



Assessment of Water Quality at River Karanga in Moshi Municipality, Kilimanjaro Region, Tanzania

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Abstract

This study assessed water quality in Karanga River, Kilimanjaro Region, Tanzania. It employed quantitative and qualitative purposive effluents water sampling from two selected points along Karanga River stations, one from point source and to the consumer level at Shirimatunda Ward for comparisons. The water samples were analyzed for Turbidity, Temperature, TDS and EC, Color, pH, DO and TSS and Total Coliforms. The results of Turbidity, Temperature, TDS, TSS, pH and DO collect in February and April were within TBS, & WHO permissible standards with no restrictions to use. Color (81.88 ± 2.59 TCUs) & Total Coliforms 712.5 CFU/100 mL collected in February-dry and April-wet seasons were above the TBS (2016) range from (1-50 TCUs, and 500 CFU/100 mL) permissible limits indicated more polluted in wet season due to runoff. It is recommended to treat the wastewater influent from domestic and industrial sources before discharging it into Karanga River.

Keywords: Wastewater, Physicochemical and biological parameters, Karanga River water, Water quality, End users' health.

1. Introduction

Water is essential to all life forms as it makes up to 50-97% of the weight of plants and animals, and about 70% of the human body. Water is also a vital resource for agriculture, manufacturing, transportation, domestic and many other human activities (Khan, 2018 and Chen et al., 2019). Clean, safe and adequate freshwater is vital for the survival of all living organisms, as well as the smooth functioning of ecosystems, communities, and the blue economies. However, the quality of the world's water is increasingly threatened as human population grows, industrial and agricultural activities expand that cause major alterations in the hydrologic cycle (Gwimbi et al., 2019). Globally, it is evident that more than two billion people are living with the risk of reduced access to freshwater resources, and by 2050, at least

25% of people are likely to live in a country affected by chronic or recurring shortages of clean and safe water (FAO, 2008). The primary focus of this study was to assess river Karanga's water quality for drawing a road map for water quality monitoring and public health safety in Moshi Municipality. This was done by the determination of physical, chemical and bacteriological parameters, then evaluated how drains discharge may influence water quality.

In international Water Quality Management, the activity of monitoring and managing the water resources all over the world is under the Department of Water Affairs; it shows that this time, quality may be a very important factor than quantity as compared to the availability of water in some areas. This solves water supply problems with structures and maintains the quality of water over the world (Luvhimbi, et al., 2022). At the National Water Quality Management,



Figure.1: Different activities conducted at River Karanga

Tanzania has several laws, tools, frameworks and strategies intending to reduce these hazards from industries and to protect human health and the environment. Tanzania has Water Utilization and Control Act (1974), Prohibition of Water Pollution S. 109, Prohibition of Water Pollution S. 110, Article 103 – Polluting Inland Water by Dumping wastes, National Water Quality Assessment Programme, National water policy (Tanzania) and other many which all maintains the quality of water in the country.

Regarding Regional Water Quality Management, Regional monitoring programme deals with water quality within a region like Kilimanjaro and certain zones. In Kilimanjaro, this program only deals with monitoring and controlling the quality of water especially from the rivers and streams. The programme can be introduced or changed in response to specific water quality problems identified in a certain system. Consequently, Kilimanjaro under Pangani Basin monitoring systems isolates the causes

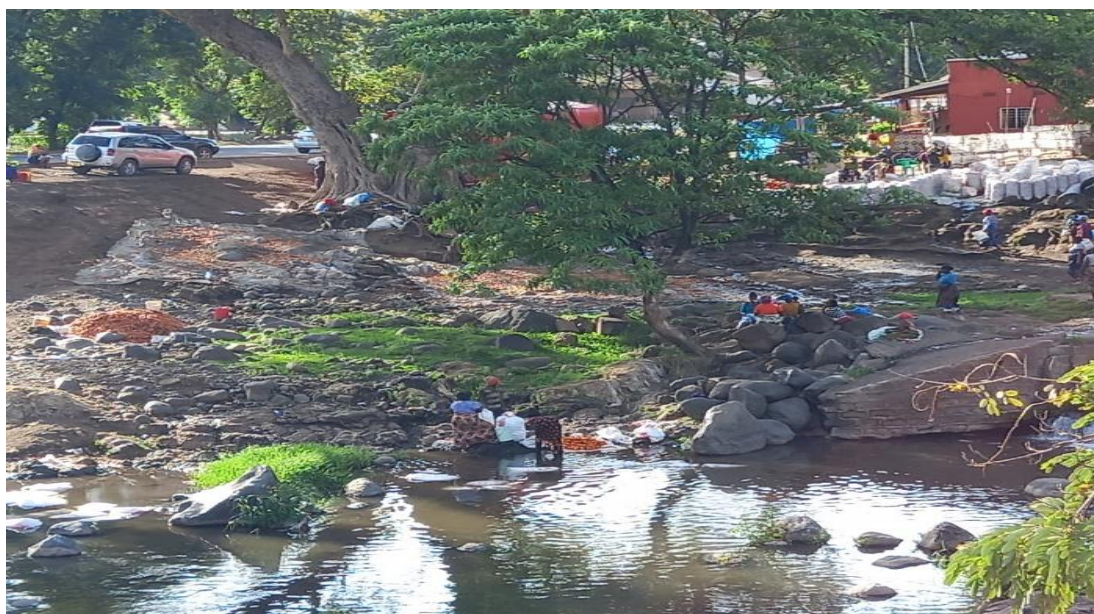


Figure 2: Farmers washing carrots in River Karanga

of changes in the water quality and quantity within a region (Lyimo, et al., 2016).

