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Flowing Through Change: Investigating the Impacts of Human Activities on Urban River Water Quality in the Kumba River, South West Region of Cameroon

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Abstract: This study seeks to examine the relationship between the different urban land use activities in the Kumba metropolis and the related implications on the Kumba river water quality. This involved collection of water samples from the Kumba river as well as performing laboratory tests to determine variations in the river's Physical, chemical and bacteriological properties. The parameters analyzed were temperature, dissolved oxygen, total dissolved solids, total suspended solids, Electrical Conductivity, odour, colour, turbidity, nitrite, nitrate, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, phosphorus, chlorine, nitrates, nitrites and some heavy metals like copper, phosphate, iron, zinc, calcium, magnesium and Faecal Coliform. Water samples were collected from five sampling points in the month of February 2023(peak dry season) and in the month of April 2023(for the rainy season). The data from the analysis of the water samples were analyzed using both descriptive and inferential statistics, on both Microsoft Excel and SPSS. The study found that the p values were less than 0.05 at a confidence level of 95%, which suggests that the Kumba River is polluted due to the effects of different urban land use activities in the city. The water quality parameters of the collected samples showed that areas with high dependence on the river for urban activities registered significantly poor water quality, compared to samples with limited dependence on the river for urban land uses. Based on these findings, it is recommended that anthropogenic activities within the area be closely monitored as urbanization continues to rapidly occur and its effects continue to pollute the river, making it harmful not only to ecosystems but also rendering it unfit for river channel crop cultivation. Additionally, the study concluded that changes in Land Use Land Cover (LULC) between 2007 and 2023 have statistically significant effects on the physicochemical and microbial water quality of the Kumba River. Therefore, it is vital to address the rate at which forests are being converted to agricultural lands and the intense use of agrochemicals on these farms and plantations.

Keywords: Activities, Implications, Land Use, Pollution, River, Water Quality

1. Introduction

From the beginning of civilization Water has been an essential natural resource which forms the chief constituent for the development of a supportive ecosystem and livelihood sustenance [1]. Despite the very important role water plays in human livelihood and ecosystem sustenance the quality and quantity of water has over time been affected by the prevailing human activities [2]. The poor utilization of urban water bodies especially in cities with poor urban planning has been decried by the United Nations 2018 World Water Development report which projects that by 2050, nearly 6 billion people globally are likely to face acute water scarcity [3-5]. As urbanization continues to rapidly occur, it is crucial to understand the connections between urban land use and water quality. This understanding is essential in identifying threats to water quality as well as urban activities that hamper the achievement of sustainable development goals in this era of large-scale urbanization [6]. Thus the relationship becomes very relevant in targeting urban land use activities as well as to establish measures to mitigate pollution load.

With the evolution of human populations, growths in commercial as well as industrial activities in urban centres, surface water in urban areas receive a large quantity of contaminants from numerous sources such as the destruction of forested areas to make way for housing and urban infrastructure, inadequate urban planning and waste management systems, as well as the excessive use of agrochemicals along urban watersheds and river channels, resulting in changes to urban land use and land cover [7, 8].

In the same vein, [9] reported that, anthropogenic activities impact on urban surface water quality through the discharge of untreated wastes and effluents from urban activities such as slaughterhouses as well as from domestic and industrial sewer systems are dumped/ discharged directly or indirectly into stream channels which leads to the pollution of urban water bodies. These unethical way pf discharging domestic and industrial wastes into urban river systems not only pollutes the water but also constitutes a serious threat to human health, economic growth and ecological balance [2, 10].

This research had as objectives to collect and illustrate variations in the physical, chemical and biological properties of the Kumba river. To do this water samples were collected at certain points of the river and laboratory tested to determine their physical, chemical and biological properties vis-à-vis the human activities taking place within the metropolis. This way the results from the analysis will go a long way helping public administration alongside stakeholders' design and implement policies that will enhance efficient land fuse and sustainable water management.

2. Materials and Methods

2.1. Description of the Study Area

Figure 1 illustrates that Kumba is situated within the Meme Division of Cameroon's South West Region. As the capital of Meme Division, Kumba is positioned at a latitude of 4°30" North of the Equator and a longitude of 9°40" East of the Greenwich Meridian. It covers a surface area of about 8.213Km^2. Kumba is bounded to the South by Fako Division, to the East by Ndian Division and to the West by Kupe Muananguba [11]. The climate of Kumba is dominated by the equatorial type of high rainfall and high temperature. the metropolis is a junction city noted for its commercial activities and extensive cultivation of cocoa, a major cash crop in Cameroon. The Kumba River traverses the city of kumba, draining more than 70% of the metropolis.

Equally the metropolis is situated in a Plain, between Mount Cameroon and Rumpi Mountains in the Douala Basin. The town's geology is controlled by three volcanic activities and has a mean elevation of 220m. The highest point of the metropolis is located at 467m and has a crater lake to the west called Lake Barombi.

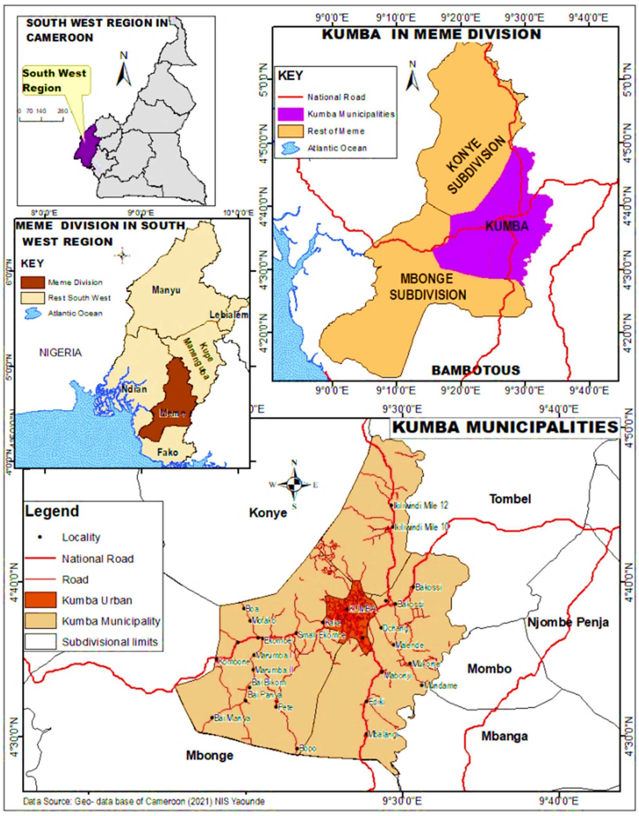

Figure 1. The location of the study area in meme Division, south west region of Cameroon. Source: adapted from (Sop Sop & Njumba, 2022).

2.2. Water Samples Collection Points

Water samples were collected from five points within the metropolis with the aid of Garmin GPS 60 CX as shown on table 1. These points were selected to check effects of many human activities on the adjacent Kumba river within the dry and the rainy season.

Table 1. *Water samples collection points.*

Sample Locations	X (latitudes)	Y (longitudes)
Kumba Town (Baptist)	4^0.37'24.255"N	9^0.26'17.363"E
Meta Quarters	4^0.38'56.348"N	9^0.25'37.837"E
Town Green	4^0.38'17.885"N	9^0.26'33.814"E
Total Junction/Fiango	4^0.38'2.485"N	9^0.26'34.215"E
Buea Road	4^0.37'9.533"N	9^0.26'54.260"E

Source: field work, 2023

Water samples were obtained from the aforementioned locations during February 2023, which marked the peak of the dry season, as well as in April 2023, during the rainy season. The collection of water samples occurred in the morning, specifically between 6:30 am and 11:00 am. These samples were taken at depths ranging from approximately 8 to 10 cm, located 2 meters away from the river banks. The purpose of this approach was to select points where the river consistently maintained a steady flow. water samples were collected using plastic bottles of two different sizes: 0.5 ml and 1.5 L containers. To prevent potential contamination from the containers used for sample storage, the plastic bottles were thoroughly washed three times with water from the same collection point before the water samples were collected. Each sample was then carefully labelled with information including the location, date, time, and the specific type of analysis to be conducted on the sample. Subsequently, the water samples were assigned unique codes based on their respective names, locations, and dates. This coding system served to facilitate the subsequent laboratory analysis of the samples.

The samples were later stored in ice containers with regulated temperatures of 4^{o}c for about 4-6 hours to counter microbial and chemical activities within samples prior to laboratory analysis. The following laboratory analysis were conducted on the water samples. Figure 2 presents water samples collection points within the Kumba river.

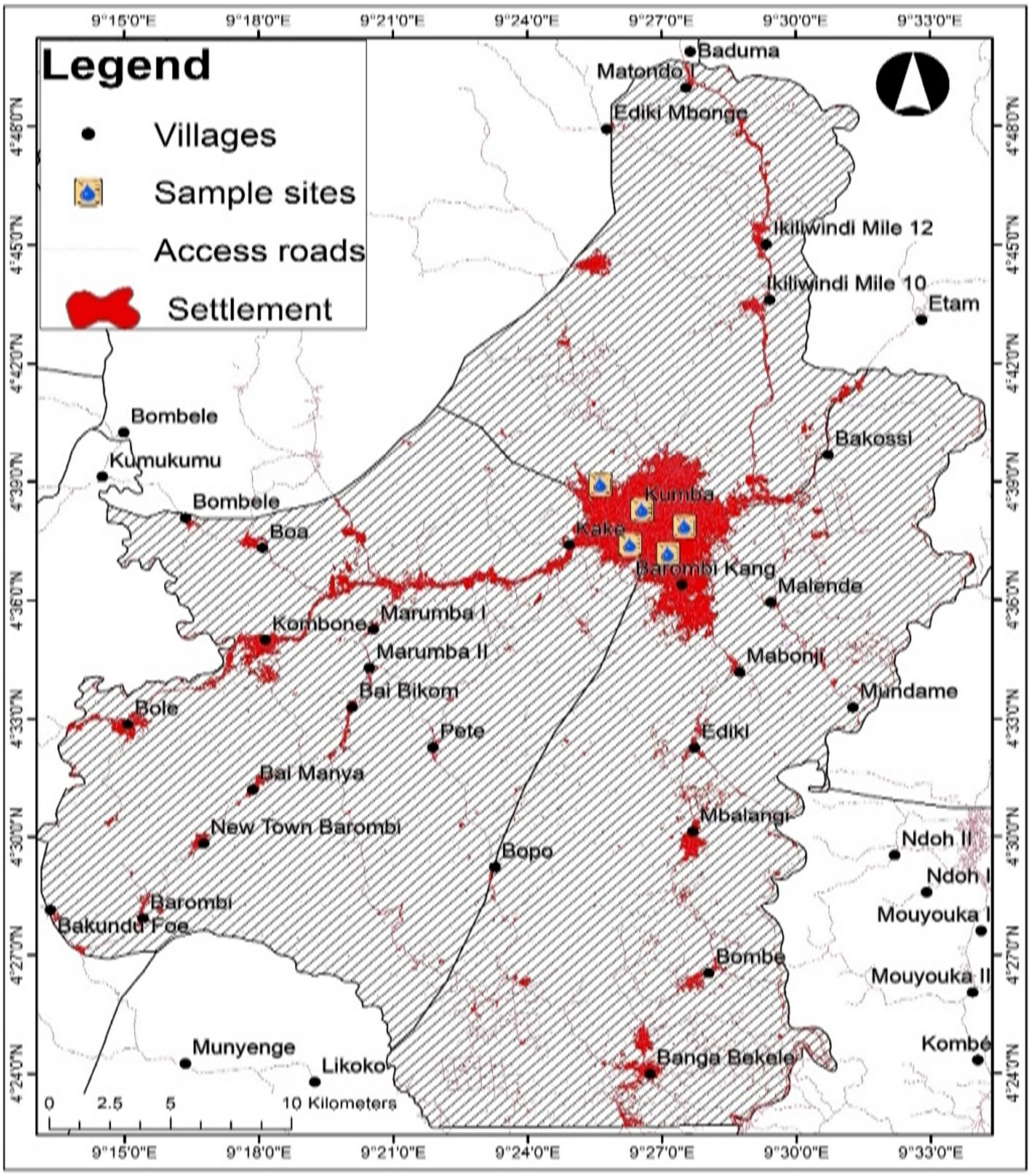

Figure 2. *Water samples collection points. Source: field work, 2023.*

The following laboratory analysis were conducted on the water samples.

Table 2. *Types of laboratory analysis to be done on water samples.*

1	Temperature in degree celcius (°C),	12	Sulphate in (milligrams per litre),
2	Turbidity in Nephelometric turbidity units (NTU),	13	Nitrate in (milligrams per litre),
3	Electrical Conductivity in Microsiemens Per Centimeter (µS/cm),	14	Iron in (milligrams per litre),
4	pH in logarithmic units	15	Phosphates in (milligrams per litre),
5	Total Dissolved Solids (TDS) in (milligrams per litre),	16	Biological Oxygen Demand(mg/l),
6	Total Suspended Solids (mg/l),	17	Chemical Oxygen in (milligrams per litre),

7	CU in (milligrams per litre)	18	Dissolved Oxygen in (milligrams per litre),
8	NH_3 (Mg/I)	19	Escherichia coli and Total Coliform (cfu/100ml)
9	zinc	20	Nitrites (mg/l)
10	Colour	21	Calcium (Mg/I)
11	Magnesium (Mg/I)		

Source: field work, 2023

During the fieldwork, the temperature of the water was measured on site using a thermometer, while its color was assessed visually by inspecting it with the naked eye as it is a sensory characteristic. Laboratory analysis were separately done in the Baptist hospital and standard laboratories Kumba.

In the laboratory biological tests were done according the views of [12-14]. To prepare the culture media, individual conical flasks were filled with 3.6 g of Eosin methylene blue agar (EMBA), 4.95 g of MacConkey agar (MCA), 3.6 g of Nutrient agar (NA), and 6.3 g of Salmonella shigella agar (SSA), and mixed with 100 mL of distilled water. The mixture was then heated on an electric hot plate until dissolved. The dissolved agars were each combined with 9 mL of distilled water in 16 test tubes, which were then sterilized in an autoclave for 15 minutes. after sterilization, the water samples were diluted with the sterilized water and then incubated for 24 hours. The agar plates were examined for colony formation, and the colonies were counted using a colony counter. Gram staining analysis was then performed on a bacterial smear on a slide using crystal violet solution, iodine, ethanol, safranine, and a microscope.

To perform chemical analysis on the water samples, the samples were assessed for turbidity and pH using a turbidity meter and pH meter, respectively while chemical oxygen demand was determined using a COD reactor along with a multipara meter instrument. Other tests such as biochemical oxygen demand on the water samples was determined using the BOD test kit by incubating them in BOD test bottles for 5 days. the concentration of calcium and magnesium was done using EDTA complexometric titration method, nitrates, nitrites, sulphates and phosphates were measured using ion chromatography on a Dionex ICS-900. The concentration of other chemical properties such as chloride, zinc, arsenic, manganese, and lead was estimated using a colorimeter. The colorimeter was zeroed, and the program number was entered before using the appropriate chemical reagents for each test. Total dissolved solids and total suspended solids were measured by titrating 0.02-M HCl solution to each sample and stir until a pH of 4 to 4.5 was obtained. test for copper and iron was performed on the water samples using Acideacitique, Tethramethyle–Diamino–Diphenylmethane (T. D. D), periodate de sodium, and Neutraliser (soide). A solution was made with the reagents and dropped into the water samples. The samples were left untouched for 10-15 minutes each and then read from colour display. The laboratory analysis to determine total Escherichia coli and Total Coliform in the water samples involved the use of sel de mohr, solution of potassium, sulphuric acid (1/4 volume) a beaker of 250ml, a 150ml test tube and a 10ml pipette. Each sample was mixed with the chemicals mentioned above, and the moist content of each sample determined by drying 2grams from each sample in temperatures of 105^{o}C for 18 hours.

For land use and land cover change analysis, we used the earth explorer website of the USGS to obtain high resolution Landsat images for land cover/use change detection from 2007–2023. The timescale was also linked to image availability for the study area. For the 3 time periods, we acquired and analyzed Landsat satellite images with QGIS 3.2. We used a supervised interactive classification technique in QGIS for image classification with the aid of the SCP plugin. This technique consists of drawing training areas across the composite image, then group similar training areas to form training samples to which land cover class is assigned for classification. Table 3 shows the images that were used in this study.

3. Results and Discussions

3.1. