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Environmental sustainability in restoration of water and wastewater treatment sectors in Africa

Mohammad Shahidul Islam[1], Stélio Rafael Sumbane[1,2*]

[1]*School of Science and Engineering, Atlantic International University, Pioneer Plaza, 900 Fort Street Mall 905, Honolulu, Hawaii 96813, USA.*
[2]*Karl Marx Avenue, number 1704, 2nd Floor, Maputo City, Maputo Province, Mozambique, East Africa.*

Corresponding author: Stélio Rafael Sumbane (*Email: ssumbane@live.com*)

Abstract

This article addresses environmental sustainability in the restoration of the water and wastewater treatment sector in Africa. It is well known that water is an essential resource for human health worldwide. However, it is becoming increasingly important to develop projects and build infrastructure for water systems to effectively manage this vital resource. The Water Treatment Plant (WTP) is a component of the water systems infrastructure responsible for providing water treatment processes. The primary goal of this research was to evaluate the environmental sustainability of restoring the water treatment sector in Africa, based on the following pillars of sustainability: ecological, economic, and social. This research was prepared based on a sample, where the environmental sustainability of water treatment processes and their related infrastructures was evaluated. The samples analyzed included river water, groundwater, and industrial wastewater effluent collected from Mozambique and Nigeria. These two countries are located on the southeastern and western coasts of Africa, respectively. Drawing upon the author's professional experience and referencing international guidelines and regional standards for water quality and wastewater discharge in African countries, the discussion underscores the restoration of the water and wastewater treatment sector in Africa.

Keywords: Ecology and Economics, Sustainability, Treatment, Wastewater, Water.

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1. Introduction

The history shows that water treatment processes have been implemented since the pre-Christian era. At that time, it was difficult to distinguish clean water from contaminated water, but efforts were made to improve the taste, remove bad odors, and reduce bitterness in the water. In advance, it is described the processes used to treat water in the pre-Christian era: (i) The water was heated using the sun and cloth to strain the hot water, removing the bad smell [1] (ii) In the Holy Bible, it is described that in Mara, Moses and the Israelites discovered that the water was bitter. They then threw a tree into the water to remove the bitterness [2].

Over the years, water treatment processes have been modernized to those used today. Since the United Nations (UN) recognized water as a human right, regardless of social, economic, cultural, or gender conditions, access to treated water has remained a challenge. Despite this, according to the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), today, around 2.2 billion people still lack safely managed drinking water (treated water) at home, 3.4 billion people do not have safely managed sanitation, and 2 billion people cannot wash their hands with soap and water at home [3].

The United States of America first implemented safe drinking water standards in 1914, focusing on public water supplies. In the 1940s, these standards were expanded to cover all municipal drinking water systems. The Safe Drinking Water Act (SDWA), a comprehensive federal law aimed at ensuring the safety of public drinking water, was enacted in 1974 [1].

Water treatment processes involve various actions to treat and purify water, making it safe for human consumption or meeting the required standards for a specific purpose. There is a dilemma surrounding the concept of pure water, as literature suggests that chemically pure water does not exist naturally on the Earth's surface. The expression of "pure water" is often used as a synonym for drinking water to indicate that the water meets the necessary quality standards for human consumption. In the context of this research, the following definition must be addressed: (i) The contaminated water is water that contains pathogenic organisms and toxic substances, making it dangerous for human use [4]. This means the water is not suitable for human consumption and domestic purposes; (ii) the polluted water is water that contains quantities of substances that alter the quality, making it harmful to use and affecting its appearance, taste, and odor [4] (iii) The substances, due to their inherent characteristics or elevated concentrations, that cause water pollution are referred to as "impurities in water" [4].

The aim of this research article is "environmental sustainability in the restoration of the water and wastewater treatment sector in Africa." This focus is supported by previous definitions, such as contaminated water, polluted water, and impurities in water, which highlight the necessity of effective water treatment processes in water systems to achieve the main purpose, "water for human consumption or human utility."

