Institute for Water and Energy Sciences (incl. Climate Change)

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TITLE:

Assessment of the Influence of Agriculture and Domestic Waste on Surface Water Quality A case study of Senegal River (Rosso, Mauritania)

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DEDICATION

This work is dedicated to my beloved parents Ablaye M'BAYE and Fatimata Sy, my son Ablaye KANE (habibi)

My sisters; Aicha LY and Hawa M'BAYE.

My brothers; Mohamed Ly and Baidi LY.

My aunties and uncles.

For your unwavering love, unending support, and continuous prayers.

STATEMENT OF THE AUTHOR

I, Aissata Abdallahi M'BAYE, hereby declare that the thesis titled 'Assessment the Influence of Agriculture and Domestic Waste on Surface Water Quality A case study of Senegal River (Rosso, Mauritania)' is my original work. I have not submitted this work to any institution of higher education for the award of a degree, diploma, or certificate. I have followed all regulations of the Pan African University (PAU) Scholarship, and all the words and ideas borrowed from other works presented in this thesis have been appropriately cited and referenced according to academic rules and regulations. This statement reaffirms my dedication to academic integrity and knowledge growth within the parameters of moral research procedures.

Signature 

Date : 25 March 2025

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ABSTRACT

The physicochemical and bacteriological characteristics of the Senegal River in the Rosso region were meticulously examined across various sampling stations (Back, Djourbel, Iset, and M'Pourier) and were assessed for a total of twenty-three physicochemical and three biological parameters. These parameters encompassed Bicarbonate (HCO_3^-), Temperature, Turbidity, Potential of Hydrogen (pH), Electrical Conductivity (EC), Alkalinity ($CaCO_3$), Chemical Oxygen Demand (COD), Barium (Ba), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Iron (Fe), Chromium (Cr), Copper (Cu), Potassium (K^+), Manganese (Mn_2^+), Nitrate (NO_3^-), Nitrite (NO_2^-), Ammonia (NH_4^+), Phosphate (PO_4^{3-}), Sodium (Na+), Sulfate (SO_4^{2-}), and Zinc (Zn). The Water Quality Index (WQI), a methodological technique used to assess the effect of household and agricultural waste on the surface water quality of the Senegal River in Rosso, Mauritania, was calculated using the biological parameters, which included Escherichia coli, Total Coliforms, and Enterococcus. The findings showed that the pH level at the Djourbel Station was below the World Health Organization's (WHO) cutoff point. Additionally, all monitoring sites (Back, Djourbel, Iset, and M'Pourier) had turbidity and Chemical Oxygen Demand (COD) levels beyond allowable limits, suggesting a substantial organic load and possible human pollution. Concentrations of copper (Cu) were observed to exceed WHO recommendations at the Back and Djourbel stations, while elevated concentrations of barium (Ba) and chromium (Cr) raised concerns at the Iset and M'Pourier stations. Significantly, the M'Pourier Station had a more noticeable pollution profile, with higher concentrations of potassium (K^+), ammonium (NH_4^+), nitrites (NO_2^-), bicarbonates (HCO_3^-), electrical conductivity (EC), and total dissolved solids (TDS). Suggesting a variety of contaminant sources likely associated with domestic and agricultural runoff. Bacteriological evaluations indicated widespread contamination by Escherichia coli, Enterococcus, and total coliforms across all monitoring stations, signifying considerable fecal pollution and presenting a significant health risk. The Water Quality Index (WQI) further substantiated these findings. When the analysis included bacteriological parameters, WQI values surged to alarming levels, particularly at the Back (2660.5) and M'Pourier (2572.1) stations, indicating the water's unsuitability for any application. Even in the absence of microbiological assessments, WQI indices

remained elevated, particularly at the Back (184.21) and Iset (108.31) stations, signifying substantial chemical contamination.

Keywords: Agriculture, Domestic Waste, Mauritania, Senegal River, Surface Water Quality, Water Quality Index.

1. CHAPTER 1: INTRODUCTION

1.1. Background

Water-related health problems are one of the world's greatest concerns. Over two billion people globally, or one in four people, do not currently have access to quality drinking water services. (Deng et al., 2023). Human health depends on the quality of the drinking water supply, especially in underdeveloped areas with limited access to water and/or the inability to afford expensive treatment methods to enhance drinking water quality. Unsafe water sources cause 1.4 million deaths worldwide each year, with low-income nations accounting for 5% of these deaths (Wang et al., 2023).

Water is essential to the survival of life and humanity. One of the most basic human needs is clean drinking water, and diseases proliferate when people cannot have access to safe water sources(Ummah, 2019). Because they provide water for the various socioeconomic activities that are conducted in human settlements, surface water sources are the foundation of human progress. Ironically, though, many of these activities also modify and degrade the quality of water sources (García-Ávila et al., 2022). The rising pollution of surface water, primarily in rivers, because large volumes of fertilizers from agricultural sources are carried by surface runoff areas and municipal discharge, is the cause of the inadequate quality (Bojarczuk et al., 2018). Surface water is essential for home uses and irrigation. However, surface water quality has been declining due to untreated industrial waste discharges. (Abdullateef Abdullahi Ibrahim et al., 2021). Contamination of drinking water can cause disease and is often associated with the spread of poliomyelitis, diarrhea, dysentery, and cholera (Azzirgue et al., 2022). According to estimates from the World Health Organization (WHO), polluted waters are responsible for over 80% of human illnesses. As a result, surface water management and monitoring has emerged as a crucial procedure that has to be incorporated into political viewpoints for sustainable development.

The quality of river water has grown to be a major global concern. On the one hand, rivers serve as the main supply of water for agriculture and inland businesses, and drinking (Huang et al., 2014). Numerous scholarly investigations have demonstrated that the overutilization of synthetic fertilizers and pesticides significantly contributes to severe non-point source water contamination. Diffuse and other forms of water pollution represent a critical challenge in numerous agroecosystems, particularly in irrigated regions associated with high-value ecological systems. (Česonienė et al.,

2023). The ongoing rise in municipal trash is one of the human activities having a detrimental effect on the environment. Runoff from irrigated fields, rainwater release from agricultural crops, and water runoff can all lead to pesticide pollution. Drinking water is increasingly being found to contain contaminants, especially pesticides, which could be harmful to human health. The amount and duration of exposure to contaminants affect the concentrations of those contaminants in water (Basta & Ciuła, 2024).

Microbiological pollution can be caused by bacteria, viruses, protozoa, and fungus that are mostly brought on by human activity and sewage discharge, as well as by physicochemical and ecophysical processes that occur in aquatic systems as a result of expanding human populations. Bacterial contamination from total coliforms in surface water comes from point sources such latrines, septic tanks, trails, cow pens or stables, untreated sewage discharges, and runoff of rains carrying feces (Megchún-García et al., 2015). Microbiological pollution can be caused by bacteria, viruses, protozoa, and fungus that are mostly brought on by human activity and sewage discharge, as well as by physicochemical and ecophysical processes that occur in aquatic systems as a result of expanding human populations. Bacterial contamination from total coliforms in surface water comes from point sources such latrines, septic tanks, trails, cow pens or stables, untreated sewage discharges, and runoff of rains carrying feces (Reitter et al., 2021).

On average, Senegalese agriculture consumes 1,336,560 liters of liquid pesticides and 598 tons of solid pesticides each year. Agriculture remains the sector that uses the most of these chemical products, particularly in the Niayes area. (Ngom et al., 2012). Pesticides are currently a global concern. Indeed, the number of diseases and deaths related to pesticides continues to rise. According to the FAO, nearly 750,000 people contract chronic illnesses such as cancer each year due to pesticide exposure. More than 20,000 accidental deaths and 3 million pesticide-related poisonings are recorded annually. Many aquatic ecosystems have metal concentrations above the water quality guidelines meant to protect people, animals, and the environment (Pargi et al., 2024). Any metal or metalloid that is poisonous even at very low concentrations and has a relative atomic density greater than $4g/cm^3$ or $5g/cm^3$ is referred to as a "heavy metal." It is commonly known that heavy metal pollution offers major health concerns to both humans and animals. Compared to their natural abundance, heavy metals have become

more prevalent in the environment in the last many years (Ghosh et al., 2023). Environmental pollutants with a high density/nucleon number are known as heavy metals (HMs). Through cation exchange mechanisms, they are adsorbed in sediment and made easily accessible to plants and aquatic life after dissolving in soil solutions and surface and interstitial fluids. (Kehinde et al., 2024). Through surface runoff, solid waste disposal, atmospheric sedimentation, and other means, heavy metal contaminants can enter rivers, where they steadily build up and impair the aquatic ecosystem's ability to operate. Because of their toxicity, persistence, and high bioaccumulation, heavy metals are especially harmful contaminants in aquatic settings. Therefore, determining the health risks associated with river water and improving its quality are essential components of efficient water management (Liu et al.,2023).

1.2. Problem Statement

Land use changes can have a significant impact on the quality of surface water. While increased every year, millions of m3 of wastewater are released by aquaculture operations, and this effluent contains significant levels of pathogens, biodegradable organic matter, nitrogen, phosphorus, and sludge. Agriculture is the source of high concentrations of these elements as well as pesticide residues, which include fungicides, herbicides, and insecticides (Wehrheim et al., 2023). It has been stated that Over 80% of wastewater globally is discharged into the environment without any treatment. Massive amounts of water are needed for most manufacturing businesses, and they might infiltrate the interface along with hazardous chemicals (Akhtar et al., 2021) (Akhtar, Ishak, & Umar, 2021). Although access to this vital resource is necessary for human survival, many African nations lack potable water, which presents significant challenges. One of the factors contributing to illnesses that impact human health is contaminated or low-quality water. Although access to drinking water and sanitary facilities is a human right and water is essential for life, its degradation and inadequate management can also make it a cause of disease(Baye et al., 2021). Every year, an estimated 1.6 million people pass away from diseases linked to water. Monitoring and evaluating changes in surface water quality has become essential for safeguarding human health (Elemile et al., 2022).

Water contamination in Senegal, predominantly attributable to intensive agricultural methodologies, arises from the overutilization of fertilizers and pesticides. A prominent

illustration of this phenomenon is the Richard Toll sugarcane cultivation region, overseen by the Senegalese Company of Sugar (CSS). Irrigated agricultural practices and agro-industrial operations constitute the principal contributors to the pollution generated by pesticides and fertilizers within river basins. Residues from pesticides, herbicides, fungicides, and other chemical agents, frequently released via drainage from irrigated crops such as rice, considerably impair water quality (Faye, 2018). The Senegal River is subjected to significant threats to its physical, chemical, and microbiological integrity owing to the discharge of untreated industrial and domestic wastewater at various sites. A multitude of studies has emphasized the physical, chemical, and microbial states of the water located on the right bank of the river (Malang, 2013). Despite its vital function as a surface water supply for Mali, Senegal, and Mauritania, the river remains susceptible to contamination. Numerous communities residing along its banks utilize the water directly for domestic and recreational activities without prior treatment, thereby heightening the possibility of waterborne illnesses (Mbaye et al., 2016).

Africa has a wide range of intricate water issues, such as:

- Climate and runoff fluctuation;
- Issues with managing water resources;
- Water scarcity brought on by growing population pressure and rising standards of living; poor availability and quality of services for the delivery of water for home and commercial usage;
- Contamination of lakes, rivers, and streams, especially the ones that receive urban water bodies, with potentially dangerous health effects;

The ongoing Sahelian drought has negatively impacted water availability and has jeopardized the stability of some rivers, including the Niger and Senegal, which are the primary supplies of surface water in the Sudano- Sahelian zone of West Africa (OYEBANDE, 2009).

The country of Mauritania has a water shortage due to its Sahelian climate. Mauritania, an arid region with little rainfall, lots of sunshine, and little water, has to deal with its limited supply of water. The river's waters are expected to be widely utilized for irrigation and drinking (Med Fadel et al., 2024). That means that although needs are

growing, resources are finite. The Senegal River is especially important since it is the main source of surface water for Mali, Mauritania, and Senegal. The Senegal River is very important since it is the main source of surface water for Mauritania, Senegal, and Mali. In addition to its domestic uses, this river is used for irrigation, drinking, and fishing (Demba N'diaye et al., 2013). The physical, chemical, and metallic properties of this important river are currently being threatened by restrictions. This river receives discharges of industrial or domestic wastewater in various geographic locations (N'diaye et al., 2013: N'diaye et al., 2014; Diallo et al., 2014; EL Mahmoud-Hamed et al., 2019).

The Rosso city faces recurring issues with water quality, such as persistent turbidity following treatment, disagreeable odors, and extended periods without access to drinkable water. The condition is frequently complained about by the populace, which raises concerns about water management and the longevity of existing treatments.

1.3. Research Objectives

1.3.1. Main Objective

To determine and analyse the influence of agriculture and domestic waste on the Senegal River's surface water quality in the Rosso region of Mauritania.

1.3.2. Specific Objectives

- To determine the relative contributions of agricultural runoff and domestic waste discharge affecting the Senegal River's surface water quality in Rosso, Mauritania.
- To evaluate the human activity which significantly degrades the water quality of the Senegal river in Rosso.
- Assess the adherence of the examined variables to international norms (WHO).
- Determine the primary contributors to pollution (agricultural, domestic) influencing the Senegal River in Rosso region.

1.4. Research Questions

- How do agricultural and domestic waste disposal practices impact the Senegal river's water quality?
- Which human activity is most responsible for the Senegal River's declining water quality?
- To what extent do the physico-chemical parameters of the Senegal River water in the Rosso region comply with international water quality standards (WHO)?
- What are the primary sources of pollution (agricultural, domestic) affecting the water quality of the Senegal River in the Rosso region?

1.5. Significance of the Study

The challenge concerning water quality and sustainable development in Rosso cannot be comprehensively resolved unless the issue of pollution affecting one of its principal sources of drinking water, the Senegal River, is addressed. This is predicated on the notion that a nation's development is intrinsically linked to the health of its populace, which, in turn, is contingent upon the quality of water accessible. An examination of the current state of water quality in the river will facilitate enhancements in its quality management methodologies. This investigation will critically evaluate the existing conditions of water quality in the river and analyze the associated costs of treatment. Additionally, it will identify the pollution challenges that may be confronting the river and furnish a scientific foundation for findings that will assist authorities in determining the most suitable interventions and remedies to the situation, thereby alleviating the adverse impacts on the communities that depend on the river while concurrently reducing the expenses associated with water treatment. The outcomes and recommendations are anticipated to advance the sustainable management of natural resources within the Senegal River. This methodological approach to the diagnostic assessment of our principal river will significantly contribute to the effective management of water resources.

CHAPTER 2. LITERATURE REVIEW

2.1. General overview of Surface water quality

Rivers, streams, lakes, ponds, springs, and reservoirs are some of the places where surface water can be found. It can enter and settle in these bodies of water because it is produced by precipitation in the watershed, with rivers being the most widely used surface water sources worldwide for domestic purposes (Azhari et al., 2023). Due to their accessibility and quantity, consumption, agriculture, and industry have increased rapidly, leading to the advancement of human population expansion in the vicinity of watercourses (Azhari, et al., 2022). Along with the decreased volume, freshwater from surface water bodies also has a lower quality because of several contaminants that are disposed of along or into the water body due to human activities such as irrigation, bathing, and washing. Both underground and aboveground water sources could be tainted (Bangani et al., 2023). Over a million individuals continued to drink surface waters directly without any treatment in 2022, despite increased efforts to regulate drinking water during the previous two decades. Human health may be significantly impacted by the quality of surface waters, since drinking water is one of the main ways that people are exposed to potentially harmful pollutants (Wang et al., 2023).

Water quality is mostly evaluated by looking at its biological quality, heavy metal content, and physicochemical components. When organic, inorganic, biological, thermal, or radioactive pollutants are present in water systems at levels that are likely to deteriorate or adversely affect the quality of the water and, thus, its usefulness, the systems are considered contaminated (Saalidong et al., 2022). The quantity and quality of river discharge have been altered by anthropogenic activity for approximately 3,000 years. About a millennium ago, there was a significant increase in the amount of silt found in rivers due to a first human impact amplification (Mbaye et al., 2016). Surface water quality deteriorates as a result of a variety of domestic and industrial activities, forestry, livestock farming, aquaculture, and other activities. The aquatic ecology as well as the availability of clean water for human consumption may be impacted by this reduction in water quantity and quality. (García-Ávila et al., 2022). Both point and nonpoint sources of pollution have an impact on the quality of water in both rural and urban regions. Sewage discharge, industrial discharge, and agricultural runoff are a few of these causes. Floods, droughts, and end-user ignorance all have an impact on the

quality of water (Khatri & Tyagi, 2014). The pollution of the water system by heavy metals, chemical elements, and biological compounds originates from a variety of sources, including rock weathering, precipitation, the interface of water and soil, as well as the discharge of human-generated wastewater from activities like mining, industrial operations, and agricultural practices (Al Asadi et al., 2023). Because of their dangerous characteristics, enduring existence in the ecosystem, and propensity to accumulate in living things, heavy metals are widely acknowledged as environmental pollutants (Ahmed, 2023). Water and soil are contaminated when pollutants such as heavy metals are present in urban and industrial wastewaters. Various pollutants are carried into the sewage system by storm water, comprising home effluents, drainage water, corporate effluents, air deposition, and emissions from traffic (Getahun & Selassie, 2013). When the metal concentrations exceed allowable limits, they may become poisonous or undesirable. Consequently, a deeper comprehension of the origins of elements and/or metals and their existence in water is crucial.
Metals and metal salts can cause bioaccumulation, biomagnification, and geoaccumulation when they enter the ecosystem (A. Kumar & Kumar Singh, 2023).