This study, therefore, assessed the water quality at River Karanga in Moshi Municipality, Kilimanjaro Region, Tanzania. The utilization of available water resources in Karanga river is a highly controversial political issue because of three major challenges to traditional water use including water pollution, construction of large-scale irrigation projects, and implementation of economic and institutional reforms for socio-economic developments as shown in Figure 1.

All these led to renewed and intensified conflicts over the use of water on Kilimanjaro as well as in the

and Kirima Juu area. River Karanga receives heavy loads of industrial waste from several industries, agricultural runoff from nearby farms and domestic runoff due to the increases of population around the river that might cause the interference of the water quality by increasing organic waste and nutrients. All these may lead to eutrophication, which later causes low dissolved oxygen with an unbalanced ecosystem, fish mortality, odors and aesthetic nuisances into the aquatic systems as in Figure 2.

River Karanga and its tributaries are under pressure of pollution from agrochemicals, physical and other domestic wastes variably affecting water quality and health of water users (Mahenge, 2018). Industries like

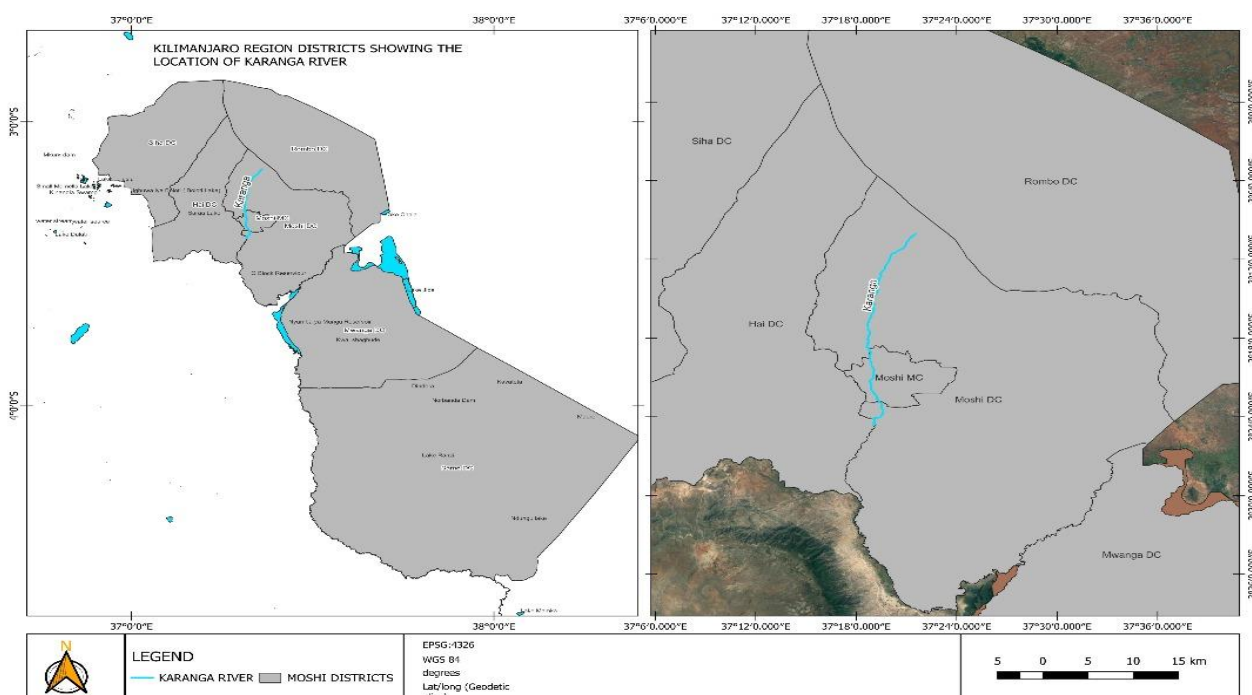


Figure 3. Map of Kilimanjaro Region showing the location of Karanga River

Pangani River. In Tanzania due to rapid population growth, industrialization and urbanization, has caused water resources to be over exploited and polluted which is leading to water shortages. River Karanga, which is 40.66 km long, is the main source of water for several activities such as domestic purposes, irrigation of crops like maize, coffee and sugarcane to the people who live nearby. It supports the population of about 7,000 of Kilimanjaro region in Shirimatunda

Bonite bottlers have increased production by increasing their machines from 3 to 7 which tend to increase pollution in the river Karanga due to discharging their wastewater into this river. To ensure water quality is maintained and human being health controlled, this study intends to assess physical chemical and bacteriological parameters of Karanga river water for enhancing socio-economic development of the area. This research contributes

baseline data to fill the gap between the policy and decision-making process in safeguarding the water quality for enhancing health and hygiene of the end users by avoiding directing wastewater in the water bodies like river Karanga, the area of this study.

2. Materials and Methods

2.1 Description of the Study Area

Karanga River in Kilimanjaro Region is in the Southwest of Mount Kilimanjaro and drains water from the western slopes of the Mountain with geographical grid latitude between $3^{\circ}12'$ to $3^{\circ}30'S$

channeled into Karanga River which exacerbates the pollution challenge.

2.2 Data Collection

2.2.1 In situ and Laboratory Measurements for Physical-chemical Parameters

The study involved the sampling water from two selected points along Karanga River purposively concentrated on its point source to the consumer level at Shirimatunda Ward. The selected 16 samples collected points coincide with where domestic, agricultural, municipal and industrial effluents were



Figure 4: Laboratory analysis at MUWSA

and Longitude $37^{\circ}15'$ to $37^{\circ}24'E$ of Greenwich Meridian. It is about 40.66 kilometers long and is fed by Nsoo, Lombanga and Umbwe Rivers upstream. Weruweru River joins Karanga River downstream then discharges its water into Kikafu River and later joins Kikuletwa River. This then discharges its water into Nyumba ya Mungu dam as shown in Figures 3 and 5. The effluents from some human activities due to population increase around the river areas use the river as an open dump for solid waste. Municipal wastes, agricultural wastes from a sugar factory farming company like Tanganyika Planting Company (TPC), runoffs and industries around from Bonite bottlers industry Figure 3, Serengeti breweries, Kibo match industry and China paper industry are

evident. This was between Kirima Juu, which was upstream, closer to the forest reserve as a control point and others to the consumer level at Shirimatunda Ward, where most domestic activities take place along Karanga River. The replicate analyses were conducted to ensure precision and accuracy of the results. The study also relied on secondary data for socio-economic impacts, which involved examining prevalent health problems in the Shirimatunda Division associated with water sources from Karanga River. Samples were collected by following the standard method (AS/NZS, 1998) and the sampling location was recorded using the global positioning system (GPS) Hussein et al., (2015). A total of 16 samples were collected from those



Figure 5: Bridge of Bonite Industry Co. Ltd.

locations in two different seasons, the dry season and rainy season months of February and April 2021 respectively from Karanga River. Two seasons were considered to get variations between them as in most cases during wet season there also runoff from nonpoint sources, which increases the level of the pollutants (NEMC, 2023). All samples collected for examinations were stored in the cool box while in the field and immediately transported to the MUWSA laboratory for analysis; thus, no preservatives were added to the size of one litre bottle of the samples.

Temperature, Total Dissolved Solids, electrical conductivity, dissolved oxygen and pH parameters were measured immediately in the field using portable equipment. The Spectrophotometry method HS Code 902730 was used in Laboratory analysis of samples was done by following procedures described in Standard Methods for Examinations of Water and Wastewater (APHA,

2022) the latest 24th edition & AWWA/WPCF, (2005) at MUWSA laboratory for Turbidity, Colour, Total suspended solids (TSS) and Total coliforms as in Figure 4.

2.2.2 Sampling for Prevalent Health Problems

Sampling for Prevalent Health Problems involved the total number of people (male and female) in the Shirimatunda Ward using Simple Random Sampling

Technique to permit a high degree of accuracy. The total number of people in Shirimatunda Ward is about 5,485, where 2,135 were males and 3,350 were females (URT, 2021 projection). The following formula was used to determine the sample size. Determination of sample size was achieved by using Yamane formula (Yamane, 1964) as in equations 1.

Whereby,

n is the sample size

N is the number of respondents (total number of people)

e is sampling error (5%)

$N = 5485$

Therefore 373 respondents were included in this study as a sample size. Also, key informants involved the Division Health Officers.

Statistical data analysis included sorting and coding, were analyzed using Statistical Package for the Social Sciences (SPSS, version 20). Data was analyzed based on descriptive features, and inferential analysis according to the objectives of the study. To ensure precision and accuracy the field instruments were calibrated, recorded measurements in consistent way, and ensured data was collected in a systematic manner. Physical-chemical and bacteriological parameters of water samples from Karanga river were determined within 24 hours of sample collection time. Then, the parameters determined were compared with

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

standard parameter limits of TBS, WHO (2016 & 2019) and FAO (2008).

3. Results and Discussion

3.1 Sex, Age, Education, Marital status and Religion profile of Respondents

Table 1 shows that 373 respondents were involved in responding to the questionnaires, males were 206,

were Muslims, 47 % of the respondents were Christian, and 1 % were non-religious.

3.2 Mean value of Physical-chemical and Bacteriological Parameters

The result showed that the mean turbidity value along the Karanga River was 26.02 NTUs. While the

Table 1: Indicating Sex, Age, Education level and marital status in years of Respondents

	Sex and Age of respondents							
	Sex		Total	Age in years				Total
	Males	Females		18 – 30	31 – 40	41 – 50	above 50	
Frequency	206	167	373	217	101	46	9	373
Percentage (%)	55	45	100	58.2	27.1	12.3	2.4	100
	Education level of respondents							
	Primary	Secondary	College/Higher	Total				
Frequency	92	208	73	373				
Percentage (%)	25	55	20	100				
	Marital status of the respondents							
	Single	Married	Cohabiting	separate	Total			
Frequency	125	123	66	59	373			
Percentage (%)	34	32	18	16	100			

which is about 55 % and females were 167, which is about 45 % of the total respondents. The results further indicated that the age of 373 respondents, 58.2 % ranged from 18 to 30 years, 27.1 % ranged 31 to 40 years, 12.3 % of respondents from 41 to 50 and 2.4 % were above 50. This implies that a large percentage of the respondents who responded to the questionnaire were between 18 to 30 years, which was equal to 58.2% of the total sample population. The result also implies that the study area is highly populated by the youths. From Table 1, about 25 % of the respondents had primary education, 55 % had secondary education, and 20 % had a college education and above.

Table 1, show that out of 373 respondents, 34% of the respondents were single, 32% respondents were married, 18% were cohabiting, and the rest, 16%, were separated. Additionally, 52 % of the respondents

mean value of temperature was 21.31 °C, the mean value of color along the Karanga River in both seasons February - dry and April - wet was 81.88 TCUs. Also, the average value of Total Dissolved Solids (TDS) was 44.43 mg/l, and the mean value of Total Suspended Solids (TSS) was 25.66 mg/l.

The mean value of Electrical Conductivity (E.C) along the Karanga River was 101.38 $\mu\text{S}/\text{cm}$, while the mean pH value was 7.51. Dissolved oxygen (DO) was 7.92 mg/l. and mean densities of Total Coliforms (TC) were 712.5 CFU/100 mL in comparison with WHO and TBS standards (2016) as shown in Figure 2. Five percent (5%) significance level or error bars as well as data labels were added for easy comprehension.

Table 2: The mean values of physico - chemical and bacteriological parameters along Karanga River

Parameters	Unit	Kirima Juu	Shirimatunda	Average	TBS	WHO	FAO
Turbidity	FTU	5.59	46.45	26.02	25	5	35
Temperature	oC	17	25.63	21.31	25	25	25
Color	Pt. Co	20.7	143.07	81.88	Jan-50	10	
TDS	mg/l	20.57	68.29	44.43	500	500	2000
TSS	mg/l	0.19	51.13	25.66	500	30	
EC	μ S/cm	46.41	156.35	101.38	600	400	700
pH	-	7.36	7.65	7.51	6.5-9.2	6.5-8.5	6.5-8.5
DO	mg/l	8.09	7.76	7.92	13	>6	>4
Total coliforms	CFU/100	280	1145	712.5	500	0	1000

3.3 Variations of Physical-chemical and Bacteriological Parameters over a Distance

The average value of turbidity was 5.59 NTUs at Kirima Juu. At Shirimatunda, turbidity was about the average of 46.45 NTUs, River water temperatures were 17.00 °C at Kirima Juu, and 25.63 °C at Shirimatunda. The color of the river water was 20.70 TCUs at Kirima Juu, and 143.07 TCUs at Shirimatunda, and then the average value of Total Dissolved Solids (TDS) was 20.57 mg/l at Kirima Juu. At Shirimatunda it was about the average of 68.29 mg/l. River water Total suspended solids were 0.19

mg/l at Kirima Juu, and 51.13 mg/l at Shirimatunda, and electrical conductivity (E.C) was 46.41 μ S/cm at Kirima Juu, and 156.35 μ S/cm at Shirimatunda. Also, the average value of pH was 7.36 at Kirima Juu. At Shirimatunda it was about the average of 7.65. The Dissolved oxygen (DO) in the river water was 8.09 mg/l at Kirima Juu, and 7.76 mg/l at Shirimatunda. Total coliforms (TC) densities were 280 CFU/100 mL at Kirima Juu and 1,145 CFU/100 mL at the Shirimatunda as in Figure 3.

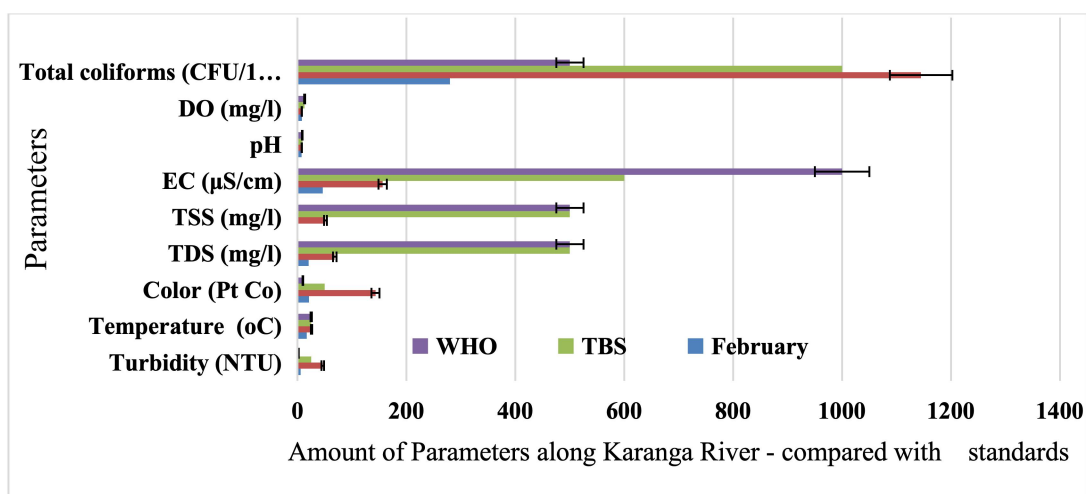


Figure 2: Physical-chemical-bacteriological parameters along Karanga river compared with TBS and WHO (2016) standards

3.4 Seasonal Variation of Physicochemical-Bacteriological Parameters

During the Dry season in February, turbidity was 24.18 NTUs and Wet season in April was 27.86 NTUs along Karanga river. The temperature was 21.6 °C in the dry season and 21.02 °C in the wet season. The color was 72.08 TCUs in the dry season, and in the wet season was 91.69 TCUs along the river Karanga. TDS was 64.88 mg/l and 23.98 mg/l in dry

stomach problems attributed to the changes of physico-chemical and biochemical parameters while 78 % were not as indicated in Figure 5. This was not very alarming, however health problems regardless of being small percentage they counted much especially in failing to do the daily routine activities by the people under medical conditions.

4. Discussion

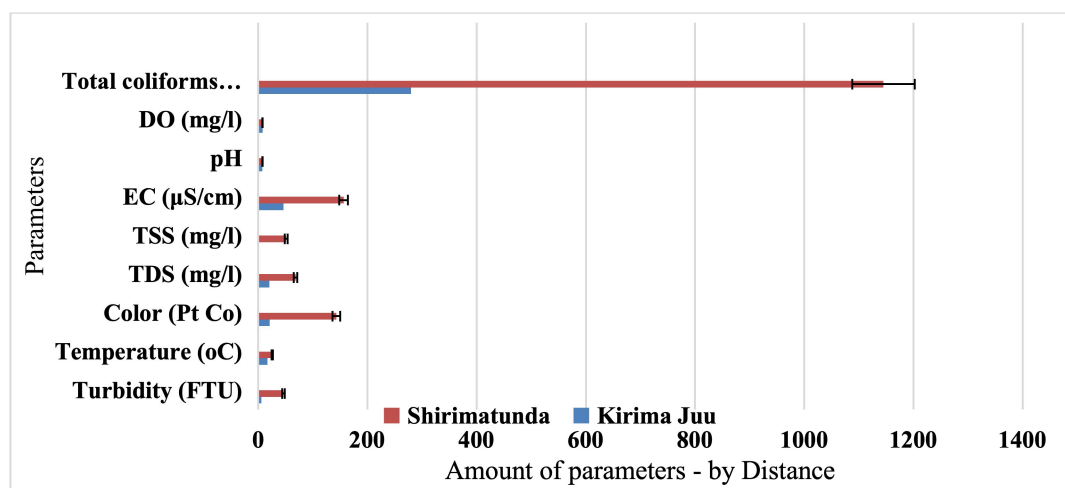


Figure 3: Variation of Physicochemical and Bacteriological Parameters along Karanga River by Distance

and wet seasons, respectively. Then TSS was 25.02 mg/l in the dry season and the Wet season was 26.30 mg/l. During the Dry season (February), E.C was 150.44 µS/cm Wet season (April) was 52.32 µS/cm; and pH was 7.75 in the dry and wet seasons was 7.27. The value of Dissolved Oxygen in the dry season was 8.25 mg/l and wet season was 7.60 mg/l. Lastly, Total Coliforms in the dry season were 615 CFU/100 mL, while in the wet season were 810 CFU/100 mL in Figure 4. Seasonal variations in parameters and correlations between different parameters like turbidity and TSS were not tested statistically.

3.5 The Prevalent Health Problems in the Community of Shirimatunda Division

Studies show that among the household members of the Shirimatunda Ward, 22 % were reported to suffer from illnesses such as diarrhea and other

4.1 Values of Physicochemical and Bacteriological Characteristics

This part discusses the values of physicochemical and bacteriological parameters such as Turbidity, Temperature, Color, total dissolved solids (TDS), Electric conductivity (EC), PH, and Dissolved oxygen (DO). Total Coliforms (TC) from two selected points which are Kirima Juu and Shirimatunda area from Karanga River, in February and April. The results are presented in figures and discussed. Also, the results of each discussed specific objective were compared with two other researchers from the same climatic regions in less developed countries or Sub-Saharan Africa. It is important to compare the results with the same climatic regions researchers where the same problems do exist as opposed to the developed countries where the conditions do differ significantly.

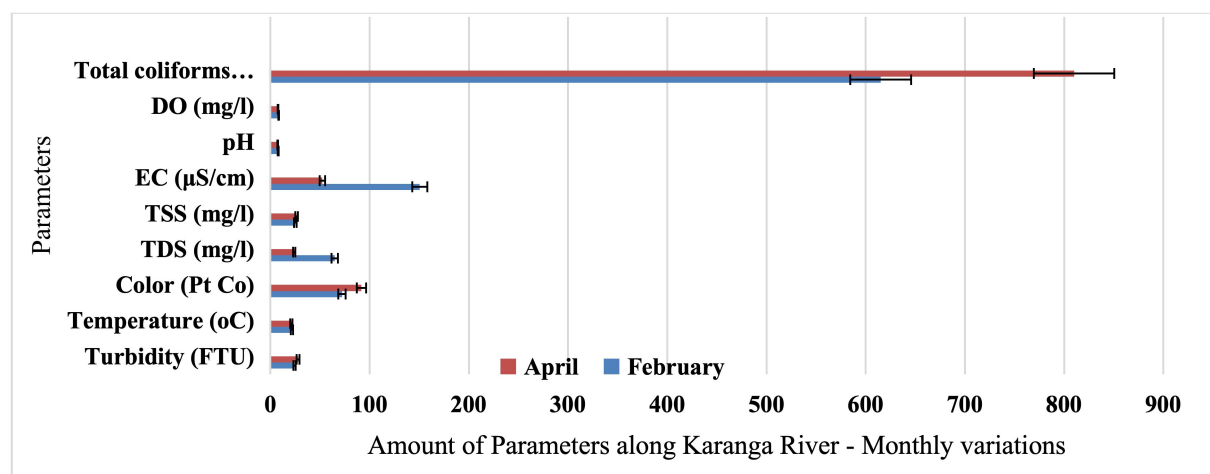


Figure 4: Monthly variations of physicochemical and bacteriological parameters along Karanga River

4.2 Turbidity, Temperature, Color and Total Dissolved Solids

4.2.1 Turbidity

According to WHO (2017) standards the turbidity of water for drinking should be < 1.00 m/L and TBS standards say it should be 5-25 m/L, Turbidity was within a range at Kirima Juu (Upstream) by TBS standard and above the range by WHO standard both in February and April; the average value of turbidity was of 5.59 NTUs. At Shirimatunda, turbidity was high compared to the standards of TBS and WHO, about an average of 46.45 NTUs, which is above the range and standard of TBS and WHO, as shown in figure 2. There is a slight difference in turbidity value between February and April, that is 3.02NTUs and 8.15NTUs, respectively. Similar ranges of turbidity (4.30 to 8.28 NTUs) were also recorded by Tanoh *et al.* (2022) in the water streams of Tai national Park, Côte d'Ivoire.

The turbidity values increase with the increasing concentrations of TSS, BOD, COD, total alkalinity, chloride, hardness, calcium, magnesium and nitrate. Runoff, domestic activities and industrial effluent with higher turbidity values into Karanga River will cause effects to aquatic organisms by reducing light penetration into water for photosynthesis and reducing the visual range of sighted animals and people (Researcher, 2023). The average turbidity

value in February and April along Karanga River was within recommended standards for TBS, WHO (2016) and FAO (2008) standards therefore, it will not cause any effect on the water users.

4.2.2 Temperature

River water temperature fluctuated between $17.00 \pm 0.31^\circ\text{C}$ and $25.00 \pm 0.13^\circ\text{C}$ during the entire period of study (Figure 2). Kirima Juu had a significantly lower level of temperature. The levels in the Shirimatunda area were nearly similar in February and April. The high temperature of the Shirimatunda area can be due to the discharge of warm effluent from Bonite bottlers industry. However, a similar study conducted by Lyimo *et al.* (2016), where temperature levels were 26°C Adogo *et al.* (2016) also reported a similar range of temperature (24°C - 26°C). All the recorded temperature values were within recommended standards for TBS, WHO (2016) and FAO (2008) standards therefore, it will not cause any effect on the water users.

The potential future climate change impacts on water quality in the Karanga River is caused by unreliable rainfall, the multiplicity of competing uses of water in agriculture, industry, domestic, and the degradation of the water sources, (Richard *et al.*, 2020). The wastewater introduced to the water sources of river Karanga releases greenhouse gases

such as Carbon dioxide and Methane gas emissions which increase global warming which exacerbate climate change scenarios (Researcher, 2023).

4.2.3 Color (TCU)

The color in the river in April was significantly higher in Shirimatunda area, about the average of (156.13 ± 2.59 TCUs) compared to the other sites, and above the TBS and WHO (2016) standard while Kirima Juu (27.24 ± 0.133 TCUs) had significantly lower levels of colour. The colour levels varied significantly between all sites, as shown in Figure 2. All the recorded values were above WHO (10 TCUs) and TBS standards (1.5 - 50 TCUs) for potable water, while that of Kirima Juu was within TBS standards. Higher colour content downstream of the Shirimatunda area was due to discharging the industrial effluents containing colour and high organic matter from the industries. Colour is usually the first contaminant to be recognized in water that affects the aesthetics, water transparency and gas solubility of water bodies. Other studies by (Onyango *et al.* 2018) also reported higher values of colour (from 65 to 111 TCUs) in Them River –Arusha. All the measured values were above the maximum permissible standards of TBS and WHO (2016) except that from Kirima Juu. This was caused by discharging industrial effluent, runoff and domestic activity with colours above recommended limit into Karanga River which affects water quality by interfering with penetration of light which affects photosynthesis (Horppila *et al.*, 2022).

4.2.4 Total Dissolved Solids (mg/l)

Figure 4 shows the Total Dissolved Solids (TDS) were high in February in all selected points; however, there were within a range and WHO standard of 500 mg/l. Total Dissolved Solids (TDS) in February was 23.77 ± 2.83 mg/l at Kirima Juu and 105.98 ± 8.9 mg/l in the Shirimatunda. In April, the values were 17.36 ± 0.719 mg/l from Kirima Juu and 30.59 ± 1.60 mg/l Shirimatunda, respectively. A similar study by Hagai *et al.*, (2019) also reported the same concentrations of TDS ranging (from 25.55 to 35.60 mg/l) from Kagera River- Kagera. All the values were within TBS (2016),

WHO (2016), and FAO (2008) permissible limits; therefore, will have no significant effect on the end user. High Total Dissolved Solids (TDS) in water can stem from both natural and human-induced sources, including mineral leaching from rocks and soil, agricultural runoff, industrial wastewater, and sewage, biological contaminants like viruses, bacteria, protozoa, and parasites are one of the main sources of high TDS in water impacting water quality and potentially causing scaling in pipes and appliances,

4.3 Total Suspended Solids, EC, pH and Dissolved Oxygen from Karanga River

4.3.1 Total Suspended Solids (mg/l)

Total suspended solids fluctuated between 0.02 mg/l and 52.25 mg/l during the entire period of study, as in Figure 2. Kirima Juu had a significantly lower level of TSS. The levels in the Shirimatunda area were significantly higher in February and April but still within TBS (2016) and WHO (2016) (500 mg/l) standards. The total suspended solids (TSS) concentration was 0.02 ± 0.98 mg/l at Kirima Juu and 50.01 ± 1.05 mg/l at the Shirimatunda in February. In April, the concentration of TSS was 0.35 ± 0.837 mg/l at Kirima Juu and 52.25 ± 1.17 mg/l at the Shirimatunda in Figure 3. Similar values of TSS of (4.6 to 42.0 mg/l) were also recorded by studies done by Aschermann *et al.*, (2016) in both February and April, the levels of TSS were significantly higher at Shirimatunda compared to Kirima Juu, but the average was within (TBS and WHO, 2016) permissible limits, therefore, will have no significant effect for the end users.

4.3.2 Electrical Conductivity (μ S/cm)

The average electrical conductivity (E.C) recorded from Kirima Juu and Shirimatunda area in February, and April was 46.41 ± 3.01 μ S/cm and 146.35 ± 1.63 μ S/cm, respectively, as shown in (Figure 2). The higher values of E.C measured from Karanga River indicate the presence of high total dissolved solids, sulphates and chlorides from various industrial and human activities. The E.C values increase with the concentration of TDS, Sulphate and Chlorides. The recorded values were within

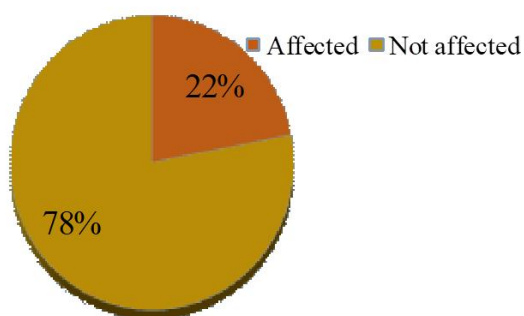


Figure 5: Prevalent of Health Problems among the Community Residences

recommended standards of TBS (2019), WHO (2016 and FAO, 2016) for river water; therefore, no effect on the water users and were not harmful to aquatic life.

4.3.3 pH levels

In Figure 2, all the recorded pH values were within TBS and WHO standards for potable waters (6.5 to 8.5 and 6.6 to 9.2); therefore, it is safe for consumption. In February, the levels of pH varied significantly, while in April, the pH levels at Kirima Juu and Shirimatunda also varied significantly. However, a similar range of pH (7.5 – 8.5) was recorded by Joel Norbat, (2017) from Ruaha River. The pH obtained from this study was well within TBS and WHO (2019) acceptable limit (Figure 3) therefore, it will not have any significant effects on the end user.

Water with pH > 9.2 tastes bitter whereas with pH < 5.3 reduces the assimilation of minerals and vitamins in the body. The pH of drinking water greatly affects the water temperature, number of organic compounds as well as solubility of toxic metals and therefore influences health and body chemistry in general.

4.3.4 Dissolved Oxygen (mg/L)

In February, the Dissolved oxygen levels were 8.16 ± 0.03 mg/l at Kirima Juu and 8.33 ± 0.1 mg/l at Shirimatunda, as shown in Figure 3. In April, DO levels were 8.02 ± 0.170 mg/l at Kirima Juu and 7.18 ± 0.031 mg/l at the Shirimatunda area. The levels at all the values recorded in February and April were within TBS and WHO standards for potable waters

which is 5 to 13 mg/l, Similar range of DO (8.6 to 9.4 mg/l) was also recorded by a similar study done by Mkude *et al.*, (2018) in Wami River, Tanzania. The entire recorded DO concentrations were within recommended standards for TBS and WHO (2016); therefore, it will not cause any effect on the water users.

4.4 Bacteriological Characteristics of Water Samples

Bacteriological characteristics are still the primary water quality issue in any water resource, especially those intended for drinking purposes. Bacteriological analyses for water samples collected from Karanga River from located sites in dry and rainy seasons are presented in Figure 3.

4.4.1 Total Coliforms

Total Coliforms densities varied between 280 CFU/100 mL at Kirima Juu and 1,145 CFU/100 mL at the Shirimatunda area. The highest count recorded at Shirimatunda in April, which was 1,300 CFU/100 mL. It is worth mentioning that all monitored points in Karanga River except in Kirima Juu are out of the WHO and TBS (2016) standard limits that should not exceed 0 CFU/100 mL. These results are much higher than what was found by Kihampa and Ndunguru (2021) fecal coliform range (<1–76 FC/100 mL) in water catchment area in Mbinga District, Saria (2015) from Mzinga river, Southern Dar es Salaam total coliform ranges from 14.17 ± 4.06 CFU/100mL to 486.80 ± 102.32 CFU/100mL, (Mihale, 2022) in Coastal rivers of Tanzania, Alphayo and Sharma (2018) in Ruvu & Pangani rivers Tanzania; Hellar *et al.*, (2013); Alphayo and Sharma, (2018), Lucy and Hadija, (2023).

Globally, according to WHO/UNICEF (2010), water pollution has become a common problem in all urban areas in Tanzania, particularly in rain seasons like April in this study. Major water pollutants include microbes, nutrients, heavy metals, organic chemicals, oil and sediments; heat, which raises the temperature of the receiving water bodies. Water pollution impairs quality, destroys important food sources, and contaminates drinking water with

chemicals that can cause immediate and long-term harm to human health. Water pollution also often severely damages aquatic ecosystems such as rivers, lakes, and oceans, which are used as open sewers for industrial and residential waste. For instance, the effects of higher high total coliform counts in portable water are causing waterborne diseases such as Cholera, Typhoid and Amoebiasis. This indicates a higher occurrence of illnesses attributable to polluted water among the people living by the side of a river. This result implies that residents tend to incur more costs for repairing their health when they are affected by waterborne diseases.

4.5 Evaluation of Prevalent Health Problems of Residences

In February, all measured parameters varied significantly at ($p < 0.05$, independent T-test) from both Kirima Juu and Shirimatunda and in April also, there was a significant variation in all measured parameters at Kirima Juu and Shirimatunda ($p < 0.05$). One-way-ANOVA showed significant variations ($p < 0.05$) of measured parameters between different sites in Karanga River. Monthly variations were also significant ($p < 0.05$) for Turbidity, Temperature, Color, Total dissolved solids (TDS), Total suspended solids (TSS), Electric conductivity (EC), Hydrogen power (pH), Dissolved oxygen (DO) and Total Coliforms (TC).

Among the household members of the Shirimatunda Ward, 373 in this study, 22 % were reported to suffer from illnesses attributable to a change in physicochemical and biochemical parameters while 78 % were not. The systemic illnesses that were significantly more among the household members of the Shirimatunda Ward were waterborne diseases such as Cholera, Typhoid and Amoebiasis. This indicates a higher occurrence of illnesses attributable to polluted water among the people living by the side of a river.

5. Conclusions

The results obtained in laboratory analyses show the parameters such as Turbidity, Temperature, Total dissolved solids (TDS), Total suspended solids (TSS),

Electric conductivity (EC), Hydrogen power (pH) and Dissolved oxygen (DO) from the Karanga river were within recommended TBS WHO and FAO standards for potable water, with no effects for the water users. On the other hand, Color and Total Coliforms (TC) were above permissible limits indicating water contamination due to the discharge of industrial, domestic, agricultural and runoff influents. It is concluded that the water quality along the Karanga River (40 km) area of the study is influenced by wastewater discharge from drains located on its riverbanks by physico-chemical and bacteriological characteristics.

The variations of physical-chemical, and bacteriological parameters over a distance from its point source to the consumer level at Shirimatunda Ward revealed the mean values of Turbidity, Temperature, Color, total dissolved solids (TDS), Total suspended solids (TSS), Electric conductivity (EC), Hydrogen power (pH), Dissolved oxygen (DO), and Total Coliforms (TC) measured originated from Kirima Juu point source. The study shows that the contamination of Karanga River came from runoff, which carries a higher number of organic pollutants. The variation of physicochemical and bacteriological parameters in water from Karanga River across different seasons of the year between February through April shows significant variations in the mean values of the parameters measured. Temperature, Electric conductivity (EC), Hydrogen power (pH), and Total dissolved solids (TDS) were high in February due to industrial activities being in high season in December, January and February.

Due to agricultural activities, turbidity, Color, Total suspended solids (TSS) and Total Coliforms (TC) measured were high in April, which is a rainy season, the high season in agricultural activities and runoff. The systemic illnesses, which were significantly more among the household members of the Shirimatunda Ward, were waterborne diseases such as Cholera, Typhoid and Amoebiasis. The limitations of the study were the sampling points only 16 but done purposively.

Recommendations

Constructed wetlands, as a natural treatment method is essential in addressing the problem of water quality degradation of effluent from Bonite industry and runoff from agriculture in Karanga areas before they enter Karanga River. The approach needs to plant the reed plants with vegetation with defined filter materials and direction of wastewater flow. Wetlands utilize wetland plants, soils and associated microorganisms to remove contaminants from polluted water. The wetlands protect society from suffering ill health associated with inappropriate polluted water treatment, management and disposal practices.

For non-point pollution sources, like farms also, alternative treatment such as wetland-type vegetation should be implemented directly with education to the people living along the rivers on how and why it is important to conserve water resources. Government Ministries, water resources stakeholders, communities and private sectors should be involved in water resources conservation directly.

There is a need to enforce fines and taxes for industries which pollute the environment and hence the water resources. The government must provide financial support for those authorities who control the river basins and lead to facilitating water quality monitoring programs and education for all water users and stakeholders to treat wastewater before discharge or reuse.

The study recommends that future studies should pay attention to the following research topics in Karanga River to reduce effect on aquatic ecosystems and biodiversity. Monitoring industrial and Agricultural effluents quality to maintain River water quality and comparing them with recommended TBS, WHO and FAO standards. Monitoring Municipal and Domestic effluents quality before discharging in the rivers.

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