2. Problem Description

Water is considered a precious resource. In Africa, as in other parts of the world, governments have been making financial efforts to build infrastructure for water management and use. However, it is essential to justify these efforts. This research explores the environmental sustainability of restoring water treatment processes, an integral part of the infrastructure responsible for water management and use, with a focus on ecological, economic, and social factors.

3. Objective of the Research

1. To describe the environmental sustainability of the restoration of the water and wastewater treatment sector in Africa.
2. To describe the various processes involved in water treatment.
3. To address action that negatively affects the environment and water.

4. Materials and Methods

This document, a research study on environmental sustainability in the restoration of water and wastewater treatment in Africa, was prepared based on templates provided by Atlantic International University (USA), educational literature from Eduardo Mondlane University Library (Mozambique), as well as sources indicated in the references.

When describing the procedures/methodology, it can be noted that, according to the subject, format, and templates provided by Atlantic International University, this research was conducted using samples of river water, groundwater, and industrial wastewater effluents collected from factories in Mozambique and Nigeria. The river and groundwater samples were evaluated against international standards for drinking water quality, while the wastewater effluent samples were assessed in accordance with effluent discharge regulations applicable in selected African countries, namely Mozambique, Nigeria, and Uganda. Following this, the results and discussions have been obtained.

5. Theoretical Background

In the previous chapters, the definition of the water treatment processes was provided. This chapter will describe the water treatment processes. Before delving into the specifics of these processes, the characteristics of water that are relevant to defining water treatment, as well as substances that can harm water quality, will be introduced. However, the characteristics of water are: (i) Physicochemical Characteristics: color, turbidity, taste, and odor; (ii) Chemical Characteristics: hardness, salinity, and aggressivity [5].

Elements and substances that can be harmful to water quality include: iron, manganese, nitrogen, chlorides, fluorides, toxic compounds (such as copper, zinc, lead, cyanides, hexavalent chromium, cadmium, arsenic, selenium, silver, mercury, and barium), organic substances, detergents, pesticides (insecticides, rodenticides, herbicides, fungicides, ant killers), radioactive substances, and microorganisms (algae, bacteria, viruses, protozoa, and worms) [5].

The Water Treatment Processes are:

Coagulation: It is a method employing a natural or chemical coagulant to coagulate suspended particles, including microbes, to enhance their sedimentation [5].

Flocculation: This method has the same purpose as coagulation. Coagulation is the first step and works for larger particles, while flocculation follows and works for smaller particles.

Sedimentation: It is a method for water treatment that involves the settling of suspended particles, including microbes, to remove them from the water [5].

Decantation and filtration: These processes separate water from solid particles after the sedimentation process. Decantation relies on the particles' density, while filtration uses a porous barrier to separate solids from water.

Disinfection: It is the process of destroying or inactivating pathogenic (disease-causing) organisms. This can be accomplished by various methods, including physical methods such as ozone or ultraviolet radiation, and chemical methods such as chlorine [6].

Aeration: This process increases contact between water and air, facilitating the exchange of gases and substances. It helps remove unwanted gases such as carbon dioxide, hydrogen sulfide, chlorine, and methane, promotes the oxidation of compounds like iron and manganese, and increases the dissolved oxygen content.

Desalination: It is used to remove salts from brackish or saline surface water and groundwater in order to render it acceptable for human consumption or other uses [5]. Desalination processes include: (i) Reverse Osmosis: a common technique that uses semi-permeable membranes allowing water to pass through while blocking salts. Saltwater is forced through these membranes under high pressure, resulting in fresh water. (ii) Distillation: the water is heated until it vaporizes, and the vapor is condensed to form pure water. (iii) Freezing: the water is frozen, and the salts are separated from the ice.

The selection of water treatment processes, as described previously, depends on the quality of the water, which is influenced by the type of water source used in the infrastructure. The water infrastructure can be:

- Clean Water Supply System;
- Wastewater System (Sewage System & Storm Water System);
- Fire-fighting System;
- Irrigation System.

