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Research Article

Analysis of Physico-chemical Parameters to Evaluate the Drinking Water Quality Between Two Districts Kambia and Tonkolili in Sierra Leone

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Abstract

The aim of the study was to compare the physico-chemical characteristics of drinking water quality in two districts in Sierra Leone. Water samples were collected for three months (September to November) across five sampling locations. These samples were then examined for a number of physico-chemical characteristics, including temperature, pH, turbidity, electrical conductivity, dissolved oxygen, salinity, total dissolved solids (TDS), nitrate, residual chlorine, aluminum, copper, fluoride, iron, arsenic, cadmium, lead, nickel, and mercury. The statistical values for the following parameters above were found to be within the WHO permissible values for both the Tonkolili and Kambia districts. However, some parameters exceeded the recommended WHO permissible limit for drinking water in the two districts: arsenic (2.36mg/l and 0.27mg/l), cadmium (3.69mg/l and 6.63), lead (3.03mg/l and 6.64mg/l), and mercury (1.21mg/l and 2.19mg/l) for Tonkolili and Kambia districts respectively, although the statistical standard deviation is very negligible for all four parameters. In terms of comparison between the two districts, the statistical values for salinity (0.00ppt and 0.00ppt) and iron (0.05mg/l and 0.35mg/l) for both Tonkolili and Kambia districts are within the WHO permissible limit for the samples collected in the Tonkolili district, while the samples collected in the Kambia district exceeded the recommended WHO permissible limit for the two parameters. Moreover, the statistical value for copper (4.44mg/l) exceeded the WHO standard for the samples collected in the Tonkolili district, while the samples collected from the Kambia district are found within the WHO standard for copper (0.002mg/l). conclusively, this study found that all water samples collected and examined in the two districts are safe and fit for drinking and domestic purposes. The author recommends that there should be regular monitoring and treatment (for instance, chlorinating) of the hand-dug wells and tap waters and also that other researchers undertake further studies in different seasons and also to consider other water quality parameters like the bacteriological parameters, radiological materials, etc.

Keywords

Drinking Water, Water Quality, Physico-chemical Properties, WHO Standard, Sierra Leone

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1. Introduction

One of the main priorities of people living in developing countries is obtaining clean and safe drinking water. In Asia and Africa, most people in rural areas depend on ground and surface water for sustenance. Eight hundred and forty-four (844) million people, just 1 in 10 of the global population in 2015 were still living without access even to basic drinking water services [34], and only 71% were using safely managed drinking water service, and sadly 58% of 159 million people who were still collecting drinking water directly from surface water lived in sub-Saharan Africa [37] and the situation is still the same 1 in 3 people do not have access to safe drinking water [39]. Also, it is estimated that 1.2 billion people around the world, or one-fifth of the world's population lack access to safe water either because of unavailability or inadequacy. This could probably be due to an increase in human and animal populations [17]. Water is a vital nutrient; our organs need it for their normal functioning and also to keep the water balance in our body [19]. On average, Water accounts for 60% of the body weight of an adult human being. The average water intake of 2 litres per day for adults is needed as commonly used by the World Health Organization and regulators in computing drinking water guidelines and standards [26].

Sierra Leone is a small, tropical country located on the West Coast of Africa. Sierra Leone is endowed with abundant water resources, including seven rivers. Sierra Leone has six months of wet season which is characterized by 90% humidity and torrential rainfall. Sierra Leone also has substantial groundwater resources. However, water is scarce during the dry season: only 11-17% of the annual river discharge occurs between December and April, with minimum discharge in April. Sierra Leone struggles to provide quality drinking water to its citizens especially during March and April. In 2019, the Centers for Disease Control and Prevention reported that 98% of Sierra Leoneans do not have access to clean drinking water and as a result, most households lack basic sanitation. It covers three quarters of the earth's crust as rivers, oceans, seas, lakes and streams. Water also occurs in the soil beneath the earth's surface as a vast ground water reservoir, and in gaseous state as water vapour. More than 80% of the residents of low-income countries use water for drinking purposes [22]. Inadequate access to water and sanitation is one of the leading contributors to mortality worldwide, with millions of residents of developing countries dying of diarrhoea and other water-related diseases every year [24]. Poor water quality is also putting over 50% of freshwater fish species and 30% of amphibians at risk of extinction [8]. The quality of fresh water is also important like its quantity. In Sierra Leone, a lack of water quality and sanitation are major problems in both rural and urban centres.

Water supply in Sierra Leone is characterized by limited access to safe drinking water. The government of Sierra Leone and numerous non-governmental organizations efforts to improve and provide quality water since the end of the Sierra Leone Civil War in 2002, stagnating at about 50% and even declining in rural areas. Significant efforts were made by the government of Sierra Leone to increase access to safe drinking water and sanitation facilities after independence in 1961 and during the International Drinking Water and Sanitation Decade (1981–1990) [6]. During these years the Water Supply Division of the Ministry of Energy and Power was responsible for water supply and sanitation outside Freetown, while the Guma Valley Water Company supplied the areas in Freetown and its environs. Despite these efforts, there is still little or no access to pipe-borne water and adequate sanitation in many communities in Sierra Leone. In Sierra Leone, alternative sources of water, such as rainwater and ground water, have become the primary sources of drinking water for many people in different parts of the country. Water quality refers to the physical, chemical and biological characteristics of water based on the standards in which it is used. It is most frequently used by reference to a variety of standards against which compliance achieved through water treatment, can be assessed. Water quality has a significant impact on water supply and often determines the supply options [37]. Water quality also refers to a set of measures including temperature, chemical levels, pH and nutrients. These levels naturally vary between different freshwater environments, but human activity can cause extreme changes in water quality, from which natural environments cannot always recover [36]. With a new decentralization policy, embodied in the Local Government Act of 2004, responsibility for water supply in areas outside the capital was passed from the central government to local councils. In Freetown, the Guma Valley Water Company remains in charge of water supply. Fortunately, there are many organizations, both internal and external, that are seeking to combat poor water quality in Sierra Leone.

All the cells and organs made up in our entire anatomy and physiology depend on water for their normal functioning. This emphasizes the importance of water in the daily maintenance of our bodies, and prevention of disease. The World Health Organization (WHO) estimates that up to 80% of health problems in developing countries are water and sanitation-related. Moreover, drinking eight glasses of water daily can minimize the risk of colon cancer by 45%, and bladder cancer by 50% and it can potentially even reduce the risk of breast cancer [23]. The inadequate supply of clean and safe drinking water and the frequent pollution of existing supplies have created very serious health problems for people living in developing countries like Sierra Leone. In 2015, it was reported that sub-Saharan Africa is characterized by one of the highest numbers of people who do not have access to clean water or sanitation [35].

The aim of this study was to assess the water quality in two districts and to compare the dissimilarities of the water samples in the north of Sierra Leone using the physicochemical parameters. Moreover, the specific objectives of that study are as follows; to assess the quality of water in terms of physical and chemical properties, to compare and contrast the water sample parameters in the two districts and to compare the water quality status in Magburaka in the Tonkolili District and Rokupr Town in the Kambia District.