2.1.1. Turbidity

One important physical characteristic of drinkable water quality is turbidity. It is a physical characteristic that results in light not traveling through a water sample in straight lines but instead being dispersed and absorbed by particles. Clarity is a key consideration when creating water for industrial and human consumption. Contrary to the previous belief that turbidity control was solely an aesthetic aspect, there is substantial evidence that it is a dependable defense against viruses in drinking water (Abed & Khudair, 2023). Turbidity significantly affects the vertical distributions of phytoplankton, aquatic animals, and plants because it changes the amount of available underwater light, which in turn affects the aquatic ecosystems' ability to develop sustainably (Lin et al., 2023). For a thorough grasp of water quality, it is therefore essential to track the geographic distribution of turbidity (J. Li & Xia, 2023).

2.1.2. Temperature (T)

Although many elements of lake and river water quality are of general interest, water temperature is a "key" variable because it affects mixing within a body of water, determines whether a habitat is suitable for plants and animals, and provides

information about the overall health of a stream. Furthermore, because temperature affects a wide range of physical, chemical, and biological processes, it is frequently seen as a "master" variable for water quality, especially in light of the ongoing climate change and land use changes (McBean et al., 2022).

River water quality metrics like dissolved oxygen (DO) and river water temperature (RWT) serve as essential indicators of the ecosystem's health (Rajesh & Rehana, 2022). Stream health, especially the benthic ecosystem of streambed sediments, is significantly influenced by temperature. Exchanges between streams and adjacent ground water which include solutes in addition to water and heat have an impact on stream temperatures (Thomas, 2021). Naturally, there are daily and seasonal variations in the water's temperature. Although they can provide as a buffer against air temperature fluctuations, aquatic creatures frequently have limited temperature tolerances. The amount of oxygen dissolved in the sample decreases with increasing temperature, which causes COD to rise (Sarda & Sadgir, 2015). Temperature is one of the key factors affecting the conductivity of water and its TDS (total dissolved solids). As the temperature rises, water's conductivity and TDS both increases. This is due to the fact that as water's temperature rises, ions and molecules move more freely, raising TDS and conductivity. Additionally, temperature can change some substances' solubility in water, which can also affect TDS (Dewangan, Sai, et al., 2023).

2.1.3. Total Dissolved Solid (TDS)

Salinization, and more generally, A rise in TDS, or total dissolved solids, has important effects on ecosystem processes and biodiversity. By lowering the quality of drinking water and/or raising the cost of water treatment, declining infrastructure, shifting ecosystem services and products, and increased TDS also has an adverse effect on human health and wellbeing (Merriam et al., 2020). Reduced flows can therefore lead to faster sedimentation and higher concentrations of total dissolved solids (TDS) in the rivers downstream. Numerous additional Research also demonstrated that exceptionally Low flows may have detrimental consequences on the ecology of rivers, such as lowering biological productivity and preventing many fish species' natural reproduction processes (Deksissa et al., 2003). Although it is commonly believed that salinization and alkalinization of fresh water are only associated in dry locations, they can be interrelated processes that degrade water quality throughout a range of climates. Salinization and alkalinization are linked because rising amounts of dissolved salts with

the pH of fresh water can be gradually raised by strong bases and carbonates (Kaushal et al., 2018). The spatial arrangement and magnitude of Changes in land usage, including extraction of resources, urbanization, and agriculture, as well as related contaminants (storm water runoff, agricultural runoff, and acid mine drainage) across the watershed, are the main causes of elevated TDS concentrations in riverine systems (Merriam et al., 2020). The best waters to drink are those with less than 500 mg/l of total dissolved solids. Increased dissolved solids can damage human physiological functions and are undesirable in industrial water because they can create scales, foam in boilers, speed up corrosion, and alter the color and flavor of many final goods (Sarda & Sadgir, 2015).

2.1.4. Electrical Conductivity (EC)

The capacity of water to conduct electricity is measured by its electrical conductivity. Temperature and the presence of dissolved ions or solids, which add to the water's total dissolved solids (TDS), are two of the many variables that affect it. Because of the increased mobility of ions, water's conductivity rises with temperature (Dewangan, Sai, et al., 2023).

2.1.5. Potential of Hydrogen (pH)

pH is probably the most important physicochemical factor affecting how other water quality indicators behave and how much metal is present in aquatic ecosystems. Complexations, oxidation-reduction reactions, acid-base reactions, and solubility reactions are among the chemical processes in aquatic systems that are impacted by the concentration of hydrogen ions (pH) (Saalidong et al., 2022). It was shown that the presence of NH_3 is the primary factor influencing ammonia toxicity, and that the concentration of NH_3 is directly and reversibly correlated with changes in water pH (Mahdi Ghanbari, 2012). The availability of various contaminants in water and the lifespan of bacteria can also be impacted by pH. For some uses, water with in general, a too high or low pH might be disagreeable. At very high pH levels, metals frequently precipitate, and chemicals like ammonia endanger aquatic life; in alkaline conditions, water tends to taste and smell terrible. At low pH levels, metals dissolve more easily and compounds like sulfur dioxide and cyanide become more dangerous. Metal pipes are also corroded by acidic waters (Saalidong et al., 2022). The connection between water's pH and dissolved oxygen levels has been emphasized by studies by Johnson et al. (2015) and Brown et al. (2018). They discovered that oxygen becomes less soluble

when pH drops, which lowers the amount of oxygen available to aquatic organisms. Fish and other aquatic creatures may suffer from hypoxic conditions that arise from this. Several investigations have also been conducted on how pH affects the availability of nutrients in water. Researchers like Wilson et al. (2016) and Thompson et al. (2012) demonstrated that pH levels can impact the availability and solubility of vital nutrients like nitrogen and phosphorus. Nutrient imbalances brought on by pH changes may encourage excessive algal development, resulting in algal blooms and subsequent water quality problems (Dewangan, Toppo, et al., 2023).

2.2. Agricultural Practices

Agriculture is regarded as the activity that demands water resources the most globally due to its high demand and role in surface water pollution(Rey-Romero et al., 2022). When agriculture dominates land use, the effects of agriculture on local water quality will be more noticeable(Schröder et al., 2004). Diffuse pollution, primarily from agricultural activities, has the greatest detrimental impact on the state of surface water bodies (42% of considerably impacted bodies). Water is contaminated by hazardous materials such as Metal-containing chemicals, nitrogen-containing heterocycles, chloro-derivates, and aromatic compounds and their metabolites, and fertilizers, pesticides, and organic wastes used in agriculture. substances, endangering human health and the environment (Falfushynska et al., 2024).

Animal dung and mineral fertilizers causing nitrogen and phosphorus molecules to seep into the soil and end up in surface water bodies is known as diffuse agricultural pollution. The level of agricultural activity determines how much of an impact there will be (Žolynaitė et al., 2023). The overuse of chemical pesticides and fertilizers has been linked to significant non-point source water pollution, according to numerous studies. The amount of NO_3^- in agricultural land's surface water bodies has increased due to the large-scale usage of inorganic fertilizers to meet crop N requirement, as well as the return flow from irrigation (Česonienė et al., 2023). Agricultural non-point source contamination is the main cause of water pollution (Ummah, 2019).

Conventional irrigation systems, excessive use of agrochemicals, and poor postharvest and animal waste management are the main contributors to agricultural pollution (Rey-Romero et al., 2022). Numerous studies have demonstrated how unpredictable the effects of agriculture on water quality may be (Derossi et al., 2024). The most common

Nitrogen and phosphorus are chemical contaminants from agricultural pollution that are present in the majority of aquifers worldwide. Substances made from various agrochemicals, including nitrate, phosphate, potassium, dieldrin, aldrin, endrin, chlordane, arsenic, cadmium, and related poisons, eventually find their way into bodies of water. Because it promotes the growth of cyanobacteria and algae, which lowers the water's dissolved oxygen content, phosphorus plays a significant role in eutrophication (Saritha Vara, 2023). Residents' health and the environment are at risk due to all of these pollutants. Chemical fertilizers and pesticides, which have successfully raised output but raised worries about two important aspects of human health and the environment are modern agriculture(S. Li et al., 2019). Water bodies have become eutrophic as a result of the direct or indirect dumping of nitrogen compounds (nitrate, nitrite, and ammonia nitrogen) from water plants, as well as leaching from sludge deposited in landfills and fields. According to numerous reports, ammonium nitrogen (NH_4^+-N) is a chemical form that is highly prevalent in aquatic environments and has a highly harmful impact on life (Haseena et al., 2016). Agricultural practices increase the amount of sulfate added to surface water, endangering aquatic ecosystems by converting SO_4^{2-} into harmful compounds (Chen et al., 2024).

The persistence, toxicity, bioaccumulation, and long-distance transport of organochlorine pesticides (OCPs), a family of persistent organic pollutants (POPs), have raised a lot of concerns (Kaddouri et al., 2024). A class of chemicals known as organochlorine pesticides (OCPs) are employed as rodenticides, fungicides, insecticides, herbicides, and nematicides. In addition to its application in agriculture, OCPs can be used as an active ingredient in wood preservatives and household cleaning products to fight disease vectors such as dengue, malaria, schistosomiasis, Chagas' disease, and typhus (Souza et al., 2020).

OCPs can penetrate the aquatic food chain, move to sediments, or sorb to suspended and particulate organic materials once they are in water bodies.
As a result, top predators like humans and aquatic birds may experience bioaccumulation and eventually biomagnification (Asefa et al., 2024). OCPs have been linked to generative anomalies, immune system disturbance, brain damage, and human cancer (Muhammed et al., 2023).

2.2.1. Nitrate and Nitrite

On land, nitrogen sources can be both diffuse and point can contribute to nitrate in surface waterways. Diffuse sources predominate globally, with agriculture accounting for the largest contribution because of huge livestock waste, increased agricultural acreage, and excessive fertilizer use. However, since the 1970s, points where nitrate is released from wastewater have grown significantly as a result of the fast urbanization, industrialization, and population growth. Furthermore, nitrates can be produced in surface waters by converting other reactive nitrogen forms (Wang et al., 2023).

Methemoglobinemia has been linked to nitrate and nitrite in water, particularly in newborns who are bottle-fed. Excessive fertilizer use or the seepage of wastewater or other organic wastes into surface and groundwater can also produce nitrate (S et al., 2018). The Environmental Protection Agency's maximum contamination limit is based on the long-standing concern that nitrate in drinking water provides a health risk owing to its capacity to cause methemoglobinemia. Nitrogen fertilizer runoff from agriculture frequently results in increased nitrate levels in the groundwater beneath agricultural areas (Coss et al., 2004). Concern over the health hazards of high nitrate (NO_3^-) levels in drinking water is developing; More than 30 epidemiological research have evaluated the connection between drinking water nitrate and adverse health consequences since 2005. Nitrite, a precursor of N-nitroso compounds (NOCs), which are known to cause cancer and teratogens, is produced in the stomach when nitrate is consumed (Lowe et al., 2021).

2.2.3. Phosphate (PO_4^{3-})

Inputs of phosphorus (P) to agricultural land are necessary to guarantee sufficient crop yields to satisfy a population's needs for food and fiber expanding population. But after rainfall, irrigation, and snowmelt, excess nutrients from agricultural land can be transferred to water bodies, causing water quality problems such as the development of massive algal blooms, alterations in the makeup of communities, and declines in biodiversity in aquatic ecosystems (Habibiandehkordi et al., 2019). On the other hand, agricultural drainage speeds up the movement of pesticides, sediment, and nutrients from fields that have been artificially drained to receiving surface water bodies (Moursi et al., 2023). Through channels including surface runoff and subsurface flow, which are impacted by precipitation, slope, and farming methods, this has increased soil P

concentrations and loss to surface waterways. In order to effectively mitigate losses, P sources, mobilization, and delivery/transport systems must be managed. Targeting critical source areas small zones that disproportionately contribute to P loss can increase the cost-effectiveness of mitigation measures (Habibiandehkordi et al., 2019). Human demand and exploitation of phosphate mineral resources have grown along with contemporary industry, research, and technology, resulting in increasingly severe pollution and environmental harm. These include the risks associated with general mining, like the depletion of land and the devastation of vegetation due to landslides, collapses, geological body breaking, and slag stacking at random (Zhang et al., 2022).

Runoff from agriculture can transport phosphorus either as soluble P (Psol), which dissolves in runoff water, or as particulate P, which is linked to sediment or organic matter. In no-till agriculture, forestry activities, or pastures, soluble P can make up as much as A Psol value of 0.01 mg L-1 can be considered the threshold for surface water eutrophication, as 80% of soil P is transferred to surface waters (Broetto et al., 2017)

2.2.4. Chromium (Cr)

Long-term, high-volume interaction with Cr can seriously injure a range of aquatic species in addition to causing corrosion, skin irritation, and cancer in humans. The significance of Cr for nutrition is highlighted by its function in insulin and fat metabolism. Fish may be exposed to Cr through their digestive or respiratory systems (Pargi et al., 2024). Long-term ingestion of tainted water can cause major health issues, endangering human life and harming important organs like the kidneys, liver, brain system, and digestive system. In order to protect the general public's health, the World Health Organization (WHO) has set rules to limit the amounts of Cr (VI) in drinking water (Li et al., 2024). Many nations have decided on drinking water standards for Cr (VI) and total chromium, which range from 3 μg/ℓ to 100 μg/ℓ (Loock et al., 2014).

2.3. The Impact of Domestic Waste on Surface water Quality

Homes and industrial areas are the primary recognized point sources of untreated wastewater flow into surface waterways like rivers and streams (Jehan et al., 2020). Waterborne disease epidemics are caused by the use of tainted surface water for recreational and household purposes. An estimated 1.8 million people die from waterborne illnesses worldwide each year, with children under the age of five

accounting for the majority of these. In Bangladesh, the Rupsha and Bhairab rivers supply water to around 1.0 million people who live in the catchment region. Without being treated, sewage and wastewater are dumped into the waterways. There are major health dangers to the population when the tainted river water is used for bathing and household functions (Islam & Islam, 2022). Municipal solid waste (MSW) disposal has been a persistent issue in the majority of developing nations, especially in regions with dense populations and substantial refuse output. Inadequate land for landfills sometimes leads to inappropriate land use systems and careless trash disposal in surface water bodies. Numerous workers have shown that open dumps, often known as landfills, seriously endanger surface and groundwater supplies (Steadfast Akhigbe et al., 2018). These operations frequently result in the release of contaminants into water bodies, such as metals, pesticides, fertilizers, salts, and other dangerous compounds. Additionally, municipal wastewater that is released into freshwater systems frequently contains nitrates from sewage effluent (Mogane et al., 2024). Globally, the production of solid waste is rising, which has detrimental effects on both the environment and society. Since poor waste management can have negative direct and indirect effects on human well-being, including the spread of diseases, clogged drains that cause floods, and pollution of both land and water bodies, it is estimated that up to 2 billion tonnes of municipal solid trash were produced worldwide in 2016 is still a crucial environmental issue for cities to take into account (Ngalo & Thondhlana, 2023). Even while fertilizers and other impurities are effectively removed, treated wastewater frequently retains trace organic contaminants that have been shown to harm aquatic ecosystems. Low to extremely low amounts (e.g., ng/L) of certain man-made water contaminants and the products of their transformation are frequently found. Aquatic species may be at risk from the wide range of organic pollutants found in surface waters, especially in relation to combination toxicity, even with such low trace level concentrations (Stalter et al., 2013).

The risk of untreated household wastewater and other industrial wastes contaminating water supplies, endangering their microbiological purity. Because of this, coliform bacteria are now frequently found in water bodies in amounts higher than those advised for drinking, enjoyment, or irrigating fresh crops (Aram et al., 2021). Microbiological monitoring is crucial for evaluating the reservoirs' water quality to produce drinking water since fecal pollution might pose health concerns to people. The hygienic-

microbiological water quality of drinking water, raw water used to produce drinking water, and recreational water is evaluated using bacterial indicators such as coliform bacteria, Escherichia coli (E. coli), and Enterococci (Reitter et al., 2021). Contamination of the feces is among the most prevalent problems. Runoff from cities or farms, bather and animal waste, and point source discharges (such as treated sewage or wastewater discharges) can all cause this. In addition to the ecosystem's quality impact, water fecal contamination has been linked to health risks for people. Specifically, E. coli has been suggested as one of the best markers for gastroenteritis and skin complaints brought on by bathing in seawater (Cárdenas-Calle et al., 2024). E. Coli and coliform bacteria are two of the main biological contaminants found in water. Coliform bacteria, which are frequently employed as an indicator, aid in identifying the presence of contaminants in water. Diarrhea may result from contaminated clean water that has higher than permissible concentrations of Escherichia coli or coliform germs.
Coliform bacteria, which have a rod-shaped, Gram-negative appearance and can digest lactose to produce gas and acid at 37°C in 48 hours, are used as markers of water quality and contamination (Fathonah & Asyfiradayati, 2024). Sewage containing feces can leak, runoff, and infiltrate into streams, marshes, reservoirs, and coastal waters due to extreme weather, increasing the amount of contaminated surface water and groundwater (Basta & Ciuła, 2024). Escherichia coli from people and other warm-blooded animals can contaminate environmental water sources. Sewage leaks, wastewater discharge, and malfunctioning septic tanks and drain fields are examples of potential human sources. Furthermore, inadequately treated sewage is occasionally released directly into rivers, either on purpose or accidentally. This practice is frequently made worse by storm events, which have been demonstrated to multiply the amount of E. coli in water by multiple times. Since Escherichia coli is found in both human waste and the environment, it is employed as a fecal contamination indicator to evaluate the quality of water (U.S.EPA 2012). Although they are not typically thought of as pathogens, their existence suggests that there may be pathogens present because high levels of E. coli in recreational waters have been linked to a higher risk of gastric sickness connected with swimming (Cho et al., 2020).

Numerous factors, including household waste, industrial pollution, and agricultural runoff, have been shown to have an impact on surface water quality. According to

studies, household waste has dangerously high concentrations of heavy metals and microbiological pollutants, and eutrophication is brought on by an excess of nutrients like phosphates and nitrates. Despite advancements in water treatment technologies, Rosso residents continue to face persistent problems such as turbidity, unpleasant odors, and intermittent access to drinkable water. These ongoing issues highlight flaws in the current water management system and cast doubt on the long-term effectiveness of treatment methods. However, there is glaringly little research specifically addressing the relationship between Rosso's surface water quality and domestic and agricultural waste. This study attempts to bridge that gap by examining the sources of pollution, assessing the effectiveness of existing treatments, and proposing long-term solutions. The results will provide valuable insights for policymakers and water management authorities to develop more effective strategies for ensuring reliable and secure water access.

CHAPTER 3. MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1. Location

The Senegal River Basin (SRB), located in West Africa, spans Guinea, Mali, Mauritania, and Senegal. It covers a total area of approximately 375,000 km² (Mbaye et al., 2018). It is situated between longitudes 7° 30′ and 16° 30′ West and latitudes 10° 30′ and 17° 30′ North (El Mahmoud-Hamed et al., 2019). The SRB is encompassed by the Senegal River, which spans 1800 km in length and ranks as the second longest river in West Africa. Its primary tributaries include the Bafing, Bakoye, and Faleme Rivers, all originating from the Fouta Djallon Mountains in Guinea. A significant portion of the SRB exhibits a sub-Saharan desert climate. The basin can be divided into three distinctive sections: the upper basin characterized by mountainous terrain, the valley region, and finally the delta, known for its rich Wetlands and biological variety. The topographical, hydrographic, and climatic characteristics exhibit significant disparities across these three regions, leading to extensive seasonal temperature fluctuations (Djaman et al., 2016). The current population of the Senegal River's watershed is approximately 3.5 million, making it an intermediate-sized river.
Its tributaries travel upstream through a variety of climate zones, ranging from the dry Sahel region near the border between Senegal and Mauritania to the wet tropicals at the source area in Guinea (Mbaye et al., 2016).

The three neighboring countries of Mali, Mauritania, and Senegal banded together and participated in the 1972 framework of the Organization for the Development of the Senegal River (OMVS) when a drought began in the 1970s. Coordinating and integrating river basin management is the goal of the OMVS
(El Mahmoud-Hamed et al., 2019). One of the world's 30 largest drainage basins is the River of Senegal (Potter et al., 2004).
Approximately 3.5 million people currently live in its catchment; but, due to strong population development, this number could treble in the ensuing decades.
Most inhabitants in the basin, especially those living in rural areas, rely heavily on the exploitation of natural resources that are mostly dependent on water (traditional agriculture, fisheries, animal farming).
Furthermore, the majority of those who live next to the river utilize its water directly

and untreated (for example, for recreation or domestic use), which raises the danger of water-borne illnesses. In addition, the water is utilized for drinking water industry, food production, water navigation, hydropower generation, and irrigated farmland

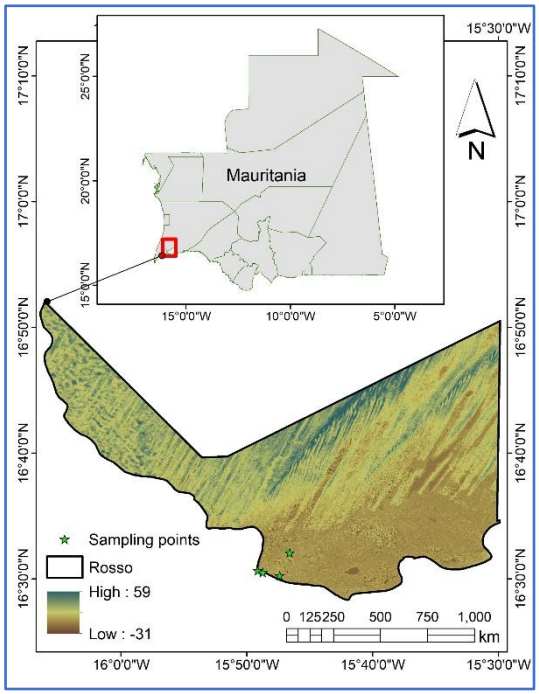


Figure 12. The Map of the Study Area

(Mbaye et al., 2016).

Rosso is a town and commune in southern Mauritania, located on the border with Senegal within the geographical coordinates 16° 30′ 46″ N latitude, and 15° 48′ 18″ W longitude with an area of 1410 km^2. It is the capital of the Rosso department and the capital of the Trarza region with a population of approximately 65 475 inhabitants. The soil is limino-clayey and is favorable for all kinds of plant cropsWith temperatures above 42°C, the climate is Sahelian. The Diama anti-salt dam and the Senegal River, the valley's primary surface water, have made it easier to irrigate the valley's agricultural sectors. The Rosso municipality is situated for the most part in a basin. Which gives it a very low topography. The clayey nature of the soil causes flooding each winter. Development and sanitation problems constitute real obstacles to the development of the municipality.

3.2. Sampling methods

3.2.1. Physicochemical Sampling

Samples of surface water were gathered for this study in December 2024, January 2025, and February 2025. Physicochemical sampling was conducted utilizing 0.75 L polyethylene bottles that underwent rigorous cleansing with distilled water to eradicate any residual contaminants. A total of four sampling excursions were undertaken to evaluate 21 distinct parameters. The specimens were procured from four discrete locations along the river, chosen according to particular anthropogenic activities: M'pourier (agricultural interventions), Back (transportation activities), Djourbel (baseline reference point), and Iset (domestic undertakings). At each location, three individual samples were amassed in 0.75 L containers. Subsequent to collection, the samples were stored in a portable cooler to preserve their integrity and avert any alterations in water quality prior to laboratory examination. In the case of heavy metals, the samples were safeguarded through the incorporation of nitric acid to mitigate the loss of volatile constituents. Specifically, 1.5 ml of concentrated nitric acid was introduced to each 0.75 L sample to guarantee the stability of the metals during transit and until their analysis in the laboratory.

3.2.2. Biological Sampling

Bacteriological sampling was conducted using 250 ml glass bottles that were thoroughly washed with a disinfectant, then submerged in distilled water to remove any residual chemicals. The bottles were then dried and sterilized to ensure they were free of any contaminants prior to sampling. Sampling was carried out at four different sites along the river: M'pourier, Back, Djourbel, and Iset. At each site, three separate samples were collected in 250 ml bottles. After completing the sample collection, the bottles were immediately placed in a portable cooler with ice packs to maintain the temperature and prevent any microbial growth or changes in the samples before laboratory analysis. This method of preservation ensured the integrity of the samples during transportation and until they could be processed for further bacteriological examination.

3.3. Methods for analyzing physico- and chemical parameters

3.3.1. Electrochemical methods

- **Determination of hydrogen potential (pH).**

The availability of additional contaminants in water and the lifespan of bacteria can both be impacted by pH. For some uses, water with a pH that is too high or too low can generally be unpleasant. Metals tend to precipitate at very high pH values, and

compounds like ammonia are harmful to aquatic life. Alkaline water also tends to taste and smell bad. At low pH levels, metals tend to dissolve more easily, making chemicals like sulfur dioxide and cyanide more dangerous. Metal pipes are also corroded by acidic water. Consequently, because heavy metals become more soluble and accessible in low pH water, they tend to be more harmful (Saalidong et al., 2022). a drop in water bodies' pH levels, a rise in metal element mobility, and maybe an encouragement of fish mercury bioaccumulation and methylation. In the end, these dangers endanger human health (Chen et al., 2024).

Operating mode

* Device: SCHOTT Instrument type pH meter (See Fig)

- Rinse the pH meter probe with distilled water then wipe it with absorbent paper.
- Pour the solution to be tested into a beaker: fill approximately half of the container.
- Dip the probe into the solution. If necessary, tilt the beaker.
- After the display has stabilized, read the pH value.

Figure 13. pH meter

- **Determination of electrical conductivity (EC), TDS and Temperature**

One of the most important metrics for assessing and monitoring water quality is electrical conductivity (EC). It measures the water's ability to conduct electricity and is affected by the concentration of dissolved ions. Electrical conductivity can be used to measure the level of TDS in water. The total concentration of organic and inorganic materials dissolved in water, such as metals, minerals, salts, and other dissolved solids, is referred to as TDS. The flavor, odor, and general palatability of water can all be impacted by elevated TDS levels, which are typically indicated by high EC readings. In water bodies, electrical conductivity is frequently utilized as a

gauge of salinity. The quantity of salts, especially sodium chloride, in water is referred to as salinity (D. Kumar et al., 2023).

Mode of operation

The multi-parameter HI 99300 device.

The steps are as follows:

- Fill the beaker with the water to be analyzed;
- Rinse the electrode thoroughly with distilled water;
- Submerge the electrode in the beaker and press the (ON) button; - Press the button (SET HOLD) to adjust the parameter;
- Note the conductivity in (µS/cm);
- Following stabilization, the TDS value (ppm) will be determined.
- Wait until the temperature value in (°C) is shown.

Figure 14. Electrical conductivity measurement.

- **Determination of Turbidity**

Fine suspensions and colloids of organic or mineral origin cause turbidity in water. Above all, it should be mentioned that turbidity affects many aspects of water that have an impact on health in addition to its aesthetic qualities. For instance, turbidity reduces in a water-distribution subsystem, the microbiological stability of water is associated with parasites and affects disinfection effectiveness (i.e., shielding bacteria from disinfectants). As a result, the treatment process for the water with a high turbidity value is significantly impeded (Szpak et al., 2020). High levels of turbidity restrict light penetration in water, have an impact on the growth of aquatic plants, and lessen the visual appeal of rivers (Ogbonna et al., 2023).

Operating mode:

Device: HI 98703 turbidimeter.

- Rinse the tank with the water to be analyzed.
- Fill the bottle to 10 ml level. Then screw on the cover and wipe it to avoid leave footprints.
- Insert the bottle into the measuring well by placing the arrow on the bottle facing the arrow on the point.
- Close the hood.
- Press “Read” and wait for a value in NTU to be displayed.

Figure 15. Turbidity measurement

3.3.2. Volumetric method

- **Determination of total alkanity (TA), total alkanity carbonate (TAC) and Bicarbonate (HCO_3)**

A solution's capacity to convert acids into carbonate or bicarbonate ion equivalent point is known as alkalinity. Since alkalinity affects the water's capacity for chemical reaction, it is crucial to Raw water's total treatability (Nabors et al., 2011).

- **Operating Mode**

To analyze a 10 ml water sample, transfer it into an Erlenmeyer flask and incorporate 1 to 2 drops of a 0.5% alcoholic phenolphthalein solution. A pink coloration should manifest, indicating alkalinity; alternatively, if no coloration occurs, the total alkalinity is determined to be zero, a condition typically observed in natural water bodies with a pH value below 8.3. Subsequently, administer acid gradually from a burette into the Erlenmeyer flask while maintaining constant agitation, until the solution becomes

completely colorless (pH 8.3). Let V denote the volume in milliliters of acid utilized to achieve this transition.

Utilize either the previously processed sample or the original sample in the absence of any discoloration. Introduce 2 drops of methyl orange solution and conduct titration with the same acid until the color transitions from yellow to orange-yellow. Ensure that any excess addition of acid prompts a color shift from yellow-orange to pink-orange. Let V' represent the total milliliters of acid dispensed since the commencement of the titration, from which 0.5 ml representing the requisite acid volume for the indicator change, occurring slightly below the pH level for the precise neutralization of hydrogen carbonate should be subtracted.

Figure 16. Volumetric measurement.

3.3.3. Spectrophotometric methods:

- **The following analyzes were carried out using Fp-640 Flame Photometer**

Determination of Potassium (K^+) and Sodium (Na^+)

The flame emission spectrophotometer allows to determine the sodium content (Na^+) and potassium (K^+) in milligrams per liter.

- **Procedure:**

Commence by introducing distilled water, sodium and potassium standards, along with the sample into three separate tubes, subsequently positioning them at the calibrated levels of the apparatus. The device should be adjusted to a baseline of zero meters, with

the resultant measurements being recorded in milligrams per liter on the spectrophotometer interface.

Figure 17. Flame spectrophotometer

❖ **The following analyzes were carried out using a photometer (7100)**

Determination of Ammonia (NH_4^+)

Drinking water with too much NH_4^+ is undesirable and can lead to a number of issues: NH_4^+ contamination can lead to eutrophication of surface waters and problems with taste and odor in water. NH_4^+ not only reduces the effectiveness of chlorine-mediated disinfection but also produces harmful disinfection byproducts ; excessive NH_4^+ intake may oxidize to nitrates (NO_3^-) and nitrites (NO_2^-), which can produce carcinogenic nitrosamines (Cheng et al., 2020).

➢ Reagents and consumables

- Ammonia tablet No. 1
- Ammonia tablet No. 2
- Wagtech photometer
- Round test tubes, glass, 10 ml

➢ Operating Mode

- Fill the tube up to 10 ml;
- Add one Ammonia No. 1 tablet and one Ammonia No. 2 tablet, crush and stir to dissolve;
- Wait 10 minutes to allow full color development;
- Select phot 4 to measure ammonia in mg/l N or select Phot 62 to measure ammonia in mg/l NH4.

- **Determination of Phosphate (PO_4^{3-})**

Usually, runoff water from agriculture releases phosphate, nitrite, and nitrate into the environment (Stern et al., 2022).

➢ Reagents and consumables

- Phosphate tablet No. 1
- Phosphate tablet No. 2
- Wagtech photometer
- Round test tubes, glass, 10 ml

➢ Operating Mode

- Fill the tube to 10 ml.
- Add one No. 1 Phosphate tablet, crush and stir to dissolve
- Add a No. 2 Phosphate tablet, crush and wait 20 minutes to allow full color development.
- Select Photo 20.
- Read the result (see instructions for use of the instrument).
- The result is displayed in mg/l PO_4.

- **Determination of Sulfate (SO_4^{2-})**

The overuse and exploitation of water resources makes SO_4^{2-} contamination in aquatic settings even worse. activities lead to an overabundance of sulfate intake in surface water, which endangers aquatic ecosystems because of the distinct isotopic composition of SO_4^{2-} from different pollution sources. For example, SO_4^{2-}can be converted into hazardous compounds (Chen et al., 2024).

➢ Operation mode**:**

- Fill the designated tube with 10 ml of sample water.
- Incorporate a sulfate tablet and proceed to crush and stir the mixture until dissolution is achieved.
- The emergence of a cloudy solution serves as an indicative marker for the presence of sulfate ions.
- Allow a duration of 5 minutes, then mix the solution once more to confirm homogeneity.
- Select photo 32 and interpret the results displayed in milligrams per liter.

- **Determination of Iron**

As a result, the World Health Organization (WHO) has established guidelines that limit iron levels in drinking water to 0.3 mg/L, taking staining potential and color into account. Iron-rich water can also affect soil health and plant growth by blocking

irrigation systems (Techniques, 2024). About 5% of the earth's crust is made up of iron, making it the second most plentiful metal (Abu Hassan Onimisi & Ifatimehin .O. Olanrewaju, 2016).

- Reagents and consumables
- Iron tablet
- Wagtech photometer
- Round test tubes, glass, 10 ml

- Operating Mode
- Fill the tube up to 10 ml;
- Add an Iron tablet. LR, crush and stir to dissolve;
- Wait 1 minute to allow color development;
- Select Photo 18;
- Read the result;
- The result is displayed in mg/l Fe.

- **Determination of Manganese (Mn^{2+})**

The oxidation of manganese, which is present as Mn_2^+, produces a dark brown MnO_2 deposit that can stain water or clog pipes. Additionally, Mn in drinking water has been linked to neurological consequences in kids and may have an impact on consumers' health (Cheng et al., 2020).

- Reagents and consumables
- Manganese tablet No. 1
- Manganese tablet No. 2
- Wagtech photometer
- Round test tubes, glass, 10 ml

- Operating Mode
- Fill the tube to 10 ml.
- Add one Manganese No. 1 tablet, crush and stir to dissolve
- Add a No. 2 Manganese tablet, crush and wait 20 minutes to allow the color to fully develop.
- Select Photo 20.
- Read the result (see instructions for use of the instrument).
- The result is displayed in mg/l Mn.

- **Determination of Copper free (Cu)**

Copper commonly comes from both natural and man-made sources in aquatic systems. The high copper levels in water bodies are mostly caused by wastewater treatment plant effluents and agricultural practices such as the use of fertilizers and pesticides (Falfushynska et al., 2024).

- Reagents and consumables
- Copper pellet No. 1
- Copper pellet No. 2
- Wagtech photometer
- Round test tubes, glass, 10 ml

- **Operating Mode**

- Fill the tube to 10 ml.
- Add one No. 1 Copper tablet, crush and stir to dissolve
- Select Photo 10.
- Read the result immediately - see instructions for use of the instrument.
- The result for Free Copper is displayed in mg/l.