6. Results and Discussion

6.1. Wastewater

The wastewater discharge effluent standard will be discussed based on the following data:

- Sample 1: wastewater discharge effluent collected after the 2M Factory (Industry), located in Maputo City, Mozambique [7].
- Mozambique Effluent Discharge Standard [8]
- Uganda Effluent Discharge Standard [9] and
- Nigeria Effluent Discharge Standard [10].

Table 1.
Wastewater - Effluent Discharge Standard.

Parameter	**Unit**	**Sample1**	**Mozambique DischargeStandard**	**Uganda DischargeStandard**	**Nigeria Discharge Standard**
pH		7.01	6-9	5.0-8.5	6-9
Turbidity	NTU	-	-	-	5
Salinity	ppm	-	-		-
Electric Conductivity	µohm/cm	1753	-	1000	-
TDS	mg/L		-	750	500
DO	mg/L	3.38	150	-	-
Nitrates (NO3)	mg/L	10.8	50	-	10
Phosphates (PO4)	mg/L	3.22	5	-	-
TotalColiform	CFU/100mL	700	400	400	400
Fecalcoliform	CFU/100mL	100		-	
Iron(Fe)	mg/L	-	0,3	3.5	-
Lead(Pb)	mg/L	-	0,01	0.1	0.05
Nitrites	mg/L	-	3	-	
Chloride	mg/L	-	250	250	250
Hardness	mg/L		500	-	

Based on the standard features of the samples shown in Table 1, the following analyses can be made:

- The analysis of the industrial effluent sample indicates that the values for conductivity, total coliforms, and fecal coliforms parameters exceed the discharge standard limits established by African countries.
- The pH value of the sample is 7.01, which falls within the acceptable discharge limits (between 6 and 9) set by these countries.
- The total coliforms and fecal coliforms values of the sample are 700 CFU/100ml and 100 CFU/100ml, respectively. These values significantly exceed the standard discharge limits. In fact, most African countries require 400 CFU/100ml of total coliforms in discharge effluent.
- In general, the discharge effluent standard limits are approximately consistent across most African countries. However, some parameter values need to be adjusted to meet compliance requirements.

6.2. Analysis of the Impacts

6.2.1. Social

The values of the total coliforms and fecal coliform parameters of discharge effluent are 700 CFU/100 ml and 100 CFU/100 ml, respectively. The excessive presence of these microorganisms can pose serious health risks, including gastrointestinal diseases in humans [11].

6.2.2. Economic

If wastewater treatment plants in these countries are not constructed to treat the effluent discharge, significant financial resources may be required in the health sector to treat the people affected by diseases caused by contaminated water.

6.2.3. Ecologic

The discharge may significantly impact the survival of local aquatic plants and animals in the affected area (where the discharge will be made).

6.3. Water

The quality of river water and groundwater will be discussed based on:

- Sample 1: River water from Shen Dam, Shen Village, Jos South Local Government, Plateau State, Nigeria (*information provided by Chris Gyang Mang*).
- Sample 2: Water from Alto Molócuè River located at Alto-Moloòcué Village, Zambezia Province, Mozambique [12].
- Sample 3: Groundwater collected from a borehole located at Mafassane Village, Inhambane Province, Mozambique [13].

Table 2.
Water – Quality Standard of the Samples.

Parameter	Unit	Sample1		Sample2	Sample3	WHO-Guideline Limits [18]
		Before WTP	After WTP	Before WTP	Before WTP	
pH	-	6.2	7.3	7.2	6.0	6.5-8.5
Turbidity	NTU	45.0	0.8	400	2.73	5
Salinity	ppm	-	-	-	0.20	
Electric Conductivity	µohm/cm	-	-	39	353	50-2000
TDS	mg/L	580	180	-	188.0	1000
DO	mg/L	3.5	7.0	-	-	
Nitrates (NO3)	mg/L	18.0	4.0	20.5	-	50
Phosphates (PO4)	mg/L	2.5	0.3	-	-	1
Total Coliform	CFU/100mL	5000	0	-	2	0
Fecal Coliform	CFU/100mL	1200	0	-	<1	0
Iron (Fe)	mg/L	1.2	0	-	-	0.3
Lead (Pb)	mg/L	0.05	<0.001	-	-	0.01
Nitrites	mg/L	-	-	20.63	-	3.0
Chloride	mg/L	-	-	22.3	-	250
Calcium	mg/L	-	-	7.2	-	50
Magnesium	mg/L	-	-	3.7	-	50
Hardness	mg/L	-	-	30	-	500