2. Data and Methods

2.1. Study Area

Magburaka is the capital and largest city of Tonkolili District in the Northern Province of Sierra Leone. Its population was 16,313 in the 2004 census Republic of Sierra Leone Census: 2004 and a current estimate of 40,313. [19]. According to Sierra Leone Country details [32], it is located at around 8°43′1″N 11°56′36″W, along the Rokel River. Magburaka lies just about 26 miles (42 km) drive south-west of Makeni, the economic centre of Northern Sierra Leone and about 80 miles (135 km) drive east of the country's capital Freetown. In Magburaka, the wet season is warm, oppressive, and overcast and the dry season is hot, muggy, and partly cloudy. Over the year, the temperature typically varies from 66 ℉ to 98 ℉ and rarely below 60 ° For above 103 ℉. The hot season lasts for 2.5 months, from February to April, with an average daily high temperature above 95 ℉. The hottest month of the year in Magburaka is April, with an average high of 95 ℉ and a low of 76^0F. The cool season lasts for 4.1 months, from June 26 to October 28 with an average daily high temperature below 85 ℉ and the coldest month of the year is August, with an average low of 72 ℉ and high of 82 ℉ [18].

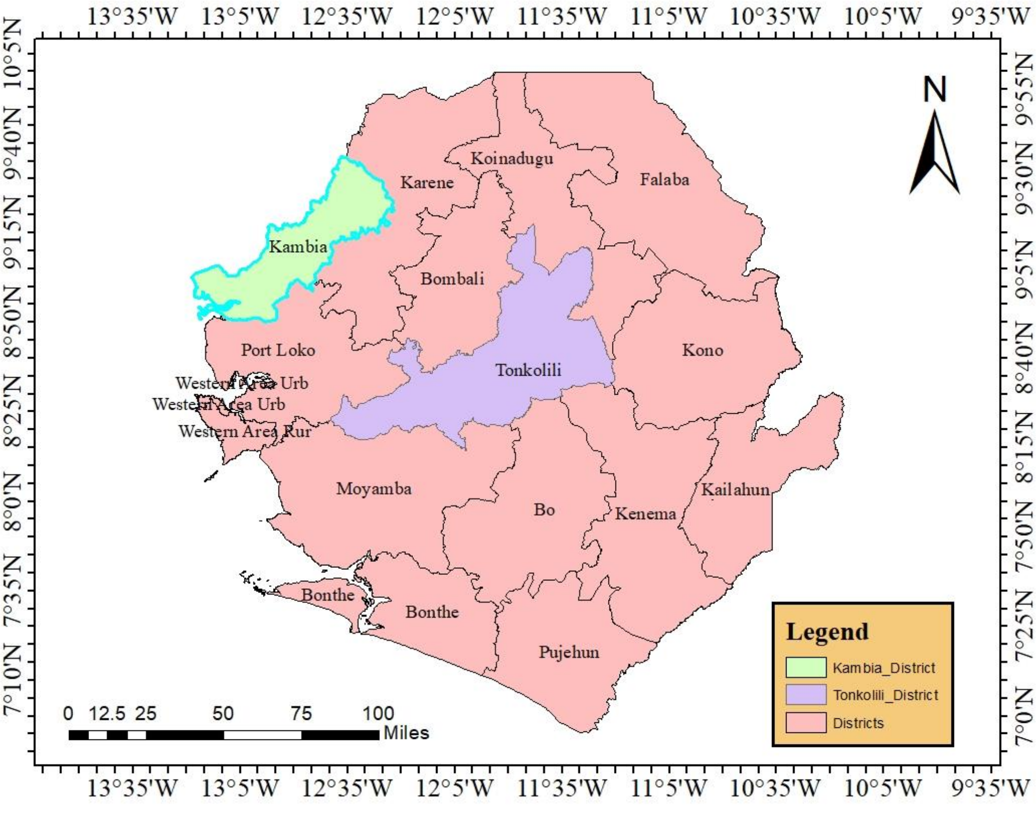

Figure 1. Sierra Leone showing the districts (Source; author, 2024).

Also, Markelie Community is in Rokupr Town, Kambia District Northern Sierra Leone. Rokupr is the second biggest town in Kambia District after Kambia Town. As of 2013, Rokupr had an estimated population of 12,744. Rokupr is located at latitude 9.012940 or 900’47’’North and longitude -12.948760 or 12056’56’’ West. It has an average elevation of 27 meters (89 feet). There are different ethnic groups in Rokupr, but the largest are the Themne, Susu, Fula and the Limba. Rokupr is the home of the famous Rice Research Station, which conducts scientific research on rice and food crops. The livelihood of most of the inhabitants in Rokupr is trading. The Great Scarcies River passes through Rokupr and empties into the sea which links to the Atlantic Ocean. A total of five samples were collected from each of the three months (September, October and November) from three water sources (hand-dug water well, hand pump and stream water) within the Markelie community. The two water sources (hand-dug water well and hand pump are located within the same community (Markelie) whilst the one water source (stream) passes through this community and empties into the Great Scarcies River. All these water sources are used for domestic uses (laundry, bathing and drinking). In addition, the stream water can be used for irrigating crops during the dry season and also for fishing.

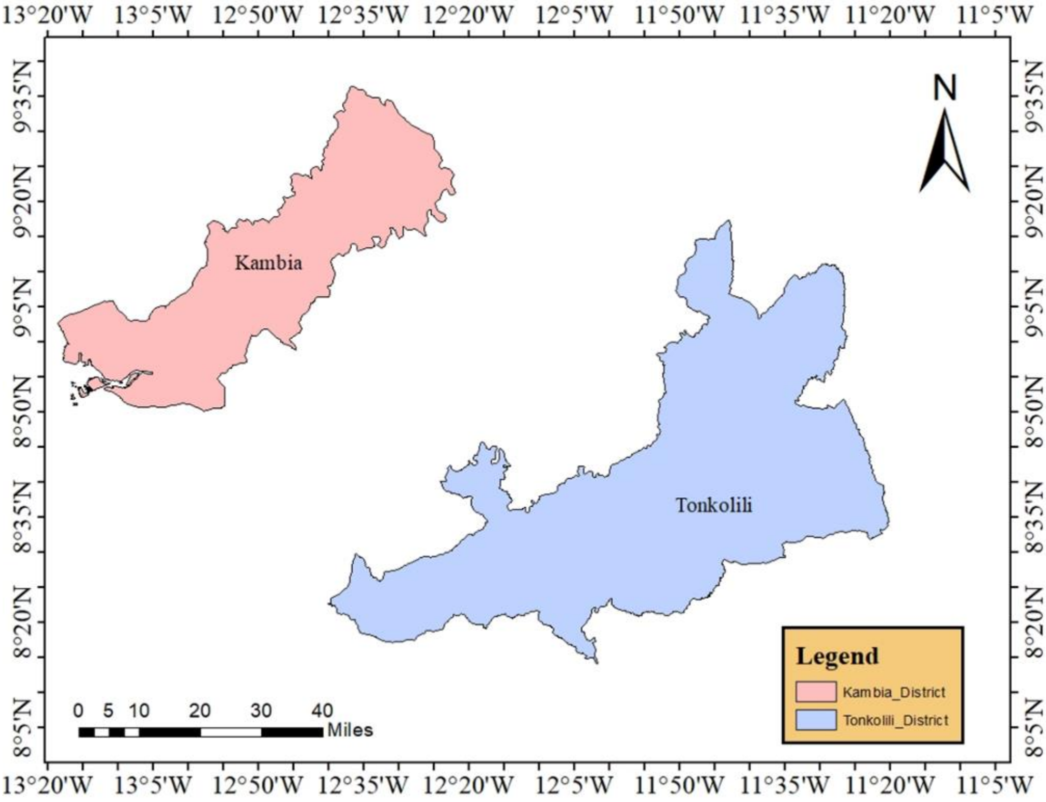

Figure 2. *Sample areas (Source; author, 2024).*

2.2. Sampling and Sampling Method

Five water samples were collected (Hand-dug well, hand pump, upstream, middle stream and downstream) from Markelie Community in Rokupr Town, Kambia District and other five water samples were collected (Hand-dug water well, Hand pump well upstream, middle stream and downstream) in Magburaka in the Tonkolili District. Both districts are found in the North of Sierra Leone. These sources were selected based on their popular uses either for domestic or agricultural activities. River Rokel was selected because of the numerous mining activities going on along the river and there is one agro-based industry that is located a few meters away from the river.