Figure 18. Photometer (7100)

- The following analyzes were carried out using the HACH DR3900 Spectrophotometer.

- **Determination of total suspended solids (TSS).**

Total Suspended Solids (TSS) is the general term used to describe the quantity of particles that suspend in a water sample. One of the most important indicators of water quality is the total suspended particles load from urban surfaces. Elevated suspended solids concentrations in rivers and streams may negatively affect the water body's total

biological diversity. Water that has a higher TSS content is more turbid and less transparent, giving the impression that it is murky (Ogbonna et al., 2023).

- **Operating mode**

- Fill a sample cell with 10 mL of sample.
- Prepare the blank: Fill a second sample cell with 10 mL of sample.
- Make sure the blank sample cell is clean.
- Press ZERO after inserting the blank into the cell holder. 0 mg/L is shown on the screen.
- The prepared sample cell should be cleaned.
- Place the ready-made sample inside the cell holder.
- Press READ. Results are displayed in mg/L TSS.

- **Determination of Barium (Ba^{2+})**

A trace element that is not necessary, barium is found naturally in large quantities. The weathering of rocks and minerals and anthropogenic emissions are two ways that barium enters the environment. Industrial processes are the primary source of barium in the atmosphere emissions. Barium in agricultural soils may come from fertilizers and soil additions. Barium enters surface waters through industrial wastewater and soil runoff containing fly ash or landfill sewage discharge (Verbruggen et al., 2020).

- **Operating mode**

Program 20: Barium (White) Preparation

- Sample Preparation

Add the specified volume of the sample, according to the test range, into a clean 10 mL sample cell.

- Blank Sample Calibration

Fill the cell holder with the blank sample. Press the button marked "ZERO." 0 mg/L Ba^{2+} should appear on the screen. The blank sample should be taken out of the cell holder.

- Sample Reaction

Fill the sample cell with the contents of a BariVerTM 4 reagent powder sachet. The presence of barium will cause the solution to react appropriately. Rotate the sample to mix thoroughly. The presence of undissolved powder does not affect measurement accuracy.

- Reaction Time

Start the timer on the device. A 5-minute countdown will begin. Do not move the sample cell during the reaction period.

- Measurement

Once the reaction time is complete, clean the prepared sample cell. Insert the prepared sample into the cell holder. Press the READ button to measure the barium concentration. The result will be displayed in mg/L Ba^{2+}.

Determination of Nitrate (NO_3^-)

In natural environments, nitrate is a common and active type of nitrogen that is dissolved and promotes primary productivity. External nitrate consumption via food and drinking water is a major source of human nitrate exposure and, if excessive, can have detrimental health effects. In order to avoid methemoglobinemia, the World Health Organization (WHO) has set a nitrate guideline of 50 mg/L and, in many countries, a national limit contamination level of 45 mg/L for nitrates in water sources (Wang et al., 2023). As for N, it can be moved from agriculture by leaching or surface drainage. NO3-N, the primary symbol for surface water close to agricultural regions can quickly absorb inorganic nitrogen from aerated soils. Nitrate Concentrations more than 10 mg L-1 have been deemed harmful to health (Broetto et al., 2017). Furthermore, because nitrate is widely used in waste treatment, agriculture, and animal husbandry, As an environmental contaminant in water, it can also make its way into the food chain. (Ferdina & Setiawan, 2024).

- **Operating mode**

Nitrate Measurement (Program 353 N, Nitrate MR PP)

- Sample Preparation

- Fill a sample cell with 10 mL of the sample.

- Add the contents of a powder reagent sachet into the sample cell.
- Start the timer on the device. A 1-minute countdown begins.
- Cap the sample cell and shake it vigorously until the timer ends.
- Start the timer again for a 5-minute reaction time.
- If nitrate is present, an amber color will develop.

➢ Blank Sample Preparation

- Fill a second sample cell with 10 mL of the sample (to serve as a blank).
- Once the reaction time has ended, clean the blank sample cell.
- Insert the blank sample into the cell holder.
- Press the ZERO button. The display should show 0.0 mg/L NO_3^-–N.

➢ Measurement

- Clean the prepared sample cell before inserting it into the cell holder.
- Within 2 minutes of the timer expiring, insert the prepared sample into the cell holder.
- Press the READ button to measure nitrate concentration.
- The result will be displayed in mg/L NO_3^-–N.

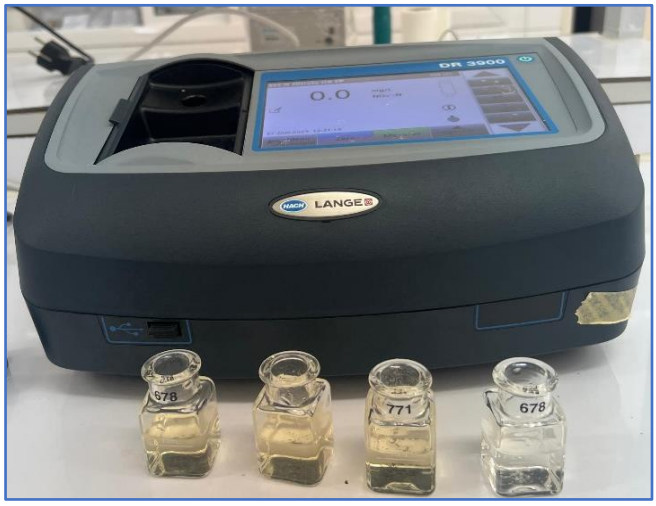


Figure 19. Nitrate measurement (Spectrophotometer DR 900)

Determination of Nitrite (NO_2^-)

Nitrites are nitrous acid salts. They can be made by reducing the melt of alkali metal nitrates, such lead, or by thermally breaking them down. With the exception of yellow silver nitrite, all nitrites dissolve readily in water. Because of the effects of fertilization ("area pollution") and wastewater breaches ("spot pollution"), nitrates and nitrites pose a threat to the environment, primarily in groundwater and drinking water sources, where they frequently surpass the maximum concentrations in water sources suitable for human use (Balejčíková et al., 2020).

- **Operating Mode**

- Launch the 371 N, Nitrite LR PP program.
- Prepare the sample by adding 10 mL of the sample to a sample cell.
- Fill a NitriVer 3 Reagent Powder Pillow with its contents.
- To blend, swirl.
- The presence of nitrite in the sample is indicated by a pink hue.
- Set the instrument timer to begin. A 20-minute response time begins

  Get the blank ready:
- Fill a second sample compartment with 10 mL of the sample when the timer goes off.
- Make sure the blank sample cell is clean. Fill the cell holder with the blank.
- Push ZERO. The reading on the screen is 0.000 mg/L NO2–N.

  Measurement
- Make sure the prepared Place the ready-made sample inside the cell holder.
- Press READ. Results are displayed as mg/L NO2–N.

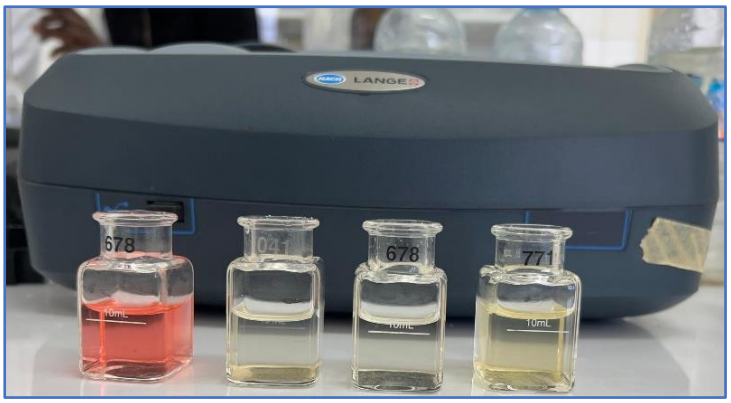


Figure 20. Nitrite measurement (Spectrophotometer DR 900).

- Determination of Zinc

Although Zinc is necessary for all living organisms, large doses of it can be hazardous to aquatic life (Wardhani et al., 2022). Both natural and man-made processes emit zinc, the 24th most abundant element, into the environment, with more man-made sources than natural ones. Products containing zinc, mining, and metallurgy all play a major role in its dispersion in soil, water, and air. Furthermore, runoff from agricultural operations, renewable energy installations, and municipal facilities all contribute to the inflow of zinc (Falfushynska et al., 2024).

- **Operating mode**
  - Choose the test. If necessary, insert an adaptor. For 20 mL of the sample into a 25 mL graduated mixing cylinder.
  - Fill the mixing cylinder with the contents of one ZincoVer 5 Reagent Powder Pillow.
  - Stopper. To fully dissolve the powder, invert many times.
  - Failure to dissolve all the particles could lead to inconsistent readings. The sample ought to be orange.
  - To prepare a blank, fill a sample cell with 10 mL of the solution.
  - The sample was prepared by adding 0.5 mL of cyclohexanone to the remaining solution in the mixing cylinder using a disposable dropper.
  - Set the instrument timer to begin. There will be a 30-second reaction time.
  - Stop the mixing cylinder and shake the prepared sample briskly during the reaction period.
  - Set the instrument timer to begin.
  - There will be a three-minute reaction time.
  - Fill a second sample cell with the prepared sample solution that was taken out of the mixing cylinder.

- Wipe the blank and put it in the cell holder when the timer goes off. The instrument is zero.
- The screen will display: 0.00 mg/L of zinc
- After the sample is ready, wipe it and place it in the cell holder.
- READ the Zn mg/L findings.

Figure 21. Zinc measurement (Spectrophotometer DR 900).

- **Determination of Chemical oxygen demand (COD)**

The chemical oxygen demand (COD) often provides a quantitative indication of surface water contaminants, which are primarily organic (Han et al., 2022).

➢ **Operating mode**

- To get the sediment into suspension, invert a few times.
- Pipette 2.0 mL of the sample carefully.
- Close the cuvette and give its outside a good cleaning.
- Flip it around.
- The thermostat's heat.
- In the normal program, HT 200 S 15 minutes of HT.
- Take the heated cuvette out.
- COD classic: flip twice with caution.
- HT 200 S: Carefully invert twice after the lock unlocks. Let cool till at room temperature. Traditional COD: in a cooling rack.
- In the thermostat is HT 200 S.
- Clean the cuvette's outside thoroughly, then assess.
- Place the cuvette into the holder for the cell. DR 1900
- Choose the test and press READ.

Determination of Chromium (Cr)

Surface water and groundwater are frequently contaminated by chromium, a metal that occurs naturally in the earth's crust as compounds or as ions in water. One of the main causes of chromium contamination in the environment is human activity, which releases chromium into the atmosphere (Alemu & Gabbiye, 2017).

- **Operating mode**
  - The foil on the screwed-on DosiCap Zip should be carefully removed.
  - The DosiCap Zip should be unzipped. Pipette 2.0 mL of the sample carefully.
  - The DosiCap Zip should be reattached right away, with the top fluting.
  - Give it a good shake.
  - The thermostat HT 200 S should be heated for 15 minutes using the regular HT program.
  - After digestion, do not invert the cuvette.
  - Let cool until it reaches room temperature. Take the DosiCap Zip off.
  - Attach a DosiCap B in orange by screwing it onto the cooled cuvette.
  - To fully dissolve the freeze-dried ingredients, invert a few times.
  - After two minutes, invert a couple more times, clean the cuvette's exterior completely, and assess.
  - Place the cuvette within the holder for the cell. DR 1900:
  - After choosing the test, press READ.

Figure 22. COD and chromium measurement (DosiCap Zip).

3.4. Methods for analyzing bacteria

3.4.1. Total Coliforms and Echerichia. Coli

Microbiological monitoring is crucial for evaluating the quality of the water in reservoirs that supply drinking water since fecal contamination may be harmful to human health. Bacterial indicators like coliform bacteria, Escherichia coli (E. coli), and enterococci are used to assess the hygienic-microbiological water quality of drinking water, raw water for drinking water production, and recreational water (Reitter et al., 2021)

- **Reactive**

- Chromogenic agar for coliform bacteria (CCA)
- Tryptone soy agar (TSA)
- Oxidase reactive
- Diluent

- **Materiel**

- Steam sterilization device (autoclave)
- Incubator, adjustable to (36 ± 2) ^{o}C
- Incubator at (44 ± 0.5) ^{o}C
- pH meter, accurate to 0.1
- Membrane filtration equipment, in accordance with ISO 8199.
- Filtration membranes, composed of cellulose esters, generally around 0.45 um

- Tweezers with rounded ends, for handling membranes.
- Petri dishes, plastic, 100 diameters.
- Colony counting device.

➢ **Operating mode**

- Before examination, homogenize the sample by giving it a good shake to ensure that the microorganisms are distributed evenly. This will depend on the type of water and the anticipated number of bacteria present.
- Connect the sterile filtration equipment to a source.
- Lay a membrane on the porous disc at the base of the device, grid side up. filtration device, grasping only the outer edge of the membrane using sterile flat-edged forceps.
- Correctly reposition the sterile funnel on the base of the device.
- With the tap connecting to the vacuum closed, pour 100 ml of the sample to be analyzed onto the filter membrane.
- Open the tap and create enough vacuum to slowly filter the water through the membrane.
- immediately as the sample is filtered,
- Turn off the faucet using sterile forceps, remove the funnel and transfer the membrane, making sure that the membrane and the plate surface containing the chromogenic coliform agar (CCA) do not have any air bubbles.
- Incubate at (36 ± 2) °C for 21 hours ± 3 hours.
- Examine the filter membranes and count all colonies showing a positive ß-D-galactosidase reaction (pink to red color) as presumptive coliform bacteria that are not E.Coli.
- Count all colonies showing a positive ß-D-galactosidase reaction and a positive ß-D-glucuronidase reaction (dark blue to purple color) as E. Coli.

3.4.2. Enterococcus

➢ **Reactives**

- Slanetz and Bartley agar at TTC.
- Bile, esculin, and sodium azide agar (BEA).
- Diluent (tryptone-salt).

➢ **Operating mode**

- Before examination, homogenize the sample by giving it a good shake to ensure that the microorganisms are distributed evenly. This will depend on the type of water and the anticipated number of bacteria present.
- Connect the sterile filtration equipment to a source.

- Place a membrane, grid side up, on the porous disc of the base of the filtration device, grasping only the outer edge of the membrane using sterile flat-edged forceps.
- Correctly reposition the sterile funnel on the base of the device.
- With the tap connecting to the vacuum closed, pour 100 ml of the sample to be analyzed onto the filter membrane.
- sample by giving it a good shake to ensure that the microorganisms are distributed evenly. This will depend on the type of water and the anticipated number of bacteria present.the Slanetz and Bartley agar (TTC).
- Incubate the boxes at 36 ± 2 °C for 44 ±4 hours.
- After incubation, consider as typical all bumped colonia showing a red, brown or pink color, either in the center or over the entire colonia.
- If there are typical colonies, transfer the membrane and colonies, using sterile forceps without turning, to a dish of bile-esculin-azide agar that has been preheated to 44 °C.
- Incubate at 44 °C ± 0.5 for 2 hours.
- Read the box without delay.
- Consider all typical colonies showing brown to black colors in the surrounding environment as giving a positive reaction, and count them as intestinal enterococci.

Figure 13. Vacuum filtration manifold system

Figure14. Figure a Emmert Incubator

3.4.3. Calculations for counting methods

- ❖ Calculation of counting on box: general case (counting colonies in totality or characteristic colonies without confirmation)

Calculate the number N of microorganisms in colony-forming units per gram or per milliliter (cfu/g or cfu/ml) of the test portion using Formula.

$$\mathbf{N} = \frac{\boldsymbol{\Sigma C}}{\boldsymbol{V[n1(0.1*n2)]*d}}$$

- ΣC is the sum of the colonies counted in all the boxes selected from one or two successive dilutions;
- V Is the volume of inoculum applied to each Petri dish, in ml;
- N1 is the number of boxes retained at the first dilution;
- N2 is the number of boxes retained at the second dilution (n2 = 0 if not prepared);
- D is the dilution corresponding to the first dilution retained (d = 1 for a liquid product not diluted).

❖ Calculate the density on a particular scale: maximum colony count based on characteristic size.

$$\mathbf{N} > \frac{\boldsymbol{C}}{\boldsymbol{V*d}}$$

- C is the maximum number of colonies indicated in the specific standard;
- V is the volume of inoculum applied to each Petri dish, in ml;
- d is the dilution corresponding to the highest dilution (the most diluted) (d = 1 for a liquid product undiluted).

3.5. Water Quality Index

Like any other tool, Water quality is evaluated using water quality indexes and necessitate an understanding of the fundamental ideas and principles pertaining to water and related topics. It is a popular way to convey the quality of water and provides a reliable and repeatable unit of measurement that adapts to variations in the primary properties of water (Bharti N, 2011).

The water quality index (WQI) is widely utilized as a method for assessing the quality of surface water. It employs aggregation methodologies that facilitate the transformation of vast amounts of water quality data into a singular value or index. Internationally, the WQI has been employed to assess the quality of surface water in accordance with specific local water quality standards (Uddin et al., 2021).

In order to examine the spatiotemporal fluctuations in a river's water quality, water quality indicators aid in the analysis and interpretation of large and intricate water quality datasets. Sometimes it's crucial to understand the composite effect of the water quality metrics in order to draw insightful conclusions from sizable water quality datasets (Shukla et al., 2017).

