions, of safe wastewater application methods and control of human exposure which will help to ensure safety to the public as well as the environment.

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