The study was carried out for ten different samples at five different sources (Hand-dug water well, Hand pump well upstream, middle stream and downstream), located in Magburaka in the Tonkolili District and Markelie in Rokupr town in Kambia District. Sampling was done during morning hours and all water samples were collected in polyethylene bottles. For stream water sample collection, the closed bottle was dipped in the stream at a certain depth, and then a bottle was opened inside and closed again to bring it out to the surface. The samples were collected from three different points and were mixed to prepare an integrated sample. For tap water sample collection the bottle was placed under the tap and then filled by opening the tap. From the time of sample collection and to the time of actual analysis, many physical and chemical reactions would change the quality of the water sample therefore, to minimize this change the sample were preserved soon after the collection. The water samples were preserved by adding chemical preservatives and by lowering the temperature. The water Odour, Colour and Taste were analyzed immediately on the spot after the collection, whereas the analyses of the remaining parameters were done in the laboratory. The study was carried for a period of three months (September 2022 to November 2022). The collected water samples were brought to the laboratory and relevant analyses were performed.

2.3. Data

Samples were collected in the field by trained researchers using a sterilized sample bottle (500ml), the containers were rinsed three times with the samples to avoid contamination, and these sample bottles were sealed and placed in a dark environment at a constant temperature range of 5-15℃ to avoid any contamination and the effects of light and temperature. The water samples were then transported to the lab (Directorate of Water Resources, in the Ministry of Water Resources in the district). All testing were done by a trained technician in a special room with suitable conditions for analyzing water quality within six hours of the samples being collected.

Inserting a digital thermometer into a sample of water and turning on the electrode, at the location of the sample collection, temperature, pH, conductivity, and turbidity measurements were made on-site using various calibrated standard instruments following the recommended protocols and methods of the American Public Health Organization [4] and American Society for Testing and Materials (ASTM) [11]. The temperature was checked. Duplicate readings were recorded in degrees Celsius.

A digital pH meter was used to determine the pH of the water samples. The pH meter is first calibrated (verified) to ensure that it is in good working condition. About 10 ml of water sample was poured into a clean glass beaker and the probe was inserted in it. The selector of the pH meter was switched on the pH value was read and recorded instantly. The procedure was repeated twice for all other samples and the probe was rinsed with distilled water after each experiment for all the samples.

The conductivity was determined using the Digital Conductivity Meter in the Laboratory. The meter was first calibrated by setting the temperature knob at 25℃, and the function knob was turned to check and adjust the display value to 1.00 by turning the screw at the back of the instrument. The probe was then dipped into a 0.1 M potassium chloride (KCl) solution and the reading was adjusted to 1.408 with the cell constant knob. The function knob was then turned to conduct and the value displayed was recorded. 10 ml of each sample was poured into a clean beaker. The probe was dipped into each sample one after the other. After it was removed from one sample it was rinsed with distilled water and then wiped thoroughly with the tissue before it was dipped into another sample. The fixed or steady value displayed on the screen is been recorded as the conductivity value. The process was repeated three times for each sample to ensure accuracy and consistency.

Turbidity was determined in the Laboratory using the HACH 2100Q turbidimeter measured in a Nephlometer turbidity unit (NTU). The instrument was calibrated first using standards such as 20, 60, 80, 100, and 10 (verification standards) respectively. After calibration, a portion of each sample is poured into its specific labelled clean oiled turbidity vial after the sample had been shaken several times. The turbidity vial was filled to the white line, gently inverted several times, and then placed into the turbidimeter. The final readings were obtained after 60 seconds and the average reading was obtained. This process was repeated three times to ensure accuracy and consistency.

2.4. Analysis

TDS in water samples were measured using the filter method following the American Public Health Association (APHA's) [4] and Sawyer [30], recommended standards. The accuracy and precision of the procedures below are so well-acknowledged and referenced in the scientific literature. Before beginning the vacuum filtration procedure, a pre-weighed glass fiber filter with a predetermined pore size was filled with a defined volume of the water sample. By using the gravimetric method, the TDS of the water samples was measured, and the filtrate of the TDS was cooked in an oven at a temperature over 100^0 C until all the water had evaporated. The amount of TDS in a sample is represented by the residue's residual mass.

The WAGTECH PHOTOMETER, 7100, was used to analyze chemicals and heavy metals such as NO_2, NO_3, PO_4, NH_3, Cu, Zn, Fe, and Cd to look into the chemical properties. References from the operational handbook were used before the analysis. To calibrate the photometer, a blank solution (reference, 0.00 mg/L) was initially prepared. One chemical tablet was inserted in a test tube with a 10 ml sample of water, and it was crushed and mixed to create a uniform mixture before being let to stand for 10 minutes to be fully coloured. The cell holder was then inserted, and the lid was shut. After setting the photometer to the proper wavelength and turning on the power, the concentration of each sample was recorded in milligrams per litre.

3. Results and Discussion

3.1. Results

Tables 1 to 7 illustrate the results of physical and chemical parameters from five different sites: hand-dug wells, upstream, midstream, downstream, and tap water at Rokupr Town in the Kambia District and Magburaka Town in the Tonkolili District. The results are presented in statistical methods (mean, variance, and standard deviation).

From the results in Table 1, it can be seen that all the values are within WHO permissible limits for samples collected from Magburaka, Tonkolili District, for the month of September with the exception of copper, arsenic, cadmium, lead, and mercury, which are slightly above WHO permissible limits.

Table 1. Samples from Magburaka, Tonkolili District for the month of September.

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	25.70	25.33	25.30	24.73	24.30	25.06	0.55	0.31	-
pH (pH Units)	7.15	6.79	7.04	7.09	7.05	7.02	0.14	0.02	6.5-8.5
Turbidity (NTU)	6.29	5.80	4.82	0.42	4.15	4.30	2.32	5.39	<5.0
TDS (mg/l)	0.00	3.00	0.00	0.00	0.00	0.60	1.34	1.80	500
Dissolved Oxygen (% Sat.)	89.30	88.60	67.30	75.50	85.50	80.27	9.55	91.14	80 - 120%
Salinity (ppt)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Electrical Conductivity (μs/cm)	0.00	4.00	0.00	0.00	0.00	0.80	1.79	3.20	300
Nitrate (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<10
R. Chlorine (mg/l)	0.00	0.01	0.03	0.00	0.00	0.01	0.01	0.00	0.3-0.5
Aluminum (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.2
Copper (mg/l)	0.00	0.00	0.00	3.09	11.05	2.83	4.79	22.92	<1.0
Fluoride (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<1.5
Iron (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.3
Arsenic (mg/l)	1.15	0.32	0.00	3.59	11.75	3.36	4.90	23.97	0.01
Cadmium (mg/l)	2.84	2.82	8.41	1.51	4.06	3.34	2.66	7.09	0.01
Lead (mg/l)	2.84	2.82	8.41	1.51	4.06	3.34	2.66	7.09	0.1
Nickel (mg/l)	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.05
Mercury (mg/l)	1.05	0.55	4.52	11.32	3.39	2.51	4.32	18.67	0.001

Table 2 shows samples collected from Magburaka, Tonkolili District, for the month of October, and from the table below, it can be evident that all the values are within WHO permissible limits for samples collected, with the exception of copper, arsenic, cadmium, lead, and mercury, which are slightly above WHO permissible limits.

Table 2. Samples from Magburaka, Tonkolili District for the month of October.

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	23.63	23.80	23.80	23.00	23.25	23.49	0.36	0.13	-
pH (pH Units)	6.92	6.98	6.93	4.60	7.02	6.41	1.06	1.12	6.5-8.5
Turbidity (NTU)	4.44	4.07	12.10	6.29	0.35	3.44	4.30	18.47	<5.0
TDS (mg/l)	3.00	0.00	0.00	0.00	0.00	0.60	1.34	1.80	500
Dissolved Oxygen (% Sat.)	90.00	88.20	86.00	88.50	101.10	90.61	5.95	35.45	80 - 120%
Salinity (ppt)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Electrical Conductivity	5.00	0.00	0.00	0.00	4.00	1.80	2.49	6.20	300

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
(μs/cm)									
Nitrate (mg/l)	0.016	0.012	0.00	0.00	0.017	0.01	0.01	0.00	<10
R. Chlorine (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3-0.5
Aluminum (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.2
Copper (mg/l)	4.34	2.45	2.12	1.68	53.04	12.73	22.56	508.91	<1.0
Fluoride (mg/l)	0.00	0.00	0.00	0.00	0.10	0.02	0.04	0.00	<1.5
Iron (mg/l)	0.00	0.00	0.00	0.02	0.40	0.08	0.18	0.03	<0.3
Arsenic (mg/l)	0.01	0.00	0.66	8.41	0.39	1.89	3.65	13.34	0.01
Cadmium (mg/l)	0.98	107.18	4.05	2.26	1.51	4.29	46.96	2205.51	0.01
Lead (mg/l)	0.98	107.18	4.05	2.26	1.51	4.29	46.96	2205.51	0.10
Nickel (mg/l)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05
Mercury (mg/l)	2.83	1.08	0.58	0.64	0.13	0.68	1.05	1.10	0.00

From the results in Table 3, from a statistical perspective, it is clear that every value falls within WHO permissible limits for samples collected from Magburaka, Tonkolili District, for the month of November with the exception of copper, arsenic, cadmium, lead, and mercury, which are slightly above WHO permissible limits.

Table 3. *Samples from Magburaka, Tonkolili District for the month of November.*

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	24.67	24.57	24.55	23.87	23.78	24.28	0.43	0.18	-
pH (pH Units)	7.04	6.89	6.99	5.85	7.04	6.75	0.51	0.26	6.5-8.5
Turbidity (NTU)	5.37	4.94	8.46	3.35	2.25	4.42	2.36	5.58	<5.0
TDS (mg/l)	2.00	0.00	0.00	0.00	0.00	0.40	0.89	0.80	500.00
Dissolved Oxygen (% Sat.)	89.65	88.40	76.65	82.00	93.30	85.79	6.63	43.95	80 - 120%
Salinity (ppt)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electrical Conductivity (μs/cm)	5.00	0.00	0.00	0.00	3.00	1.60	2.30	5.30	300
Nitrate (mg/l)	0.02	0.01	0.00	0.00	0.02	0.01	0.01	0.00	<10
R. Chlorine (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3-0.5
Aluminum (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<0.2
Copper (mg/l)	5.44	2.65	3.21	2.68	58.40	5.92	24.58	604.22	<1.0
Fluoride (mg/l)	0.00	0.00	0.00	0.00	0.10	0.02	0.04	0.00	<1.5
Iron (mg/l)	0.00	0.00	0.00	0.01	0.30	0.06	0.13	0.02	<0.3

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Arsenic (mg/l)	0.11	0.00	0.12	8.44	0.52	1.84	3.70	13.66	0.01
Cadmium (mg/l)	0.86	105.12	2.03	1.88	1.41	3.45	46.32	2145.76	0.01
Lead (mg/l)	0.87	1.7.14	2.05	1.88	1.41	1.47	0.53	0.28	0.1
Nickel (mg/l)	0.00	0.00	0.00	0.00	0.10	0,02	0.04	0.00	0.05
Mercury (mg/l)	1.83	1.08	0.48	0.46	0.11	0.54	0.68	0.46	0.001

Table 4 shows samples collected from Markelie in Rokupr Town, Kambia District, for the month of September, and from a statistical perspective, it can be evident that all the values are within WHO permissible limits for samples collected, with the exception of cadmium, lead, and mercury, which are slightly above WHO permissible limits.

Table 4. *Samples from Markelie Community in Rokupr Town, Kambia District for the month of September.*

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	24.40	24.50	24.50	24.30	24.50	24.44	0.089	0.01	-
pH (pH Units)	7.15	6.97	7.04	7.04	6.83	7.01	0.12	0.01	6.5-8.5
Turbidity (NTU)	0.08	0.79	0.31	0.77	0.54	0.50	0.30	0.09	<5.0
TDS (mg/l)	3.00	211.00	0.00	0.00	0.00	42.80	94.04	8842.70	500
Dissolved Oxygen (% Sat.)	98.50	98. 70	100.00	101.60	101.20	100.33	1.39	1.94	80 - 120%
Salinity (ppt)	0.00	0.09	0.00	0.00	0.00	0.02	0.04	0.00	0
Electrical Conductivity (μs/cm)	5.00	326.00	0.00	0.00	0.00	66.20	145.25	21097.20	300
Nitrate (mg/l)	0.00	0.034	0.00	0.00	0.01	0.01	0.01	0.00	<10
R. Chlorine (mg/l)	0.04	0.00	0.01	0.00	0.17	0.04	0.07	0.01	0.3-0.5
Aluminum (mg/l)	0.01	0.00	0.03	0.00	0.04	0.02	0.02	0.00	<0.2
Copper (mg/l)	0.00	0.00	0.00	0.00	0.25	0.05	0.11	0.01	<1.0
Fluoride (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<1.5
Iron (mg/l)	0.00	0.00	0.00	0.00	0.25	0.05	0.11	0.01	<0.3
Arsenic (mg/l)	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cadmium (mg/l)	16.77	33.35	5.70	41.85	1.27	19.79	17.47	305.29	0.01
Lead (mg/l)	16.77	33.35	5.70	41.85	1.27	19.79	17.47	305.29	0.1
Nickel (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Mercury (mg/l)	2.98	22.28	0.14	4.84	2.58	6.56	8.94	79.99	0.001

Table 5 also shows samples collected from Markelie in Rokupr Town, Kambia District, for the month of October, and from a statistical perspective, it can be evident that all the values are within WHO permissible limits for samples collected, with the exception of iron, arsenic, and cadmium, which are slightly above WHO permissible limits.

Table 5. Samples from Markelie Community in Rokupr Town, Kambia District for the month of October.

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	21.88	23.13	22. 75	23.80	23.50	23.08	0.84	0.71	-
pH (pH Units)	6.86	7.22	6.97	6.83	6.80	6.94	0.17	0.03	6.5-8.5
Turbidity (NTU)	0.01	0.01	0.39	0.11	0.56	0.216	0.25	0.06	<5.0
TDS (mg/l)	51.00	61.00	0.00	4.00	6.00	24.40	29.14	849.30	500
Dissolved Oxygen (% Sat.)	101.40	103.90	101.40	101.50	102.90	102.22	1.13	1.29	80 - 120%
Salinity (ppt)	0.03	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0
Electrical Conductivity (µs/cm)	79.00	95.00	0.00	0.00	10.00	36.80	46.35	2148.70	300
Nitrate (mg/l)	0.124	0.21	0.00	0.304	0.00	0.13	0.13	0.02	<10
R. Chlorine (mg/l)	0.21	0.06	0.36	0.21	0.20	0.21	0.11	0.01	0.3-0.5
Aluminum (mg/l)	0.03	0.03	0.07	0.05	0.02	0.04	0.02	0.00	<0.2
Copper (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<1.0
Fluoride (mg/l)	0.12	0.00	0.12	0.10	0.00	0.07	0.06	0.00	<1.5
Iron (m/l)	1.18	0.023	0.84	0.65	0.03	0.54	0.51	0.25	<0.3
Arsenic (mg/l)	0.00	0.00	0.02	0.00	2.00	0.40	0.89	0.80	0.01
Cadmium (mg/l)	0.12	0.02	0.07	0.03	0.23	0.094	0.09	0.01	0.01
Lead (mg/l)	0.12	0.02	0.07	0.03	0.33	0.11	0.13	0.02	0.1
Nickel (mg/l)	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Mercury (mg/l)	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.001

Table 6 shows samples collected from Markelie in Rokupr Town, Kambia District, for the month of November, and from a statistical perspective, it can be evident that all the values are within WHO permissible limits for samples collected, with the exception of iron and arsenic, which are slightly above WHO permissible limits.

Table 6. Samples from Markelie Community in Rokupr Town, Kambia District for the month of November.

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
Water Temperature (℃)	22.70	23.20	23.30	23.30	23.00	23.10	0.25	0.07	-
pH (pH Units)	6.70	7.00	7.10	6.70	6.80	6.86	0.18	0.03	6.5-8.5
Turbidity (NTU)	0.01	0.01	0.39	0.11	0.56	0.22	0.25	0.06	<5.0

Parameters	Samples					Mean ($\bar{x}$)	Stdev.S (σ^2)	Var.S (σ)	WHO
	Up stream	Middle Stream	Down Stream	Hand Dug Well	Tap Water				
TDS (mg/l)	16.00	51.00	12.00	8.00	11.00	19.60	17.78	316.30	500
Dissolved Oxygen (% Sat.)	100.20	100.60	100.20	100.70	100.00	100.34	0.30	0.09	80 - 120%
Salinity (ppt)	0.01	0.02	0.00	0.00	0.00	0.01	0.01	0.00	0
Electrical Conductivity (µs/cm)	80.00	88.00	17.00	7.00	9.00	40.20	40.26	1620.70	300
Nitrate (mg/l)	0.02	0.01	0.02	0.22	0.02	0.06	0.09	0.01	<10
R. Chlorine (mg/l)	0.21	0.06	0.36	0.21	0.20	0.21	0.11	0.01	0.3-0.5
Aluminum (mg/l)	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	<0.2
Copper (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	<1.0
Fluoride (mg/l)	0.00	0.00	0.10	0.10	0.00	0.04	0.05	0.00	<1.5
Iron (mg/l)	1.00	0.02	0.60	0.80	0.00	0.48	0.46	0.21	<0.3
Arsenic (mg/l)	0.00	0.00	0.02	0.00	2.1	0.42	0.94	0.88	0.01
Cadmium (mg/l)	0.00	0.01	0.04	0.03	0.01	0.018	0.02	0.00	0.01
Lead (mg/l)	0.02	0.01	0.04	0.03	0.01	0.02	0.01	0.00	0.1
Nickel (mg/l)	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Mercury (mg/l)	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.001

Table 7 shows the comparison of the physico-chemical parameters data and from a statistical perspective, it is clear that all the samples collected from Magburaka, Tonkolili District contains more slight heavy metals than those collected from Markelie in Rokupr Town, Kambia District.

Table 7. *Comparison of physico-chemical parameters data of the two districts using their mean values.*

Parameters	The mean of Physiochemical Parameters for each month in a District						WHO Permissible Limits
	September		October		November		
	Tonkolili	Kambia	Tonkolili	Kambia	Tonkolili	Kambia	
Water Temperature (℃)	25.06	24.44	23.49	23.08	24.28	23.10	-
pH (pH Units)	7.02	7.01	6.41	6.94	6.75	6.86	6.5-8.5
Turbidity (NTU)	1.58	0.50	3.44	0.216	4.42	0.22	<5.0
TDS (mg/l)	0.60	42.80	0.60	24.40	0.40	19.60	500
Dissolved Oxygen (% Sat.)	80.27	100.33	90.61	102.22	85.79	100.34	80 - 120%
Salinity (ppt)	0.00	0.02	0.00	0.01	0.00	0.01	0.00
Electrical Conductivity (µs/cm)	0.80	66.20	1.80	36.80	1.60	40.20	300
Nitrate (mg/l)	0.00	0.01	0.01	0.13	0.01	0.06	<10
R. Chlorine (mg/l)	0.01	0.04	0.00	0.21	0.00	0.21	0.3-0.5
Aluminum (mg/l)	0.00	0.02	0.00	0.04	0.00	0.01	<0.2

Parameters	The mean of Physiochemical Parameters for each month in a District						WHO Permissible Limits
	September		October		November		
	Tonkolili	Kambia	Tonkolili	Kambia	Tonkolili	Kambia	
Copper (mg/l)	2.83	0.05	4.58	0.00	5.92	0.00	<1.0
Fluoride (mg/l)	0.00	0.00	0.02	0.07	0.02	0.04	<1.5
Iron (mg/l)	0.00	0.05	0.08	0.54	0.06	0.48	<0.3
Arsenic (mg/l)	3.36	0.00	1.89	0.40	1.84	0.42	0.01
Cadmium (mg/l)	3.34	19.79	4.29	0.094	3.45	0.02	0.01
Lead (mg/l)	3.34	19.79	4.29	0.11	1.47	0.02	0.1
Nickel (mg/l)	0.00	0.00	0.00	0.00	0.02	0.00	0.05
Mercury (mg/l)	2.51	6.56	0.68	0.00	0.54	0.00	0.001

3.2. Discussion

3.2.1. Physical Parameters

From the results in Table 1 to Table 3 above in Magburaka town, Tonkolili District, the mean values for the temperature of the stream water, hand-dug well, and tap water are 25.06 ℃, 23.49 ℃, and 24.28 ℃, and the results from Table 4 to Table 6 above in the Markelie community in Rokupr town, Kambia District, the mean values for the temperature of the stream water, hand-dug well, and tap water are 24.44 ℃, 25.08 ℃, and 23.10 ℃, respectively. All the values of the temperature are within the World Health Organization (WHO) suggested permissible limits, and the standard deviations for stream water, hand-dug wells, and tap water are 0.55, 0.36, and 0.43, respectively, from Table 1 to Table 3, and also the standard deviations from Table 4 to Table 6 are 0.09, 0.84, and 0.25. From the statistical point of view, the deviation is very minimal. Furthermore, the statistical mean values for the six different locations in the two districts are also within the WHO permissible value as shown above (Table 7). In terms of temperature, the two districts have the same mean values for the different sources of water (the Tonkolili district has a mean of 0.45, and the Kambia district has a mean of 0.39). However, WHO does not have a specific temperature requirement for safe water but suggests that it should be 25 ℃ and have a pH of 7. Drinking water temperature can be affected by environmental factors such as soil type, water depth, and other anthropogenic causes. Temperature has a significant impact on the absorption of chemicals and the growth of microbiological organisms when examining the quality of water. And also, directly influences the availability of the amount of dissolved oxygen in water, The optical health of aquatic organisms from microbes to fish depends on temperature [21]. Pankow, J. F. reported that the temperature of the water also affects the following: the volume of dissolved oxygen it can hold (water’s ability to contain dissolved oxygen decreases as the water temperature rises), the rate of photosynthesis by aquatic plants, metabolic rates of aquatic organisms, and the sensitivity of organisms to pollution [21].

The pH parameter was also analyzed for the stream water, hand-dug well, and tap water, and the mean values for them in the two districts are as follows: 7.02, 6.41, and 6.75 for Magburaka, Tonkolili district (from Table 1 to Table 3) and 7.01, 6.94, and 6.86 for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6). pH indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution [29]. It is usually monitored for assessments of aquatic ecosystem health, irrigation and drinking water sources, industrial discharges, and surface water runoff. These values are within the permissible limit set by WHO for drinking and irrigation purposes, respectively [38]. In comparison of the two districts, the two mean values (Tonkolili district, 6.73, and Kambia district, 6.94) are almost the same with a minimal difference of 0.21, and this is also evident in Table 7 in three consecutive months above, and they are both within the WHO permissible limits.

Turbidity in the majority of water is caused by colloidal and incredibly tiny dispersions. The quantity of suspended algae determines the water purity in many aquatics, hand-dug wells, and tap water systems. Large algal populations, which are supported by eutrophic systems (those with high nutrient concentrations), cause the water's color to grow and its clarity to decrease. In severe situations, turbid water can damage wildlife and reduce photosynthesis by depositing heavy sediment on leaves [31]. Additionally, turbid water slows the development of vegetables and interferes with the effectiveness of disinfection methods like UV light and chlorination of wells and tap water. From the table above, turbidity was analyzed for the stream water, hand-dug well, and tap water, and the mean values for them in the two districts are as follows: 4.30 NTU, 3.44 NTU, and 4.42 NTU for Magburaka, Tonkolili district (from Table 1 to Table 3) and 0.50 NTU, 0.22 NTU, and 0.22 NTU for the Markelie community in Rokupr town, Kambia district (From Table 4 to Table 6). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is <5 NTU. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, are more turbid than those collected from the Markelie community in Rokupr town, Kambia district, and this is evident from Table 7, and it is also evident in the statistical mean values from Table 1 to Table 6.

Total dissolved solids indicate the salinity behavior of water [5]. Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies [29]. High TDS water is undesirable or hazardous to aquatic life and humans. It may have disagreeable smells and taste metallic, salty, or bitter. Additionally, water with a high TDS interferes with food taste and is less effective at quenching thirst. There are several health risks associated with some of the separate mineral salts that comprise TDS. Compared to irrigation with low TDS water, high TDS irrigation caused soil salinization and a reduction in macroporosity but did not reduce crop yields. From the table above, the analyzed data for total dissolved solids (TDS) for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.60 mg/l, 0.60 mg/l, and 0.40 mg/l for Magburaka, Tonkolili district (from table 1 to table 3 with a statistical mean of 0.53 mg/l) and 0.00 mg/l, 24.40 mg/l, and 19.60 mg/l for the Markelie community in Rokupr town, Kambia district (from table 4 to table 6 with a mean value of 14.67 mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is 500 mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, had less value (0.53 mg/l) than those collected from the Markelie community in Rokupr town, Kambia district (14.60 mg/l), and this is also evident from Table 7.

3.2.2. Chemical Parameters

As a regulator of organisms' metabolic processes, Dissolved Oxygen (DO) controls the metabolism of the entire biological population and serves as a gauge of the water's tropic status [13]. From the table above with regards to Dissolved Oxygen (DO) for the stream water, hand-dug well, and tap water, the mean values for them in the two districts are as follows: 80.27% sat, 90.61% sat, and 85.79% sat for Magburaka, Tonkolili district (from table 1 to table 3 with a statistical mean of 85.56% sat) and 100.30% sat, 100.22% sat, and 100.34% sat for the Markelie community in Rokupr town, Kambia district (from table 4 to table 6 with a statmean value of 100.29% sat). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which are 80-120% saturation. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, have less value (85.56% sat) than those collected from the Markelie community in Rokupr town, Kambia district (100.29% sat), and this is also evident from Table 7.

Salinity, A crucial factor in determining whether a body of water is fresh, somewhat saline, moderately saline, or very saline is salinity. From the table above with regards to salinity for the stream water, hand-dug well, and tap water, the mean values for them in the two districts are as follows: 0.00 ppt, 0.00 ppt, and 0.00 ppt for Magburaka, Tonkolili district (from table 1 to table 3 with a statistical mean of 0.00 ppt) and 0.02 ppt, 0.01 ppt, and 0.01 ppt for the Markelie community in Rokupr town, Kambia district (from table 4 to table 6 with a statistical mean value of 0.01 ppt). From the statistical mean values, it can be evident that all the values of the Tonkolili district are within WHO permissible values, which is 0.00 ppt, and those from the Kambia district are slightly above the WHO permissible value, as shown in Table 7. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district show no salinity in the sample collected, and they are within WHO standards, while those collected from the Markelie community in Rokupr town, Kambia district show some amount of salinity and are not within the WHO standard, and this is also evident from Table 7.

Electrical conductivity is one of the characteristics of drinking water that ought to be routinely checked, if at all possible; it demonstrates that water can carry an electric current. From the table above with regards to electrical conductivity for the stream water, hand-dug well, and tap water, the mean values for them in the two districts are as follows: 0.80 µs/cm, 1.80 µs/cm, and 1.60 µs/cm for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 1.4 µs/cm) and 66.20 µs/cm, 36.80 µs/cm, and 40.20 µs/cm for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 47.73 µs/cm). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is 300 µS/cm. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district show almost no electrical conductivity in the sample collected, while those collected from the Markelie community in Rokupr town, Kambia district show some amount of electrical conductivity, although they are within the WHO standard, and this is also evident from Table 7 above. The differences in electrical conductivity between the two districts can be explained by the fact that the reverse osmosis treatment method yields the lowest conductivity value since it eliminates dissolved solids, turbidity, colloidal materials, and other contaminants. Likewise, it is anticipated that mineral water will have significant mineral levels, leading to a higher conductivity value. Moreover, according to Azrina et al. [2], it is currently unknown how much the electrical conductivity of tap water varies. Scatena [7] explained the variations by citing several factors that impact the mineral concentrations and, consequently, the water's electric conductivity, including land usage and agricultural and industrial operations. Human health is not directly impacted by conductivity. It is calculated for several reasons, including figuring out the rate at which minerals like potassium, calcium, and sodium are present and predicting how many chemical reagents will be needed to treat this water [20, 25, 28, 27]. Because high conductivity gives the water a mineral taste, it may reduce the water's aesthetic value. Monitoring water conductivity is essential for both industrial and agricultural operations. High-conductivity water can corrode the metal surfaces of boilers and other equipment. It also applies to household items like faucets and water heater systems. Excessive conductivity also eliminates species of plants that provide food and habitat [12].

Nitrate is one of the characteristics or parameters of drinking water that ought to be checked, Water contains both organic and bound forms of nitrogen, including urea, amino acids, nitrate, nitrite, and ammonia. All types of nitrogen, both organic and inorganic, are measured by total nitrogen. In marine waters, nitrogen is frequently the limiting nutrient and is a necessary component of plants. When there is enough oxygen present, microbes in soil and water oxidize organic nitrogen to produce nitrates. High nitrate concentrations are beneficial for irrigation, but when they enter water supplies, they promote the growth of noxious macrophytes and algae and cause pollution and eutrophication. [33]. Ammonium nitrogen causes high nitrate concentrations, which are commonly seen in treated wastewater. According to Ali. K et al [3], nitrate levels in drinking water over the 45 mg/L threshold pose a health concern to many workers and can cause methaemoglobinaemia in pregnant women and infants [14]. The most common sources of nitrogen are either natural soil nitrogen or fertilizers. However, nitrogen in irrigation water has a similar impact to nitrogen in soil fertilizer, and too much of either will lead to issues. The production of some regularly grown crops may be disrupted by excessive growth stimulation, delayed maturity, or poor quality if excessive quantities are present or applied. From the table above, the analyzed data for Nitrate for the stream water, hand-dug well and tap water and the mean values for them in the two districts are as follows; 0.00mg/l, 0.01mg/l and 0.01mg/l for Magburaka, Tonkolili district (from table 1 to table 3 with a statistical mean of 0.01mg/l) and 0.01mg/l, 0.13mg/l and 0.09mg/l for Markelie community in Rokupr town, Kambia district (from table 4 to table 6 with a statistical mean value of 0.08mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values which is <10mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district had less value (0.01mg/l) than those collected from Markelie community in Rokupr town, Kambia district (0.08mg/l) and this is also evident from Table 7.

Sewage pollution is indicated by the concentration of chloride. Laxative effects are experienced by those who are used to greater levels of chlorine in their water [31]. Chloride can be hazardous to sensitive crops at large concentrations, even though it is necessary for plants in very small amounts. From the table above, the analyzed data for chlorine residue for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.01 mg/l, 0.00 mg/l, and 0.00 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 0.00 mg/l) and 0.17 mg/l, 0.21 mg/l, and 0.21 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 0.20 mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which are 0.3–0.5 mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, have less value (0.00 mg/l) than those collected from the Markelie community in Rokupr town, Kambia district (0.20 mg/l), and this is also evident from Table 7 as shown above.

From the table above, the analyzed data for aluminum for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.00 mg/l, 0.00 mg/l, and 0.00 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 0.00 mg/l) and 0.02 mg/l, 0.04 mg/l, and 0.01 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 0.02 mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is <0.2 mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, had less value (0.00 mg/l) than those collected from the Markelie community in Rokupr town, Kambia district (0.02 mg/l), and this is also evident from Table 7 as shown above. Low amounts of aluminum are probably not bad for you. However, certain parts of the human brain and neurological system are negatively impacted by elevated aluminum levels, leading to neurodegenerative illnesses like Parkinson's disease, Lou Gehrig's disease (ALS), and Alzheimer's disease.

Rocks, soil, and water are all naturally occurring sources of copper. Surface waters typically have very low quantities of copper (less than 0.01 mg/L). From the table above, the mean values for copper in the samples collected in the two districts are as follows: 2.83 mg/l, 12.73 mg/l, and 5.92 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 7.16 mg/l) and 0.05 mg/l, 0.00 mg/l, and 0.00 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a statistical mean value of 0.02 mg/l). From the statistical mean values, it can be evident that all the values collected in the Tonkolili district are not within the WHO permissible value, and from a statistical point of view, the samples collected from the Kambia district are within WHO permissible values, which is <1.0 mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district fall out of the WHO permissible standard value, whereas the samples collected from the Markelie community in Rokupr town, Kambia district are within the WHO permissible standard, and this is also evident from Table 7 as shown above. Notwithstanding, excessive copper consumption can result in headaches, nausea, vomiting, and diarrhea. Intentionally consuming extremely high amounts of copper can result in death, and prolonged exposure to high quantities of copper over many years can harm the liver or kidneys. However, excess copper is removed from your body in a matter of days because your body is quite excellent at preventing high quantities of copper from entering your bloodstream.

From the table above, the analyzed data for fluoride for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.00 mg/l, 0.02 mg/l, and 0.02 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 0.01 mg/l) and 0.00 mg/l, 0.07 mg/l, and 0.00 mg/l for the Markelie community in Rokupr town, Kambia district (from table 4 to table 6 with a mean value of 0.02 mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is <1.5 mg/l. In comparison between the two districts, the samples collected from Magburaka and Tonkolili districts are almost the same as those collected from the Markelie community in Rokupr town, Kambia district, and this is evident from Table 7 as shown above.

From the table above, the analyzed data for iron for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.00 mg/l, 0.08 mg/l, and 0.06 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 0.05 mg/l) and 0.05 mg/l, 0.54 mg/l, and 0.48 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 0.037 mg/l). From the statistical mean values, it can be evident that all the values collected from the Tonkolili district are within the WHO permissible value, which is <0.3 mg/l, and the values collected from the Kambia district are slightly above the WHO permissible value (0.37 mg/l). In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, are within the standard value of WHO, while the ones collected from Kambia district are slightly above the WHO permissible value. And this is also evident from Table 7 as shown above.

From the table above, the analyzed data for arsenic for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 3.36 mg/l, 1.89 mg/l, and 1.84 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 2.36 mg/l) and 0.00 mg/l, 0.40 mg/l, and 0.42 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 0.27 mg/l). From the statistical mean values, it can be evident that all the values are not within WHO permissible values, which is <0.01 mg/l. In comparison between the two districts, both of the samples are not within WHO standards; the samples collected from Magburaka, Tonkolili district, have a higher value (2.36 mg/l) of arsenic than those collected from the Markelie community in Rokupr town, Kambia district (0.27 mg/l), and this is also evident from Table 7 as shown above. The chemical fertilizers used in the nearby rice fields may be the cause of the elevated arsenic amounts in the sample areas. Meharg et al. [1] revealed that artificial fertilizers had caused arsenic to be present in the soil and rice grains. Moreover, the fabrication of semiconductors, runoff from orchards, waste runoff from glass and electronics industrial facilities, and erosion of natural deposits are among additional sources of As [25, 28, 27].