WQI was first created by Horton (1965) as a numerical technique to assess the quality of water from the US Ohio River Valley Water Sanitation Commission., according to Ekere et al. (2019). WQI has the advantage of informing decision-makers, water managers, and the general public about the condition of water resources. This enables the assessment of the effectiveness or ineffectiveness of any management strategy aimed at improving the water quality (Azzirgue et al., 2022).

Researchers from all over the world have developed a variety of methodologies over the past few decades to evaluate the water quality in a water body, including the NSFWQI, the Central Pollution Control Board's Water Quality Index, the Comprehensive Pollution Index (CPI), the Overall Index of Pollution, the Eutrophication Index (EI), the Organic Pollution Index (OPI), and others based on the water quality parameters (Mishra et al., 2016).

Currently in use worldwide are water quality indices based on indicators and aggregation techniques, including the OWQI, the US National Sanitation Foundation's Water Quality Index (NSFWQI), the British Columbia Water Quality Index

(BCWQI), and the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI).

The WQI was calculated using the weighted Arithmetic Index method.

- The quality rating scale for each parameter qi was established using this expression (1)

$$q_i = \frac{C_i}{S_i} \times 100 \qquad (1)$$

Each parameter's quality rating scale (qi) is determined by dividing its concentration (Ci) in each water sample by the corresponding standard (Si), then multiplying the result by 100.

- A value inversely proportionate to the recommended standard (Si) of the relevant parameter (2) was used to determine relative weight (Wi):

$$W_i = \frac{K}{S_i} \qquad (2)$$

Where: $K = \frac{1}{\Sigma(\frac{1}{Si})}$

- The overall WQI was calculated by aggregating the quality rating (q_i) with unit weight (W_i) linearly (3):

$$WQI = \sum_{i=1}^{n} (W_i \times q_i) \qquad (3)$$

- In general, WQI was discussed in relation to a particular and planned use of water. The WQI for drinking is taken into consideration and allowed in this study. For drinking water, the WQI is 100:

$$\text{Overall } WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i} \qquad (4)$$

As shown in Table 1. the calculated WQI values are divided into five classes (Azhari et al., 2023).

Ranking	WQI Value	Explanation
<50	Excellent water	Good for human health
50–100	Good water	Suitable for human consumption
100–200	Poor Water	Water in poor condition
200–300	Very poor water	Needs special attention before use
>300	Unsuitable for drinking	Requires too much attention

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Physico parameters

4.1.1. Temperature (T °C)

According to the investigation, temperature values are influenced by the particular sampling stations. Iset has the lowest temperature at about 23.4 ± 0.73 °C, while M'Pourier has the highest at about 23.9 ± 0.83 °C. The measured temperature levels are in the range of 30 °C that is recommended by the World Health Organization (WHO 2017). The statistical analysis also reveals that there are no significant differences between a number of stations (P>0.05). Moreover, supplementary research conducted in the same geographical area has reported temperature values oscillating between 27.3 °C and 28 °C (Malang, 2013). Additionally, other investigations undertaken in the M'Pourie region have indicated temperature values ranging from 29.1 °C to 29.5 °C (Med Fadel et al., 2024).

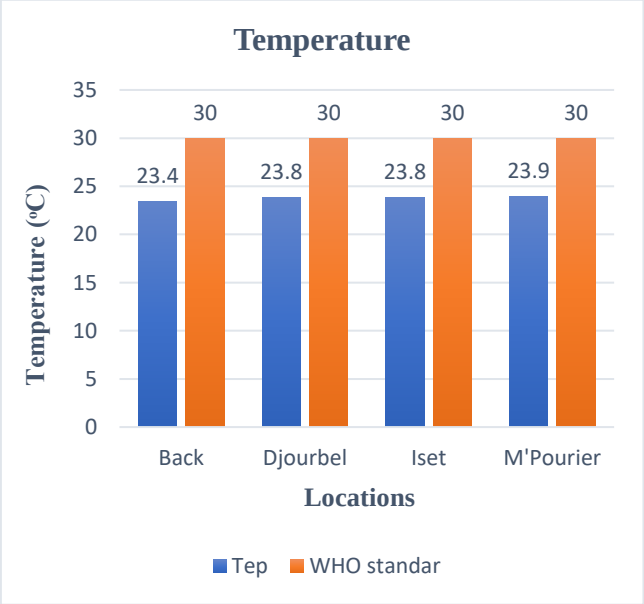


Figure 4.1.1. Variations of Temperature values for the four stations.

4.1.2. The potential of hydrogen (pH)

The analysis indicates that pH levels are contingent upon the specific sampling stations. The pH levels fluctuate between 6.13 ± 0.2 recorded at Djourbel and 7.31 ± 0.17 observed Back. Consequently, the pH values obtained are in accordance with the standards advocated by the World Health Organization (WHO 2017), which stipulate a range of 6.5 to 8.5, with the exception of the Djourbel station. The investigation further

reveals that the statistical analysis demonstrates significant differences among certain stations (P<0.05 Table A.1). Moreover, supplementary research conducted in the same geographical area has reported pH values oscillating between 6.6 and 7.8 (Malang, 2013). Additionally, other investigations undertaken in the M'Pourie region have indicated pH values ranging from 6.9 to 8.41 (Med Fadel et al., 2024).

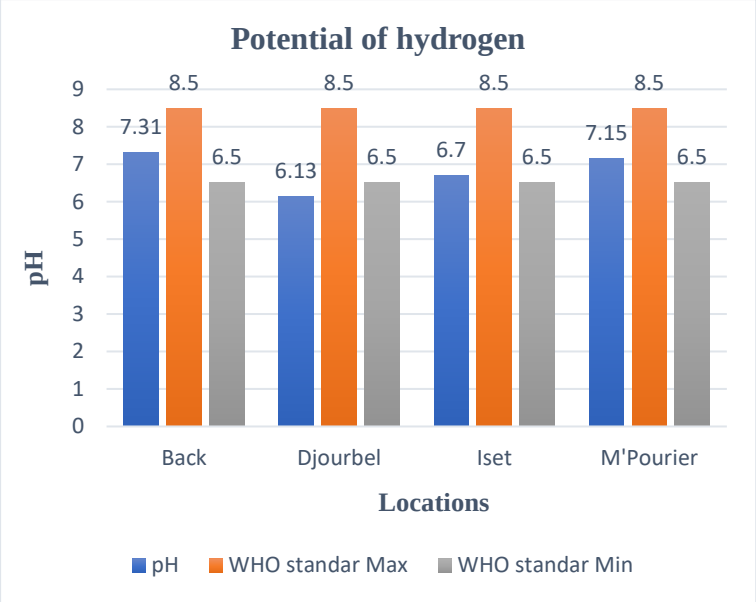


Figure 4.1.2. Variations of pH values for the four stations.

4.1.3. Electrical Conductivity (EC)

The EC levels measured depended on the particular sampling stations. Back has the lowest EC, which is about 89 ± 0.2 uS/cm, while M'Pourier has the highest EC, which is about 2902 ± 934 uS/cm. With the exception of the M'Pourier station, the EC values acquired are therefore consistent with the guidelines recommended by the World Health Organization (WHO 2017), which specify a range of 500 uS/cm. The statistical analysis also reveals that there are no significant differences between a number of stations (P>0.05). Furthermore, additional studies carried out in the same region have documented EC values that fluctuate between 61 and 115 uS/cm (Malang, 2013). Furthermore, additional research conducted in the M'Pourie region has revealed EC values between 50 and 60 uS/cm (Med Fadel et al., 2024).

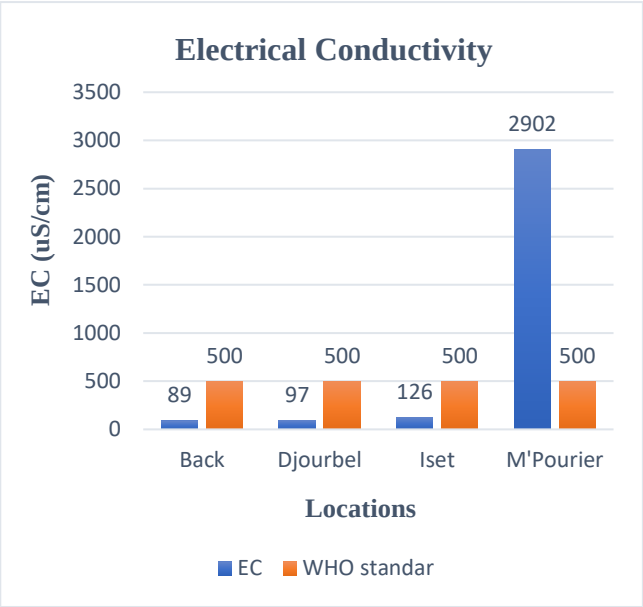


Figure 4.1.3. Variations of EC concentration for the four stations.

4.1.4. Total dissolved solid TDS

The TDS levels are influenced by the specific sampling stations, as illustrated by the analysis. At Djourbel, the TDS is at its minimum, approximately 44.7±3.84 mg/L, in contrast to M'Pourier, where it is at its maximum, approximately 1453±468 mg/L. The TDS values obtained, therefore, align with the World Health Organization's (WHO 2017) recommended thresholds, which advocate for a permissible range of 500 mg/L, with the exception of the M'Pourier station. The fluctuations of TDS between stations are not significant (P>0.05)

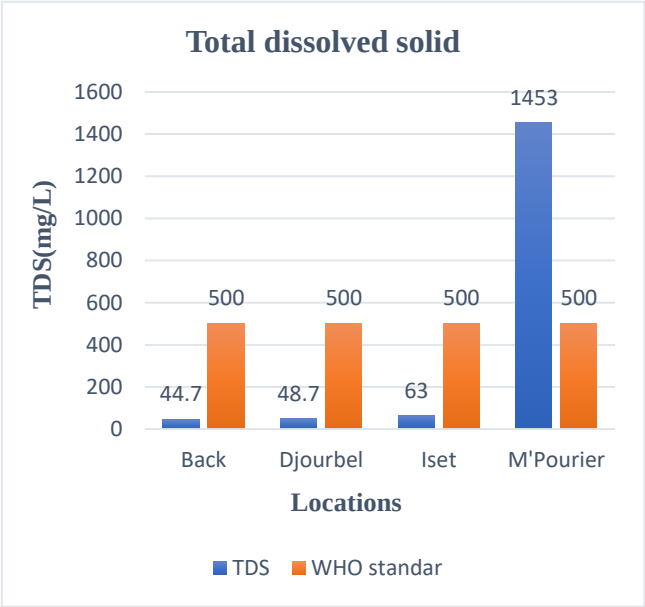


Figure 4.1.4. Variations of TDS concentration for the four stations.

4.1.5. Turbidity

The analysis indicates that turbidity values are contingent upon the specific sampling locations. The Iset station exhibits the lowest turbidity, approximately 14.7 ± 4.75 NTU, whereas Back demonstrates the highest turbidity, approximately 130.7 ± 26.4 NTU. The fluctuations of turbidity between stations are not significant (P>0.05). The turbidity values obtained are inconsistent with the guidelines posited by the World Health Organization (WHO 2017), which stipulate a maximum range of 5 NTU.

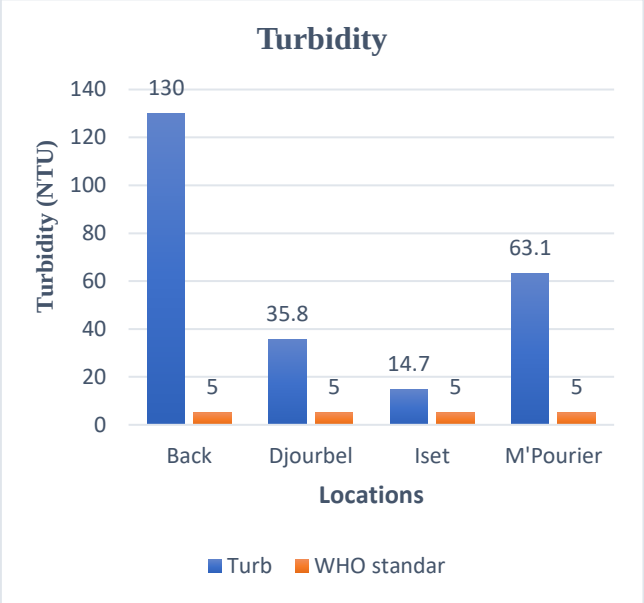


Figure 4.1.5. Variations of turbidity concentration for the four stations.

4.1.6. Total suspended solid (TSS)

The analysis reveals that TSS values are dependent on the specific sampling stations. Djourbel presents the lowest TSS, approximately 11.3 ± 0.88 mg/L, whereas M'Pourier exhibits the highest TSS, approximately 53.7 ± 0.88 mg/L. The TSS values obtained, therefore, comply with the recommendations established by the World Health Organization (WHO 2017), which specify a threshold of 500 mg/L. The investigation further elucidates that the statistical analysis reveals significant disparities among certain stations (P<0.05 Table A.5). Additionally, further studies conducted in the same region have chronicled TSS values that oscillate between 320-360 mg/L in July (Malang, 2013).

Figure 4.1.6. Variations of TSS concentration for the four stations.

4.2. Chemical parameters

4.2.1. Sodium (Na^+)

The research indicates that the specific sample sites have an impact on the Na^+ values. M'Pourier has the highest Na^+ (about 88.3 ± 14.0 mg/L), while Djourbel has the lowest (approximately 4 ± 0.58 mg/L). The fluctuations of sodium between stations are not significant ($P>0.05$). Thus, the obtained Na^+ values are in line with the World Health Organization's (WHO 2017) recommendations, which call for a range of 200 mg/L. Moreover, Na^+ levels ranging from 6 to 15 mg/L have been reported in other research conducted in the same area (Mohamedou et al., 2010). Additionally, studies in the M'Pourie region have shown that Na^+ levels range from 18 to 21 mg/L (Med Fadel et al., 2024).

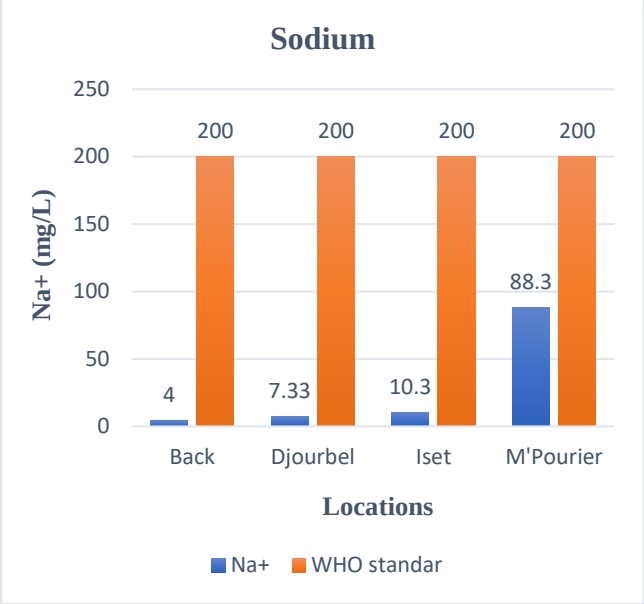


Figure 4.2.1. Variations of Na^+ concentration for the four stations.

4.2.2. Potassium (K^+)

The analysis indicates that the specific sample sites have an impact on K^+ values. M'Pourier has the highest K^+, at around 20 ± 6.43 mg/L, while Djourbel has the lowest, at about 2 ± 0.58 mg/L. The K^+ values obtained, with the exception of the M'Pourier station, are thus in line with the World Health Organization's (WHO 2017) recommended standards, which outline a range of 12 mg/L. The fluctuations of potassium between stations are not significant ($P>0.05$). Additionally, K^+ concentrations ranging from 3 to 10 mg/L have been reported in other investigations conducted in the same region (Mohamedou et al., 2010). Additionally, more studies in the M'Pourie region have shown that K^+ levels range from 2 to 6 mg/L (Med Fadel et al., 2024).

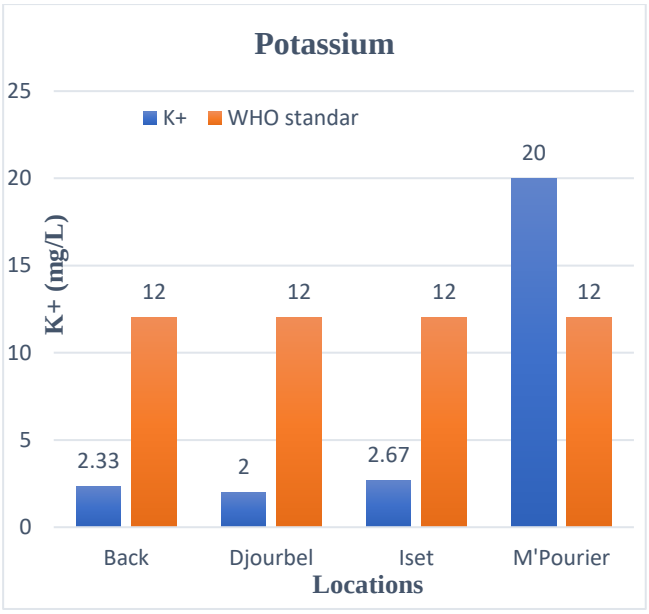


Figure 4.2.2. Variations of K^+ concentration for the four stations

4.2.3. Alkanity ($CaCO_3$)

The alkalinity levels are contingent upon the specific sampling locations, as delineated by the analysis. At the Djourbel station, the alkalinity is at its nadir, approximately 6.5±1.7 mg/L, in contrast to the M'Pourier station, where it reaches its zenith, approximately 26.7 ± 12 mg/L. The fluctuations between stations are not significant ($P>0.05$). The alkalinity values thus obtained conform to the guidelines established by the World Health Organization (WHO 2017), which advocate for a permissible range of 200 mg/L.