Based on the standard features of the samples indicated in Table 2, the following analyses can be made:

- pH is one of the most important water quality parameters for operation. The recommended pH range for drinking water is between 6,5-8,5 [5]. The pH values of samples 1 and 3 are approximately within the recommended range, while the pH value of sample 2 is outside the recommended range for drinking water.

- Turbidity in drinking water should be less than 5 NTU [5]. The turbidity values of samples 1 and 2 exceed the recommended limit, with sample 1 having lower turbidity than sample 2. Sample 3, which is groundwater, has a turbidity value below the recommended 5 NTU, which is typical for groundwater.
- According to the World Health Organization (WHO), the palatability of water with a Total Dissolved Solids (TDS) level of less than 600 mg/L is generally considered good. The TDS values of samples 1 and 3, where available, are within the recommended limits for drinking water.
- The presence of total coliforms and fecal coliforms in drinking water is undesirable, meaning both parameters should be absent [5]. In the samples, these parameters are present in higher concentrations in the river water (sample 2) and in lower concentrations in the groundwater.

Based on the recommended values for drinking water parameters indicated by WHO and the information of the samples indicated in Table 1, it is clear that water treatment processes are essential for ensuring safe water consumption in Africa.

6.4. Analysis of the Impacts

6.4.1. Social

Beginning with the social analysis of the sustainability of water treatment process restoration in Africa, the following points can be considered:

1. As per Figure 1, the river water contains values of total coliform and fecal coliform of 5000 CFU/100 mL and 1200 CFU/100 mL, respectively. According to WHO, drinking water should be free of these parameters [5]. This indicates that the water poses a threat to human health. The groundwater contains values of total coliform and fecal coliform at 2 CFU/100 mL and 1 CFU/100 mL, respectively. It means that the water represents a long-term health risk. Consumption of water containing total coliforms and fecal coliforms can lead to gastrointestinal diseases in humans [11].