From the table above, the analyzed data for Cadmium (mg/l) for the stream water, hand-dug well and tap water and the mean values for them in the two districts are as follows; 3.34mg/l, 4.29mg/l and 3.45mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 3.69mg/l) and 19.79mg/l, 0.09mg/l and 0.90mg/l for Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a statistical mean value of 6.63mg/l). From the statistical mean values, it can be evident that all the values are not within WHO permissible values which is <0.01mg/l. In comparison between the two districts, both of the samples are not within WHO standard, the samples collected from Magburaka, Tonkolili district has lesser value (3.69mg/l) of Cadmium(mg/l) than those collected from Markelie community in Rokupr town, Kambia district (6.63mg/l) and this is also evident from Table 7 as shown above. Cadmium (mg/l) is found naturally in rocks and soils and enters water by contact with soft groundwater or surface water, according to Hanaa et al. [16]. Additionally, mining and smelting activities, paints, pigments, plastic stabilizers, and other industrial processes like electroplating and the disposal of fossil fuel, fertilizer, and sewage sludge can all introduce it. When compared to samples from the Tonkolili District, the water samples from the Kambia District have the greatest cadmium levels (6.63 mg/L). This could be the result of galvanized steel corroding. Likewise, fittings with cadmium soldering may also include cadmium (mg/l) [15].

From the table above, the analyzed data for lead (mg/l) for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 3.34 mg/l, 1.51 mg/l, and 1.47 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 2.11 mg/l) and 1.27 mg/l, 0.33 mg/l, and 0.02 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a statistical mean value of 0.54 mg/l). From the statistical mean values, it can be evident that all the values are not within WHO permissible values, which is <0.1 mg/l. In comparison between the two districts, both of the samples are not within WHO standards; the samples collected from Magburaka, Tonkolili district, have a higher value (2.11 mg/l) of lead (mg/l) than those collected from the Markelie community in Rokupr town, Kambia district (0.54 mg/l), and this is also evident from Table 7 as shown above. The piping used for the water distribution system [9] and the nearby soil, which may contain more lead, could be the cause of the slightly higher lead concentration (2.11 mg/L) in the same areas of the Tonkolili district than the Kambia district.

From the table above, the analyzed data for Nickel for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 0.00 mg/l, 0.00 mg/l, and 0.02 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 0.01 mg/l) and 0.00 mg/l, 0.00 mg/l, and 0.00 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a statistical mean value of 0.00 mg/l). From the statistical mean values, it can be evident that all the values are within WHO permissible values, which is ≤0.05 mg/l. In comparison between the two districts, the samples collected from Magburaka, Tonkolili district, have a slight value (0.01 mg/l) of nickel than those collected from the Markelie community in Rokupr town, Kambia district (0.00 mg/l), and this is also evident from Table 7 as shown above.

From the table above, the analyzed data for mercury (mg/l) for the stream water, hand-dug well, and tap water and the mean values for them in the two districts are as follows: 2.51 mg/l, 0.68 mg/l, and 0.54 mg/l for Magburaka, Tonkolili district (from Table 1 to Table 3 with a statistical mean of 1.24 mg/l) and 2.58 mg/l, 0.00 mg/l, and 0.00 mg/l for the Markelie community in Rokupr town, Kambia district (from Table 4 to Table 6 with a mean value of 0.86 mg/l). From the statistical mean values, it can be evident that all the values are not within WHO permissible values, which is <0.001 mg/l. In comparison between the two districts, both of the samples are not within WHO standards; the samples collected from Magburaka, Tonkolili district, have a higher value (1.24 mg/l) of mercury (mg/l) than those collected from the Markelie community in Rokupr town, Kambia district (0.86 mg/l), and this is also evident from Table 7 as shown above. The erosion of natural deposits, which are plentiful in these residential areas of the Tonkolili and Kambia districts, could be the cause of the trace amounts of mercury found in the samples. According to I. A. Katsoyiannis et al. [10], runoff from landfills and crops, trash discharged by refineries and associated enterprises, and erosion of natural deposits are some of the other common sources of mercury.

4. Conclusion

The current study concludes that the majority of the physico-chemical parameters examined are within the WHO's allowable or permissible limit for drinking waters. In terms of comparison between the two districts, the statistical values for salinity (ppt) and iron (mg/l) are within the WHO permissible limit for the samples collected in the Tonkolili district, while the samples collected from the Kambia district exceeded the recommended WHO permissible limit for the two parameters. Moreover, the statistical value for copper exceeded the WHO standard for the samples collected in the Tonkolili district, while the samples collected from the Kambia district are found within the WHO standard for copper.

The authors, therefore, conclude that all the water samples (hand-dug wells and tap waters) collected and examined in the two districts are safe and fit for drinking purposes, and the streams are safe and fit for domestic uses, especially in the Tonkolili district, since the majority of the parameters are within the WHO permissible limit and the deviations of the four parameters that exceeded WHO permissible limits are very negligible.

The author recommends that there should be regular monitoring and treatment (for instance, chlorinating) of the hand-dug wells and tap waters and also that other researchers undertake further studies in different seasons and also consider other water quality parameters like the bacteriological parameters, radiological materials, etc.

Abbreviations

Al	Aluminium
APHA	American Public Health Associations
As	Arsenic
ASTM	American Society for Testing and Materials
Cd	Cadmium
Cu	Copper
DO	Dissolved Oxygen
F	Fluoride
Fe	Iron
Hg	Mercury
KCl	Potassium Chloride
NH_3	Ammonia
Ni	Nickel
NO_2	Nitrogen Dioxide
NO_3	Nitrate
NTU	Nephelometer Turbidity Unit
Pb	Lead
pH	Potential of Hydrogen
PO_4	Phosphates
TDS	Total Dissolved Solid
WHO	World Health Organization
Zn	Zinc

Author Contributions

Sahr Emmanuel Lebbie: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft

Olanrewaju Lawal: Supervision, Validation, Writing – review & editing

Umaru Kanneh: Funding acquisition, Resources

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Sahr Emmanuel Lebbie is a renowned Sierra Leonean environmentalist, an articulate and creative person with good organizational and industrial managerial skills, competent in chemical analysis, quality control, human resource development, and administrative and research works at Njala University, Department of Chemistry. He completed his master's in environmental chemistry from Njala University in 2021 and his bachelor's degree in environmental chemistry from the same university in 2019. In addition, he holds a French Certificate from IMATT College, Freetown, in 2023, and a Generic Research Competency License Supervising Certificate for the Postgraduate Supervision Course, Editorial Assistant and Technical Editing, APA Referencing, and Canons of Research from Njala University in 2024. Recognized for his exceptional skills and academic excellence, he was employed as a lecturer at Njala University and also an associate lecturer in the Health Sciences Department, Central University, Sierra Leone. He has participated in multiple international research collaboration projects in recent years. Lebbie is dedicated to advancing environmental issues and research in Sierra Leone.

Umaru Kanneh is a lecturer at Njala University Sierra Leone. 80% of is time is allocated to teaching, research and community service. He was born in Daru Town Eastern Sierra Leone on the 14th April, 1984. He grew up in Daru Town, at the age of ten He was enrolled in Junior Secondary School (JSS1) at Wesley Secondary School Segbwema, seven miles from Daru. During this period there was rebel war in Sierra Leone, and Kailahun District was the headquarter of the rebels. As a result, their schooling was frequently interrupted. In 1999. He transferred to the regional head quarter town Kenema to pursue his Senior Secondary School (SSS1). He has both BSc. Chemistry Education (2002) and MSc.in Environmental Chemistry, (2013) both from Njala University.

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