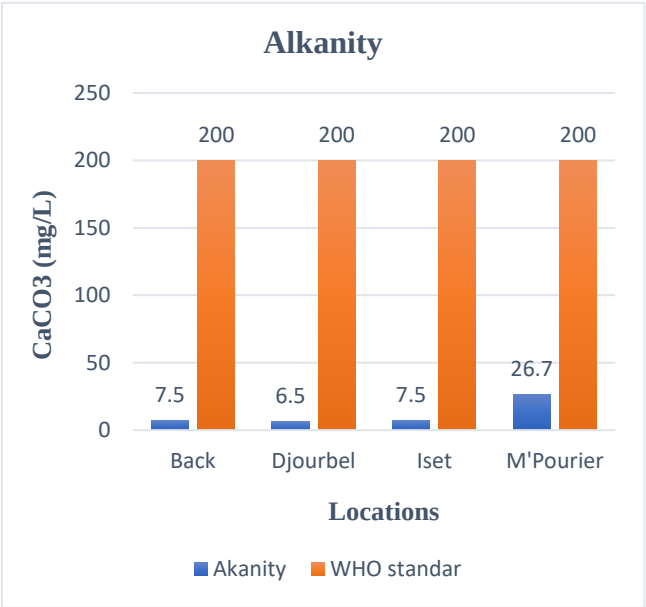


Figure 4.2.3. Variations of alkanity concentration for the four stations.

4.2.4. Bicarbonate (HCO_3^-)

The investigation indicates that HCO_3^- concentrations fluctuate based on the designated sampling stations. At M'Pourier, the HCO_3^- levels are at their acme, approximately 325 ±147 mg/L, whereas at Djourbel, they present their minimum, approximately 79.3±19.6 mg/L. The fluctuationsof bicarbonate between stations are not significant (P>0.05). With the singular exception of the M'Pourier station, the HCO_3^- values obtained thus adhere to the World Health Organization's (WHO 2017) recommended thresholds, which delineate a minimum range of 120 mg/L. Moreover, supplementary research conducted in the M'Pourier vicinity has disclosed HCO_3^- values ranging between 42.7 and 79.3 mg/L (Med Fadel et al., 2024).

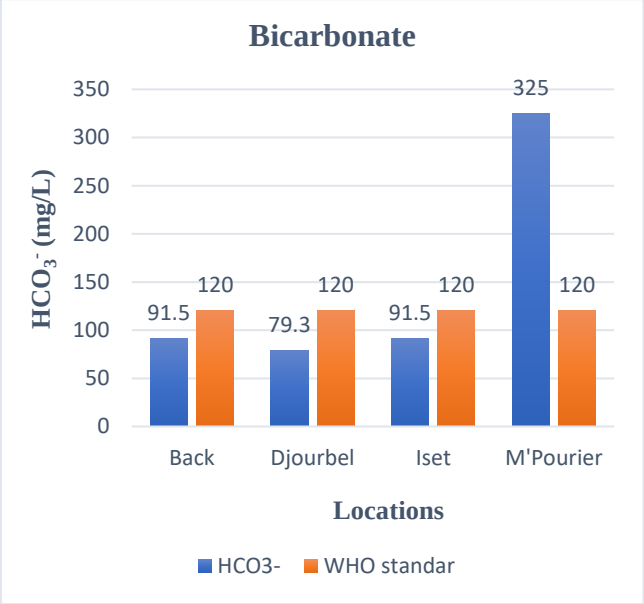


Figure 4.2.4. Variations of HCO_3^- concentration for the four stations**.**

4.2.5. Nitrite (NO_2^-)

The analysis indicates that the NO_2^- values are contingent upon the specific sampling locations. Djourbel presents the minimal NO_2^- concentration, approximating 0.002 ± 0.002 mg/L, whereas M'Pourier denotes the maximal NO_2^- concentration, at approximately 1.34 ± 0.044 mg/L. Excluding the M'Pourier station, the NO_2^- values obtained are thus aligned with the parameters established by the World Health Organization (WHO 2017), which stipulate a threshold of 0.5 mg/L. The fluctuations of nitrite between stations are not significant (P>0.05). Moreover, supplementary investigations conducted in the identical region have reported NO_2^- levels that oscillate between 0.05 and 1.1 mg/L (Mohamedou et al., 2010). Additionally, further empirical research executed in the M'Pourier area has unveiled NO_2^- concentrations ranging from 1.15 to 13.69 mg/L (Med Fadel et al., 2024).

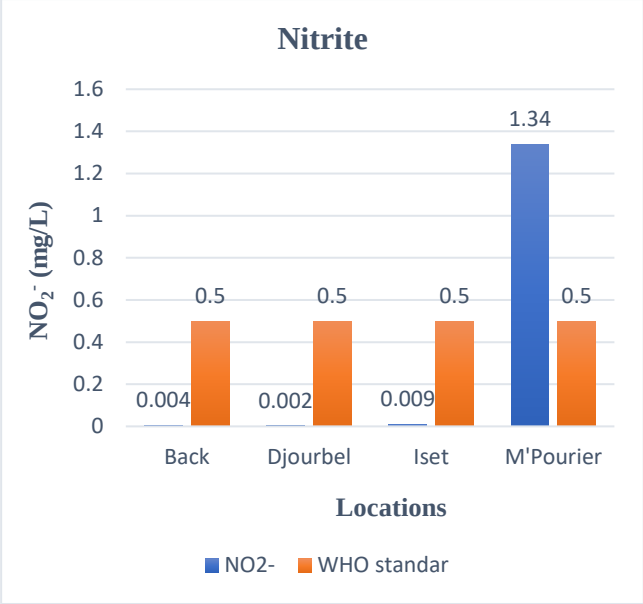


Figure 4.2.5. Variations of NO_2^- concentration for the four stations**.**

4.2.6. Nitrate (NO_3^-)

The analysis suggests that NO_3^- concentrations are reliant on the specific sampling sites. Back exhibits the lowest NO_3^- concentration, estimated at 89 ± 0.2 mg/L, while M'Pourier holds the highest NO_3^- concentration, approximately 12.1 ± 0.9 mg/L. The NO_3^- values obtained are therefore in accordance with the prescribed standards established by the World Health Organization (WHO 2017), which delineate a permissible limit of 50 mg/L. The inquiry further elucidates that the statistical analysis reveals significant disparities among certain sampling stations ($P<0.05$ Table A.2.). Furthermore, additional scholarly investigations in the M'Pourier region have disclosed NO_3^- concentrations ranging from 1.54 to 18.26 mg/L (Med Fadel et al., 2024).

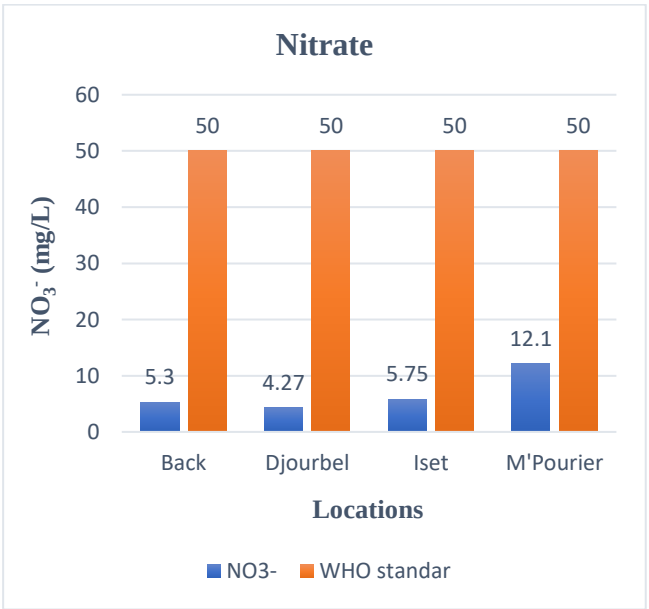


Figure 4.2.6. Variations of NO_3^- concentration for the four stations.

4.2.7. Ammonia (NH_4^+)

The levels of NH_4^+ reported only the Back and and M'Pourier station range from 0.16 ± mg/L and 1.02 ± 0.53 mg/L, respectively. Excluding the M'Pourier station, the NH4 + levels recorded are thus in alignment with the guidelines delineated by the World Health Organization (WHO 2017), which suggest a threshold of 0.5 mg/L. The examination further reveals that the statistical analysis showed non-significant differences between stations (P>0.05). Additionally, further research conducted in the M'Pourier area has indicated NH_4^+ concentrations ranging from 0.17 to 0.93 mg/L (Med Fadel et al., 2024).

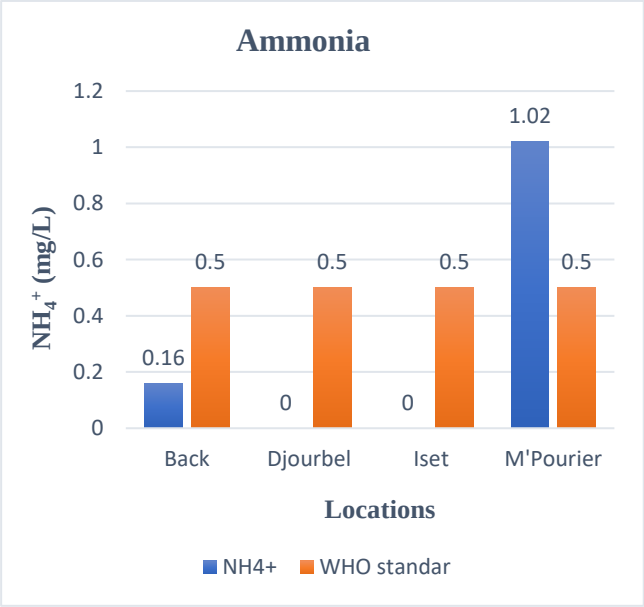


Figure 4.2.7. Variations of NO_4^+concentration for the four stations.

4.2.8. Phosphate (PO_4^{3-})

The analysis posits that PO_4^{3-} concentrations are contingent upon the specific sampling locations. Iset demonstrates the lowest PO_4^{3-} concentration, approximately 0.35 ± 0.18 mg/L, while Back exhibits the highest PO_4^{3-} concentration, estimated at 0.85 ± 0.3 mg/L. The PO_4^{3-} values obtained are thus in consonance with the standards recommended by the World Health Organization (WHO 2017), which delineate a permissible limit of 5 mg/L. The fluctuations of phosphate between stations are not significant (P>0.05).

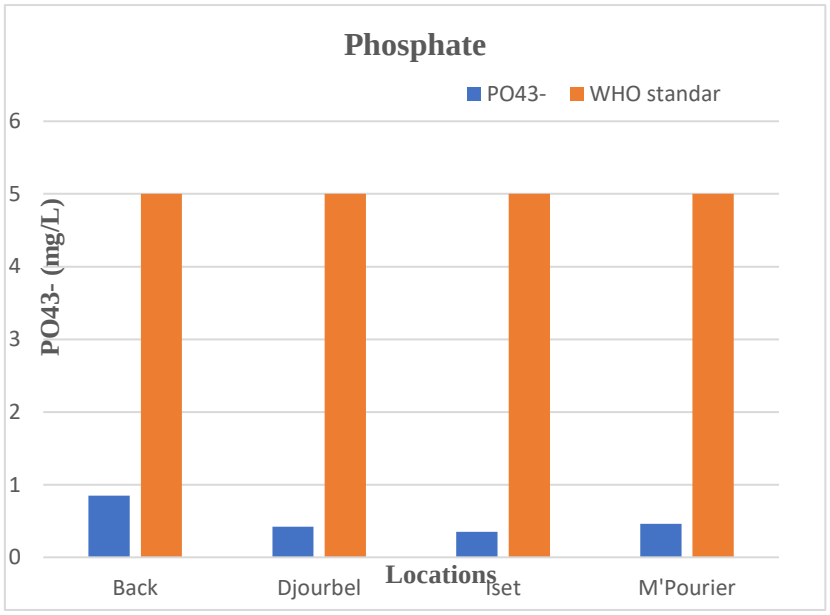


Figure 4.2.8. Variations of PO_4^{3-} concentration for the four stations.

4.2.9. Sulphate (SO_4^{2-})

The analysis indicates that the specific sample stations affect the SO_4^{2-} values. M'Pourier has the greatest SO_4^{2-}, at roughly 61.3 ± 11.9 mg/L, while Djourbel has the lowest, at about 14 ± 4.04 mg/L. Therefore, the obtained SO_4^{2-} values are in line with the World Health Organization's (WHO 2017) recommended limits, which call for a range of 250 mg/L. The analysis also shows that there are notable variations among several stations, according to the statistical analysis (P<0.05 Table A.3).

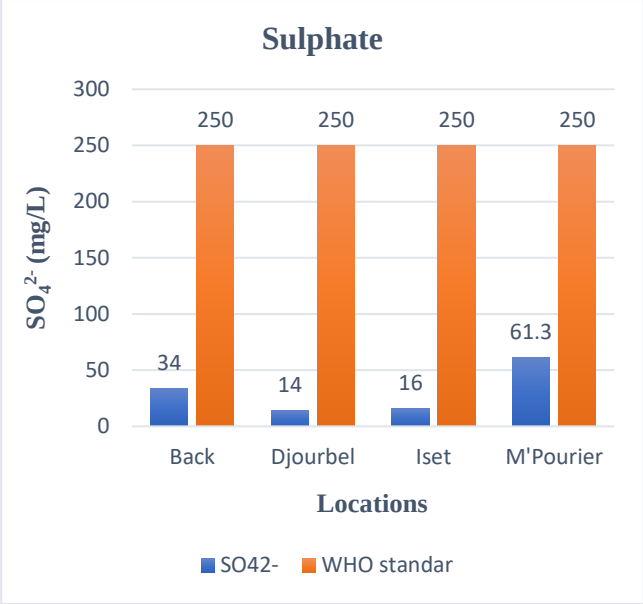


Figure 4.2.9. Variations of SO_4^{2-} concentration for the four stations.

4.2.10. Manganese (Mn^{2+})

The research indicates that the specific sample stations have an impact on Mn^{2+} readings. Mn^{2+} is lowest in Back (about 0.004 ± 0.003 mg/L) and greatest in M'Pourier (approximately 0.005 ± 0.003 mg/L). Thus, the obtained Mn^{2+} values are in line with the World Health Organization's (WHO 2017) recommendations, which call for a range of 0.05 mg/L. The fluctuations of manganese between stations are not significant (P>0.05).

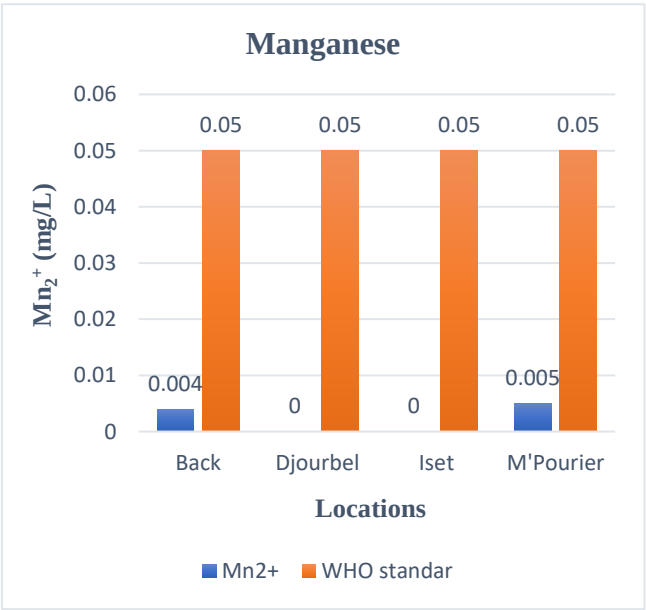


Figure 4.2.10. Variations of Mn^{2+} concentration for the four stations

4.2.11. Chemical Oxygen Demand (COD)

According to the investigation, COD values are influenced by the particular sampling stations. Iset has the lowest COD at about 32.1 ± 2.23 mg/L, while M'Pourier has the highest at about 62.9 ± 3.32 mg/L. The measured COD levels are below the range of 20 mg/L that is recommended by the World Health Organization (WHO 2017). The statistical analysis also reveals that there are significant differences between a number of stations (P<0.05 Table A.4).

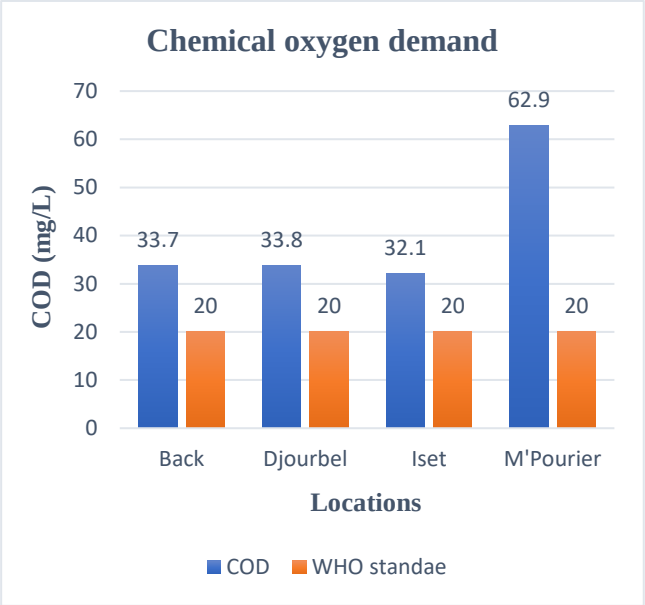


Figure 4.2.11. Variations of COD concentration for the four stations.

4.3 Metals parameters

4.3.1 Iron (Fe)

The research indicates that the specific sample sites have an impact on the Fe readings. Fe is lowest in Djourbel (about 0.01 mg/L) and greatest in Back (approximately 0.22 ± 0.06 mg/L). The fluctuations of iron between stations are not significant (P>0.05) Thus, the obtained Fe values are in line with the World Health Organization's (WHO 2017) recommendations, which call for a range of 0.3 mg/L. Additionally, Fe concentrations ranging from 0.056 to 0.195 mg/L have been reported in other investigations conducted in the same region (Mohamedou et al., 2010).

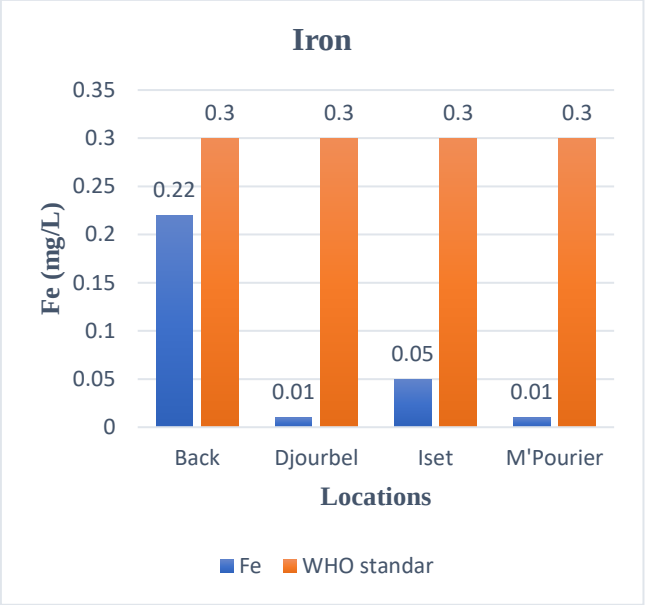


Figure 4.3.1. Variations of Fe concentration for the four stations.

4.3.2. Copper (Cu) free

The analysis indicates that the specific sample sites have an impact on Cu readings. Back has the most Cu (about 0.56 ± 0.27 mg/L), whereas M'Pourier has the lowest (around 0.07 ± 0.02 mg/L). The Cu readings obtained, with the exception of the Back and Djourbel stations, are thus in line with the World Health Organization's (WHO 2017) recommended limits, which call for a range of 0.1 mg/L. The fluctuations of copper between stations are not significant (P>0.05).

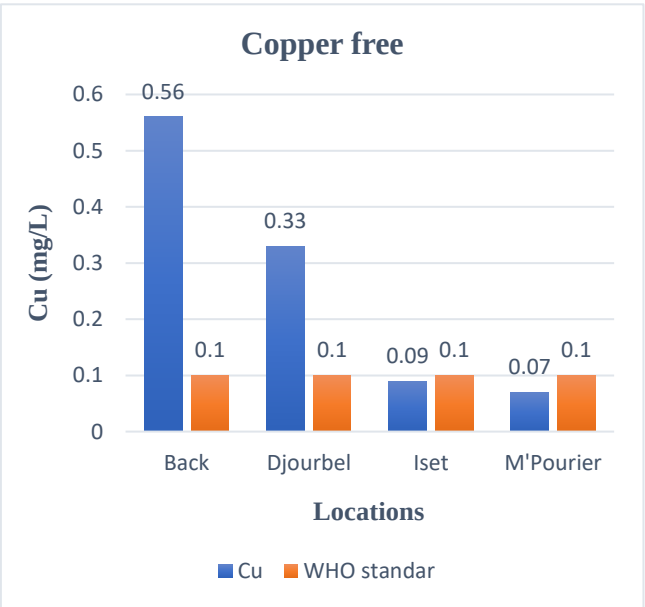


Figure 4.3.2. Variations of Cu concentration for the four stations.

4.3.3. Zinc (Zn)

The analysis indicates that the specific sample sites have an impact on Zn readings. Zn is lowest in Iset (about 0.013 ± 0.007 mg/L) and greatest in Djourbel (approximately 0.093 ± 0.015 mg/L). Therefore, the Zn values obtained are in line with the World Health Organization's (WHO 2017) recommended limits, which call for a range of 3 mg/L. The analysis also shows that there are notable variations among several stations, according to the statistical analysis (P<0.05 Table A.7). Moreover, research conducted in the same area has reported Zn levels ranging from 0.052 to 0.108 mg/L (Mohamedou et al., 2010).

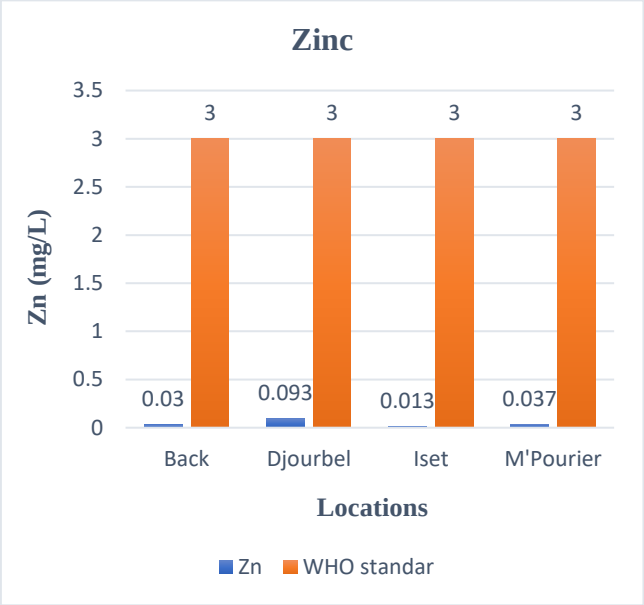


Figure 4.3.2. Variations of Zn concentration for the four stations.

4.3.4. Chromium (Cr)

The analysis indicates that the specific sample sites have an impact on Cr readings. Back has the greatest Cr (about 0.11 mg/L), while Djourbel has the lowest (around 0.03 mg/L). The Cr readings obtained, with the exception of the Djourbel station, do not align with the World Health Organization's (WHO 2017) suggested range of 0.05 mg/L. The analysis also shows that there are notable variations among several stations, according to the statistical analysis (P<0.05 Table A.6).

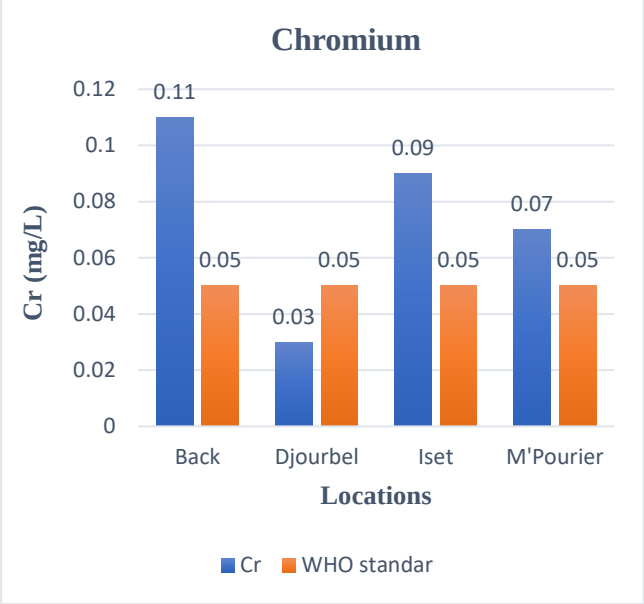
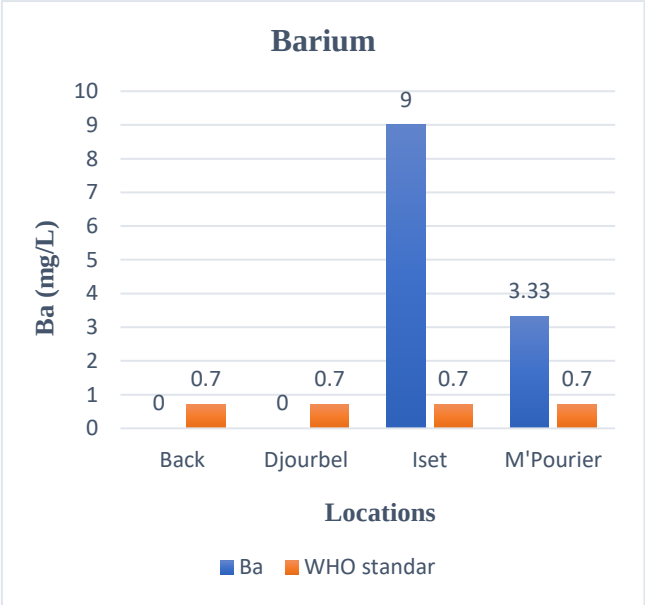


Figure 4.3.4. Variations of Cr concentration for the four stations.

4.3.5. Barium (Ba)

The analysis indicates that the specific sampling stations have an impact on Ba levels. Iset has the highest Ba, at roughly 9 ± 0.58 mg/L, while Back has the lowest, at roughly 0 mg/L. The review also revealed that statistical analysis showed non-significant differences between stations (P>0.05). The Ba readings obtained are thus in line with the World Health Organization's (WHO 2017) recommended limits, which prescribe a range of 0.7 mg/L, with the exception of the Iset station and M'Pourier station



(3.33±0.33).

Figure 4.3.5. Variations of Ba concentration for the four stations.

4.4. Weighted Arithmetic Water Quality Index Method

Table 3. WQI Computation physicocchemical and bacteriological parameters for Back station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	7.31	8.5	86.000	0.118	10.118
EC	89	500	17.800	0.002	0.036
TDS	44.7	500	8.940	0.002	0.018
TSS	38.7	500	7.740	0.002	0.015
HCO_3^-	91.5	120	76.250	0.008	0.635
$CaCO_3$	7.5	200	3.750	0.005	0.019
Turbidity	130	5	2600.000	0.200	520.000
NO_2^-	0.004	0.5	0.800	2.000	1.600
NO_3^-	5.3	50	10.600	0.020	0.212
NH_4^+	0.16	0.5	32.000	2.000	64.000
Na^+	4	200	2.000	0.005	0.010
K^+	2.33	12	19.417	0.083	1.618
SO_4^{2-}	34	250	13.600	0.004	0.054
PO_4^{3-}	0.85	5	17.000	0.200	3.400
Mn_2^+	0.004	0.05	8.000	20.000	160.000
Fe	0.22	0.3	73.333	3.333	244.444
COD	33.7	20	168.500	0.050	8.425
Cu	0.56	0.1	560.000	10.000	5600.000
Zn	0.03	3	1.000	0.333	0.333
Cr	0.11	0.05	220.000	20.000	4400.000
Ba	0	0.7	0.000	1.429	0.000
E. Coli	1500	15	10000.000	0.067	666.7000
Total Coliform	1500	20	7500.000	0.050	375.000
Enterococcus	1500	1	150000.000	1.000	150000.000
Total				60.9	162056.6

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

$$WQI = 2660.5$$

Table 4. WQI Computation physicochemical parameters for Back station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	7.31	8.5	86.000	0.118	10.118
EC	89	500	17.800	0.002	0.036
TDS	44.7	500	8.940	0.002	0.018
TSS	38.7	500	7.740	0.002	0.015
HCO_3^-	91.5	120	76.250	0.008	0.635
$CaCO_3$	7.5	200	3.750	0.005	0.019
Turbidity	130	5	2600.000	0.200	520.000
NO_2^-	0.004	0.5	0.800	2.000	1.600
NO_3^-	5.3	50	10.600	0.020	0.212
NH_4^+	0.16	0.5	32.000	2.000	64.000
Na^+	4	200	2.000	0.005	0.010
K^+	2.33	12	19.417	0.083	1.618
SO_4^{2-}	34	250	13.600	0.004	0.054
PO_4^{3-}	0.85	5	17.000	0.200	3.400
Mn_2^+	0.004	0.05	8.000	20.000	160.000
Fe	0.22	0.3	73.333	3.333	244.444
COD	33.7	20	168.500	0.050	8.425
Cu	0.56	0.1	560.000	10.000	5600.000
Zn	0.03	3	1.000	0.333	0.333
Cr	0.11	0.05	220.000	20.000	4400.000
Ba	0	0.7	0.000	1.429	0.000
Total				59.795	11014.938

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 184.2131

Discussion;

The Back station's computed WQI is as follows:

The only physical-chemical parameter that is WQI is 184.2131.

The WQI for bacteriological and physicochemical parameters is 2660.5

The stark disparity between these figures highlights the extent to which bacteriological contamination impacts the overall quality of the water.

Assessment of Physicochemical Factors; The WQI of 184.2131 denotes poor water quality when only physicochemical factors are considered.

Since the turbidity (130 NTU) is much higher than permitted limits, it suggests a high organic or particle matter load in the water.

Organic contamination is suggested by an elevated COD (33.7 mg/L). spills of fuel and oil, Oils, diesel, and other organic materials are occasionally released by ships, especially barges and canoe engines, which raise COD. Metal structure corrosion may be the cause of detectable concentrations of heavy metals (Fe, Cu, Cr, and Mn). Ammonium and nitrate may be signs of agricultural fertilizer runoff or sewage contamination. There are additional nutrients (NO3-, NH4+, and PO43-).

The Impact of Bacteriological Parameters

When bacteriological indices (E. coli, total coliforms, and Enterococcus) are considered, the WQI sharply increases to 2660.5, indicating significantly deteriorated water quality (Unsuitabele for driking). E. Coli and Enterococcus levels above permissible limits confirm the presence of fecal contamination, which poses major health risks. A high level of bacterial contamination, most likely from household sewage, animal runoff, or inadequate wastewater treatment, is indicated by a total coliform count of 1500 CFU/100 mL.

Table 5. WQI Computation physicochemical and bacteriological parameters for Djourbel station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	6.13	8.5	72.118	0.118	8.484
EC	97	500	19.400	0.002	0.039
TDS	48.7	500	9.740	0.002	0.019
TSS	11.3	500	2.260	0.002	0.005
HCO_3^-	79.3	120	66.083	0.008	0.551
$CaCO_3$	6.5	200	3.250	0.005	0.016
Turbidity	35.8	5	716.000	0.200	143.200
NO_2^-	0.002	0.5	0.400	2.000	0.800
NO_3^-	4.27	50	8.540	0.020	0.171
NH_4^+	0	0.5	0.000	2.000	0.000
Na^+	7.33	200	3.665	0.005	0.018
K^+	2	12	16.667	0.083	1.389
SO_4^{2-}	14	250	5.600	0.004	0.022
PO_4^{3-}	0.42	5	8.400	0.200	1.680
Mn_2^+	0	0.05	0.000	20.000	0.000
Fe	0.01	0.3	3.333	3.333	11.111
COD	33.8	20	169.000	0.050	8.450
Cu	0.33	0.1	330.000	10.000	3300.000
Zn	0.093	3	3.100	0.333	1.033
Cr	0.03	0.05	60.000	20.000	1200.000
Ba	0	0.7	0.000	1.429	0.000
E. Coli	26	15	173.333	0.067	11.556
Total Coliform	1500	20	7500.0	0.050	375.00
Enterococcus	50	1	5000.000	1.000	5000.000
Total				60.911	10063.545

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

$$WQI = 165.217$$

Table 6. WQI Computation physicochemical parameters for Djourbel station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	6.13	8.5	72.118	0.118	8.484
EC	97	500	19.400	0.002	0.039
TDS	48.7	500	9.740	0.002	0.019
TSS	11.3	500	2.260	0.002	0.005
HCO_3^-	79.3	120	66.083	0.008	0.551
$CaCO_3$	6.5	200	3.250	0.005	0.016
Turbidity	35.8	5	716.000	0.200	143.200
NO_2^-	0.002	0.5	0.400	2.000	0.800
NO_3^-	4.27	50	8.540	0.020	0.171
NH_4^+	0	0.5	0.000	2.000	0.000
Na^+	7.33	200	3.665	0.005	0.018
K^+	2	12	16.667	0.083	1.389
SO_4^{2-}	14	250	5.600	0.004	0.022
PO_4^{3-}	0.42	5	8.400	0.200	1.680
Mn_2^+	0	0.05	0.000	20.000	0.000
Fe	0.01	0.3	3.333	3.333	11.111
COD	33.8	20	169.000	0.050	8.450
Cu	0.33	0.1	330.000	10.000	3300.000
Zn	0.093	3	3.100	0.333	1.033
Cr	0.03	0.05	60.000	20.000	1200.000
Ba	0	0.7	0.000	1.429	0.000
Total				59.795	4676.989

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 78.21765

Discussion;

The following is the calculated WQI for the Djourbel station:

WQI for physical-chemical parameters is only 78.21765.

For physicochemical and bacteriological parameters, the WQI is 165.2.

The notable discrepancy between these numbers emphasizes how much bacteriological contamination affects the general quality of the water.

Evaluation of Physical-Chemical Elements

When only physicochemical parameters are taken into account, the WQI of 78.21765 indicates that the water quality is quite good.

A greater COD (33.8 mg/L) indicates organic contamination, most likely from household waste breakdown and agricultural runoff;

The turbidity (35.8 NTU), which is significantly higher than allowed limits, indicates a high organic or particle matter load in the water. A detectable concentration of the heavy metal Cu (0.33 mg/L) could be the result of a natural geological process.

Bacteriological Parameters' Effect

The WQI rises sharply to 165.2 when bacteriological indices (E. coli, total coliforms, and Enterococcus) are taken into account, indicating poor water quality. Significant health risks are associated with fecal contamination, which is confirmed by E. Coli and Enterococcus levels above allowable limits. A total coliform count of 1500 CFU/100 mL indicates a high level of bacterial contamination, most likely from animal runoff, domestic sewage, or insufficient wastewater treatment.

Table 7. WQI Computation of physicochemical and bacteriological parameters for Iset station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	6.7	8.5	78.824	0.118	9.273
EC	126	500	25.200	0.002	0.050
TDS	63	500	12.600	0.002	0.025
TSS	30	500	6.000	0.002	0.012
HCO_3^-	91.5	120	76.250	0.008	0.635
$CaCO_3$	7.5	200	3.750	0.005	0.019
Turbidity	14.7	5	294.000	0.200	58.800
NO_2^-	0.009	0.5	1.800	2.000	3.600
NO_3^-	5.75	50	11.500	0.020	0.230
NH_4^+	0	0.5	0.000	2.000	0.000
Na^+	10.3	200	5.150	0.005	0.026
K^+	2.67	12	22.250	0.083	1.854
SO_4^{2-}	16	250	6.400	0.004	0.026
PO_4^{3-}	0.35	5	7.000	0.200	1.400
Mn_2^+	0	0.05	0.000	20.000	0
Fe	0.05	0.3	16.667	3.333	55.556
COD	32.1	20	160.500	0.050	8.025
Cu	0.09	0.1	90.000	10.000	900.000
Zn	0.013	3	0.433	0.333	0.144
Cr	0.09	0.05	180.000	20.000	3600.000
Ba	9	0.7	1285.714	1.429	1836.735
E. Coli	1500	15	10000.000	0.1	666.7
Total Coliform	1500	20	7500.000	0.1	375.0
Enterococcus	41	1	4100.000	1.0	4100.0
Total				60.9	11618.1

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 190.7

Table 8. WQI Computation physicochemical parameters for Iset station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	6.7	8.5	78.824	0.118	9.273
EC	126	500	25.200	0.002	0.050
TDS	63	500	12.600	0.002	0.025
TSS	30	500	6.000	0.002	0.012
HCO_3^-	91.5	120	76.250	0.008	0.635
$CaCO_3$	7.5	200	3.750	0.005	0.019
Turbidity	14.7	5	294.000	0.200	58.800
NO_2^-	0.009	0.5	1.800	2.000	3.600
NO_3^-	5.75	50	11.500	0.020	0.230
NH_4^+	0	0.5	0.000	2.000	0.000
Na^+	10.3	200	5.150	0.005	0.026
K^+	2.67	12	22.250	0.083	1.854
SO_4^{2-}	16	250	6.400	0.004	0.026
PO_4^{3-}	0.35	5	7.000	0.200	1.400
Mn_2^+	0	0.05	0.000	20.000	0.000
Fe	0.05	0.3	16.667	3.333	55.556
COD	32.1	20	160.500	0.050	8.025
Cu	0.09	0.1	90.000	10.000	900.000
Zn	0.013	3	0.433	0.333	0.144
Cr	0.09	0.05	180.000	20.000	3600.000
Ba	9	0.7	1285.714	1.429	1836.735
Total				59.795	6476.410

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 108.311

Discussion;

The computed WQI for the Iset station is as follows: WQI is only 108.311 for physical-chemical parameters. The WQI for bacteriological and physicochemical parameters is 190.1. The stark disparity between these figures highlights the extent to which bacteriological contamination impacts the overall quality of the water.

Assessment of Physicochemical Factors

The WQI of 108.311 denotes poor water quality when only physicochemical factors are considered. Excessive suspended particles, possibly from waste discharge or soil erosion, are further indicated by high turbidity (14.7 NTU). A higher COD (32.1 mg/L) indicates organic contamination, most likely from household waste breakdown and agricultural runoff. Heavy metal concentrations that can be measured, such as Cr (0.09 mg/L) and Ba (9 mg/L), greatly influence the WQI. Household wastewater; some soaps, detergents, and cleaning products contain barium traces. Wastewater from residences and commercial buildings. Possible sources of chromium (Cr) emissions from small-scale handicrafts, such as mechanical, leather tanning, and textiles.

The Impact of Bacteriological Parameters

When bacteriological indices (E. coli, total coliforms, and Enterococcus) are considered, the WQI sharply increases to 190.1, indicating poor water quality. The largest contributors are Enterococcus (41 CFU/100 mL), Total Coliform (15000 CFU/100 mL), and E. Coli (1500 CFU/100 mL). These results demonstrate the existence of severe fecal contamination, which is indicative of pollution from human or animal waste.

Table 9. WQI Computation physicochemical and bacteriological parameters for M'Pourier station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	7.15	8.5	84.118	0.118	9.896
EC	2902	500	580.400	0.002	1.161
TDS	1453	500	290.600	0.002	0.581
TSS	53.7	500	10.740	0.002	0.021
HCO_3^-	325	120	270.833	0.008	2.257
$CaCO_3$	26.7	200	13.350	0.005	0.067
Turbidity	63.1	5	1262.000	0.200	252.400
NO_2^-	1.34	0.5	268.000	2.000	536.000
NO_3^-	12.1	50	24.200	0.020	0.484
NH_4^+	1.02	0.5	204.000	2.000	408.000
Na^+	88.3	200	44.150	0.005	0.221
K^+	20	12	166.667	0.083	13.889
SO_4^{2-}	61.3	250	24.520	0.004	0.098
PO_4^{3-}	0.46	5	9.200	0.200	1.840
Mn_2^4	0.005	0.05	10.000	20.000	200.000
Fe	0.01	0.3	3.333	3.333	11.111
COD	62.9	20	314.500	0.050	15.725
Cu	0.07	0.1	70.000	10.000	700.000
Zn	0.037	3	1.233	0.333	0.411
Cr	0.07	0.05	140.000	20.000	2800.000
Ba	3.3	0.7	471.429	1.429	673.469
E. Coli	1500	15	10000.000	0.1	666.7
Total Coliform	1500	20	75000.000	0.1	375.0
Enterococcus	1500	1	150000.000	1.0	150000.000
Total				60.9	156669.3

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 2572.1

Table 10. WQI Computation physicochemical parameters for M'Pourier station.

Parameters	Ci	Si	qi	Wi	Wi*qi
pH	7.15	8.5	84.118	0.118	9.896
EC	2902	500	580.400	0.002	1.161
TDS	1453	500	290.600	0.002	0.581
TSS	53.7	500	10.740	0.002	0.021
HCO_3^-	325	120	270.833	0.008	2.257
$CaCO_3$	26.7	200	13.350	0.005	0.067
Turbidity	63.1	5	1262.000	0.200	252.400
NO_2^-	1.34	0.5	268.000	2.000	536.000
NO_3^-	12.1	50	24.200	0.020	0.484
NH_4^+	1.02	0.5	204.000	2.000	408.000
Na^+	88.3	200	44.150	0.005	0.221
K^+	20	12	166.667	0.083	13.889
SO_4^{2-}	61.3	250	24.520	0.004	0.098
PO_4^{3-}	0.46	5	9.200	0.200	1.840
Mn_2^+	0.005	0.05	10.000	20.000	200.000
Fe	0.01	0.3	3.333	3.333	11.111
COD	62.9	20	314.500	0.050	15.725
Cu	0.07	0.1	70.000	10.000	700.000
Zn	0.037	3	1.233	0.333	0.411
Cr	0.07	0.05	140.000	20.000	2800.000
Ba	3.3	0.7	471.429	1.429	673.469
Total				59.795	5627.632

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

WQI = 94.116

Discussion

The exceptionally high WQI score of 2572.1 (Table 9) indicates that the water is seriously contaminated. This is primarily due to the fact that the addition of bacteriological characteristics (E. Coli, Total Coliforms, and Enterococcus) considerably raises the pollution index. The water quality is in poor condition, as indicated by Table 10's WQI rating of 94.116. because this computation excludes bacteriological markers.

Chemical and nutrient pollution.

Significantly high NO_2^- (1.34 mg/L) and NH_4^+ (1.02 mg/L) levels indicate possible fertilizer runoff from agricultural operations, as do elevated levels of NH_4^+ (ammonium) and NO_2^- (nitrite). The decomposition of organic materials is indicated by elevated levels of ammonium, EC (electrical conductivity), and TDS (total dissolved solids). TDS (1453 mg/L) and EC (2902 µS/cm) both show a high concentration of dissolved salts and ions, which are most likely brought on by fertilizers, herbicides, and soil erosion. The high level of turbidity (63.1 NTU) may be brought on by sediment runoff, erosion, or the decomposition of organic waste.

Toxic elements and heavy metals include manganese (Mn^{2+}), copper (Cu), zinc (Zn), and chromium (Cr). While many of these metals are safe, Cr and Cu are very dangerous (perhaps because of agricultural pesticides or natural leaching).

Fecal contamination: Enterococcus, Total Coliforms, and E. Coli are signs of direct contamination from livestock farming, animal waste runoff, or poor sanitation practices.

CHAPETER 5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The purpose of this study was to assess how household waste and agricultural practices affected the Senegal River's surface water quality in the Rosso region of Mauritania. Analysis of the water quality using physicochemical and bacteriological tests at four sample points showed a marked decline, with high levels of multiple indicators surpassing WHO recommendations.

The findings indicate that the pH value at the Djourbel Station is below the threshold advised by the WHO. Furthermore, turbidity and Chemical Oxygen Demand (COD) are higher than permitted limits at all test stations (Back, Djourbel, Iset, and M'Pourier), suggesting a sizable organic load and potential pollution from human activity. Copper (Cu) concentrations at the Back and Djourbel stations exceed WHO guidelines, while barium (Ba) and chromium (Cr) concentrations at the Iset and M'Pourier stations are alarming. Importantly, the pollution profile at the M'Pourier Station is more severe, with higher levels of potassium (K^+), ammonium (NH_4^+), nitrites (NO_2^-), bicarbonates (HCO_3^-), electrical conductivity (EC), and total dissolved solids (TDS). These levels suggest a range of contaminant sources, most likely associated with residential and agricultural runoff.

Severe fecal pollution and a major health risk were indicated by bacteriological analyses that revealed widespread contamination by Escherichia coli, Enterococcus, and total coliforms across all monitoring stations.

The Water Quality Index (WQI) confirmed these findings. By including bacteriological indicators in the assessment, WQI scores rose to concerning levels, particularly at the Back (2660.5) and M'Pourier (2572.1) sites, indicating that the water was unfit for any purpose. Even without microbiological analyses, WQI indices were still high, especially at the Back (184.21) and Iset (108.31) stations, suggesting substantial chemical contamination.

These findings demonstrate how human activity degrades riverine water quality, particularly when it comes to household and agricultural waste. The importance of implementing wastewater management plans and controlling pollution sources is emphasized in order to safeguard this vital resource and lessen risks to public health and environmental integrity.

5.2. Recommendation

1. Increasing the efficacy of wastewater treatment: The high prevalence of organic and bacteriological contaminants indicates inadequate treatment of wastewater from commercial and residential sources. Installing or upgrading wastewater treatment facilities is a crucial part of improving sanitary infrastructure.

2. Monitoring of agricultural and industrial operations: High levels of heavy metals (Cu, Ba, and Cr) and nutrients (NH_4^+, NO_2^-, and K^+) suggest contamination from industrial effluent, fertilizer, and pesticide use. Sustainable farming methods must be encouraged, and more stringent regulations governing the use of these substances must be put in place.

3. Systematic monitoring and assessment of water quality: It would be simpler to identify changes in pollution and assess the effectiveness of remediation techniques if a regular monitoring program that incorporates physicochemical and bacteriological analyses.

4. Raising awareness and involving local communities: Lack of information among local residents and agricultural professionals is often linked to the problem of water contamination. It is essential to implement programs that teach the public about waste management, the negative effects of household trash, and the responsible use of fertilizers and pesticides.

5. Fostering collaboration among stakeholders: The fortification of partnerships among local authorities, researchers, agriculturalists, and industrial entities is vital for the formulation of integrated water management policies tailored to the specific circumstances of the river ecosystem.

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APPENDICES

Table A.1. The statistical results for pH

	diff		upr	p adj
Djourbel-Back	-1.18	-169,823,603,127,272	-0.661763968727282	0.000387161430595806
Iset-Back	-0.606666666666667	-112,490,269,793,939	-0.0884306353939481	0.0234016004251949
M'pourier-Back	-0.160000000000001	-0.67823603127272	0.358236031272718	0.759839458657714
Iset-Djourbel	0.573333333333334	0.0550973020606149	1.09156936460605	0.0310722319009509
M'pourier-Djourbel	1.02	0.501763968727281	1.53823603127272	0.00104892254270172
M'pourier-Iset	0.446666666666666	-0.0715693646060529	0.964902697939386	0.0933367336072751

Table A.2. The statistical results for Nitrate

	diff	lwr	upr	p adj
Djourbel-Back	-103,133,333,333,334	-378,245,337,942,826	1.71978671276159	0.643361082034625
Iset-Back	0.441999999999997	-230,912,004,609,493	3.19312004609492	0.953281156381983
M'pourier-Back	6.77733333333333	4.02621328723841	9.52845337942825	0.000222273546968133
Iset-Djourbel	1.47333333333333	-127,778,671,276,159	4.22445337942826	0.376313126425306
M'pourier-Djourbel	7.80866666666667	5.05754662057174	10.5597867127616	7.99604975000312e-05
M'pourier-Iset	6.33533333333333	3.58421328723841	9.08645337942826	0.000357767657833796

Table A.3. The statistical results for Sulphate

	diff	lwr	upr	p adj
Djourbel-Back	-20	-601,750,201,218,852	20.1750201218852	0.432755547373503
Iset-Back	-18	-581,750,201,218,852	22.1750201218852	0.514245880451221
M'pourier-Back	27.3333333333333	-128,416,867,885,519	67.5083534552186	0.208649509917764
Iset-Djourbel	2.00000000000001	-381,750,201,218,852	42.1750201218852	0.998433701306055
M'pourier-Djourbel	47.3333333333333	7.15831321144809	87.5083534552186	0.0226424101438282
M'pourier-Iset	45.3333333333333	5.15831321144808	85.5083534552186	0.0281788644897476

Table A.4. The statistical results for COD

	diff	lwr	upr	p adj
Djourbel-Back	0.0666666666666558	-120,797,775,194,326	12.2131108527659	0.999997873636597
Iset-Back	-160,000,000,000,002	-137,464,441,860,992	10.5464441860992	0.973129786108949
M'pourier-Back	29.2	17.0535558139008	41.3464441860992	0.000264355572013319
Iset-Djourbel	-166,666,666,666,667	-138,131,108,527,659	10.4797775194326	0.969855794988361
M'pourier-Djourbel	29.1333333333333	16.9868891472341	41.2797775194326	0.000268663256288049
M'pourier-Iset	30.8	18.6535558139008	42.9464441860992	0.00018085043063254

Table A.5. The statistical results for TSS

	diff	lwr	upr	p adj
Djourbel-Back	-273,333,333,333,333	-318,621,429,708,647	-22,804,523,695,802	2.22461286614184e-07
Iset-Back	-866,666,666,666,666	-13,195,476,304,198	-413,785,702,913,532	0.00126475262950643
M'pourier-Back	15	10.4711903624687	19.5288096375313	2.55011084833168e-05
Iset-Djourbel	18.6666666666667	14.1378570291353	23.195476304198	4.91147132908321e-06
M'pourier-Djourbel	42.3333333333333	37.804523695802	46.8621429708647	1.09841274964495e-08
M'pourier-Iset	23.6666666666667	19.1378570291353	28.195476304198	7.84767977379808e-07

Table A.6. The statistical results for Chrome

	diff	lwr	upr	p adj
Djourbel-Back	-0.078	-0.0856231225498583	-0.0703768774501417	6.74944911072117e-09
Iset-Back	-0.019	-0.0266231225498584	-0.0113768774501417	0.000204535205218126
M'pourier-Back	-0.0413333333333334	-0.0489564558831917	-0.0337102107834751	5.76873464663841e-07
Iset-Djourbel	0.059	0.0513768774501417	0.0666231225498583	2.83590059213523e-08
M'pourier-Djourbel	0.0366666666666667	0.0290435441168084	0.044289789216525	1.51881033916279e-06
M'pourier-Iset	-0.0223333333333333	-0.0299564558831916	-0.014710210783475	6.33875548108342e-05

Table A.7. The statistical results for Zinc

	diff	lwr	upr	p adj	
Djourbel-Back	0.0633333333333334	0.0180452369580199	0.108621429708647	0.00888571992832476	
Iset-Back	-0.0166666666666667	-0.0619547630419801	0.0286214297086468	0.65567951393019	
M'pourier-Back	0.00666666666666666	-0.0386214297086468	0.0519547630419801	0.963310195252832	
Iset-Djourbel	-0.08	-0.125288096375313	-0.0347119036246866	0.00213331917776172	
M'pourier-Djourbel	-0.0566666666666667	-0.10195476304198	-0.0113785702913533	0.0164993648662662	
M'pourier-Iset	0.0233333333333333	-0.0219547630419801	0.0686214297086467	0.40609936625853	