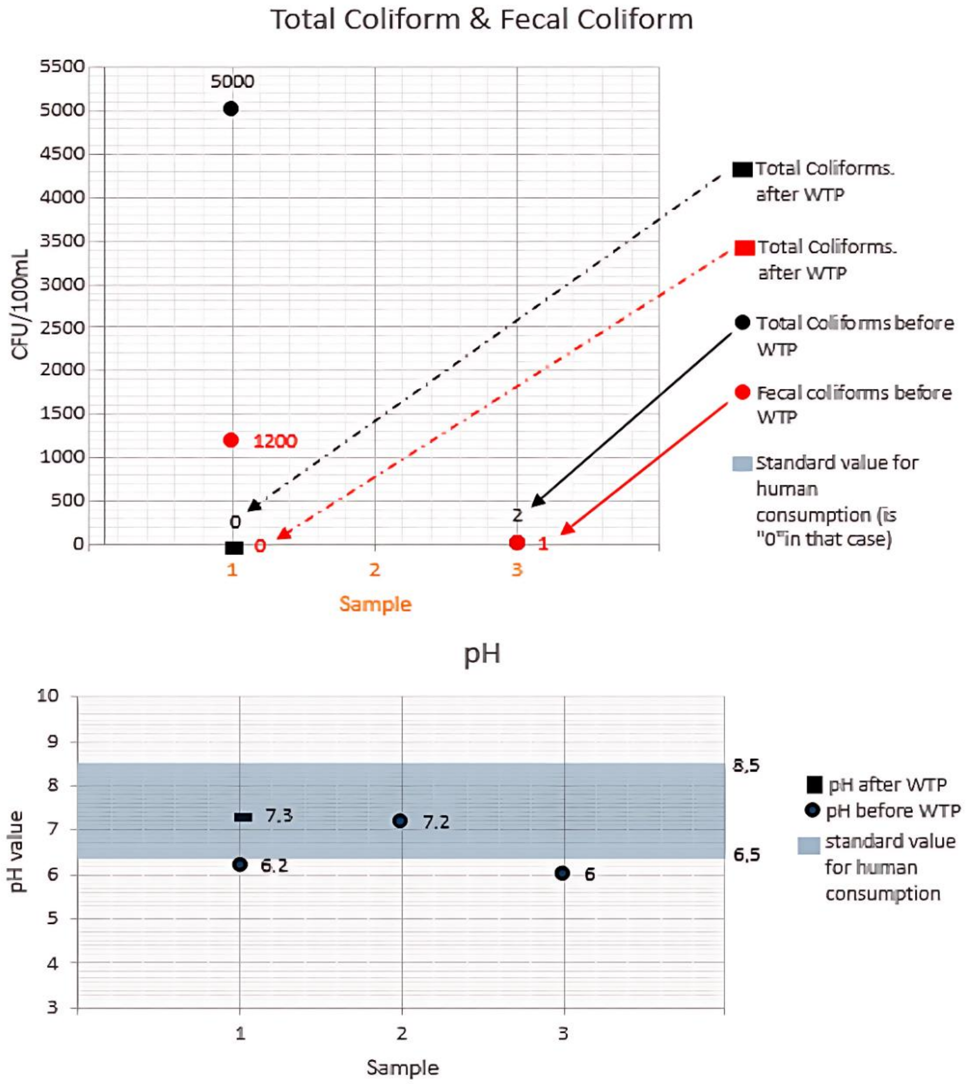

Figure 1.
Water-Information of pH, Total Coliform and Fecal Coliform.

2. As per Table 2, the river water contains an iron concentration of 1.2 mg/L. According to the World Health Organization (WHO), the recommended iron concentration for drinking water is less than 0.3 mg/L. In terms of the iron parameter, the water is not suitable for drinking in Africa. Consumption of water with iron levels above the recommended limit can cause hemorrhagic necrosis in humans [11].
3. As per Table 2, the water river has a nitrite concentration of 20.63 mg/L. According to the WHO, the recommended nitrite concentration for drinking water is less than 3.0 mg/L. Therefore, the river water is not suitable for drinking. Consumption of water with high nitrite levels can lead to pneumonia and anemia by reducing oxygen levels in the blood [11].
4. As per Table 2, the river water contains 0.05 mg/L of lead. WHO recommends that lead concentrations in drinking water be less than 0.01 mg/L. Therefore, the river water is not suitable for drinking. Consumption of water with lead levels above the recommended limit can lead to acute poisoning in humans [11].

Based on the samples, neither the river water nor the groundwater is suitable for human consumption, posing serious threats to human health. Under these conditions, the water can cause diseases such as gastrointestinal issues, skin damage, anemia, pneumonia, and poisoning. Therefore, it is crucial to construct water treatment plants to ensure safe water for consumption and protect public health in Africa.

6.4.2. Economic

As mentioned previously, consuming untreated river water and groundwater can be harmful to people, leading to gastrointestinal diseases, skin damage, anemia, pneumonia, and other health issues. Additionally, significant financial resources may be required to address the resulting health problems.

It is undeniable that the contribution of water treatment processes to water systems is of great importance, as these systems significantly impact health and quality of life. However, it is also important to highlight that these water treatment processes play a crucial role in extending the useful life of the systems. The water treatment process can protect equipment (valves, pressure meters, pumps, chambers, etc.) against silting and corrosion. This helps mitigate the need for costly equipment replacements during the management period. The following points can be considered:

1. As shown in Figure 2, the river water samples (1 and 2) have turbidity values of 45 NTU and 400 NTU, respectively. According to the World Health Organization (WHO), the recommended turbidity value for drinking water is less than 5 NTU. High turbidity can complicate the disinfection process [11], leading to increased financial costs.

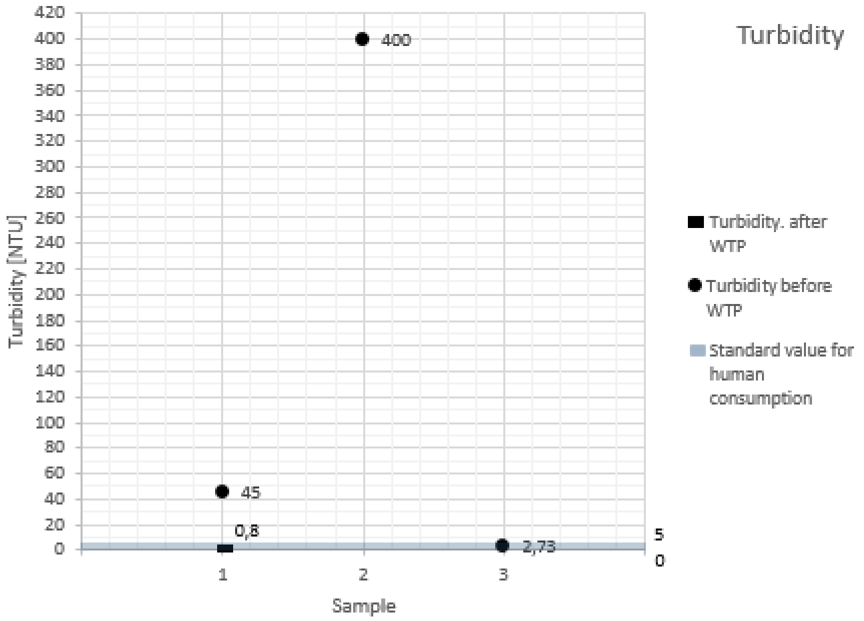

Figure 2.
Water - information about Turbidity.

2. As shown in Figure 1, the river water and groundwater samples (1 and 3), have pH values of 6.2 and 6, respectively. According to the WHO, the recommended pH range for drinking water is between 6.5 and 8.5. The low pH of this water can cause corrosion in the equipment [11], which would require additional financial resources for equipment replacement.

The clean water provided by water treatment processes enhances the quality of life in society. An example is the creation of water parks, such as Aquapark Maputo in Maputo City (Mozambique), uShaka Marine World in Durban City (South Africa), Carthage Land in Tunis City (Tunisia), Dolphina Park in Sharm El Sheikh and Hurghada Cities (Egypt), Jungle Aqua Park in Hurghada City (Egypt), Oasiria Water Park in Marrakech (Morocco), Valley of Waves in Sun City (South Africa), and Sunrise Water Park in Abuja City (Nigeria). These infrastructures attract tourists from all over the world, in turn boosting tourism in those countries and contributing to economic growth as well.

One of the impacts of the restoration of water treatment processes in society is the increased employability generated by the project, from the consulting phase to the construction phase. The construction phase, in particular, offers the most employment opportunities, as a larger workforce is required. It is also important to highlight the significance of employability during the management phase of water treatment processes, as these infrastructures require qualified human resources for their operation and maintenance.

6.4.3. Ecological

As shown in Figure 2, the river water (samples 1 and 2) has turbidity levels of 45 NTU and 400 NTU, respectively. According to the World Health Organization (WHO), the recommended turbidity level for drinking water is less than 5 NTU. High turbidity can affect the appearance of water [11], reducing the penetration of light in the water limits photosynthesis in aquatic plants. This, in turn, decreases oxygen production and can lead to the death of both aquatic animals and plants.

Finally, sustainability means meeting the present needs without compromising the ability of future generations to meet their own needs [14]. It is a rather short statement, but has prolonged implications on our ecosphere. Successive loading of pollutants in the effluent of wastewater treatment plants imposes an environmental burden on aquatic and land life. The resulting costs for treatment of waterborne diseases in these countries outweigh the costs for polluted wastewater treatment. This creates an adverse impact on the society concerned. That's why it is very important that the water and wastewater treatment plants in African countries comply with regulations to restore environmental sustainability in this region, to protect the ecosystem, and support life.

7. Conclusion and Recommendations

As described in the previous chapters, the restoration of water and wastewater treatment infrastructure in Africa has become essential, both locally and globally. This restoration is crucial for ensuring a better quality of life for people and for improving the management of water resources.

As shown in Figure 1, the river water has high levels of total coliforms and fecal coliforms. This contamination may result from the discharge of untreated wastewater effluent or the release of fecal matter into the river. It is recommended to discourage the careless disposal of wastewater effluent into rivers without prior treatment in wastewater treatment plants. The groundwater also contains total coliforms and fecal coliforms, likely due to soil contamination from improper defecation practices near latrines. The construction of latrines should be carried out only after a thorough geotechnical study to minimize the risk of groundwater contamination.

The water treatment processes require extensive knowledge of chemical products such as aluminum sulfate, chlorine, and others. Therefore, it is recommended that qualified technicians manage the processes.

There is hope that, in the future, the management of the water treatment process will become more efficient with the help of automation software and artificial intelligence, thereby enhancing water quality and the sustainability of these infrastructures.

Finally, we would like to express our deepest gratitude to our family, especially Mr. Stélio Rafael Sumbane's sons, for their unwavering support and encouragement throughout our academic pursuits. Their love and encouragement have been our greatest sources of strength.

List of Symbols

WTP	Water Treatment Plant
HDPE	High-Density Polyethylene
USA	United States of America
AIU	Atlantic International University

References

[1] Projesan Water & Co, *Together for the evolution of water: The history of water treatment*. Maputo, Mozambique: Projesan Water & Co, 2022.

[2] B. Holy, " New international version exodus," *Zondervan*, vol. 15, pp. 23–25, 2011.

[3] World Health Organization, "Women and girls bear brunt of water and sanitation crisis – new UNICEF-WHO report," World Health Organization, 2023.

[4] Water Treatment, "Water treatment," 2016. https://www.passeidireto.com/arquivo/24750174/tratamento-de-agua

[5] WHO, *Guidelines for drinking water quality*, 4th ed. Geneva, Switzerland: World Health Organization, 2011.

[6] B. Skinner, "Chlorinating small water supplies," *Water, Engineering and Development Center,* 2001.

[7] E. F. Eduardo Mondlane University Library, "Rapulua, sifia janete"- assessment of the water quality of the infulene river p-Y to NN," Eduardo Mondlane University Library, Engeneering Faculty, 2022.

[8] Bulletin of The Republic of Mozambique, "Decree No. 52/2023 of 30 august 2023" – regulation of quality standards for raw water and discharges of liquid and solid effluents," 2023.

[9] Statutory instrument supplement no.44, *The national environment standard for discharge of effluent into water or land regulations, 2020", printed by UPPC*. Entebbe, Uganda: Order of the Government, 2020.

[10] Federal Republic of Nigeria, "National environmental food, beverages and tobacco sector regulations," Official Gazette, 2009.

[11] Boletim da República de Moçambique, *Decree No. 180/2004 of 15 September 2004 – regulation on the quality of water for human consumption*. Maputo: Boletim da República de Moçambique, 2004.

[12] AIAS - Administração de Infra-Estruturas de Águas e Saneamento, *detailed design of water supply system of Alto Molocue village, Zambézia province*. Mozambique Elaborated by TECNICA – Engenheiros e Consultores Lda, 2014.

[13] SWISS LAB - Laboratório de Análises de Água, *Test report No. 4096*. Maputo, Mozambique: SWISS LAB - Laboratório de Análises de Água, 2017.

[14] M. Islam and S. Sangaran, "Sustainable treatment of emerging organic pollutants (eops), endocrine disruption chemicals (edcs) from water &waste water and role of AIU online based distance learning education system to achieve UNESCO 2030 goals towards sustainable development," *European Journal of Applied Sciences,* vol. 10, no. 4, pp. 556-569, 2022.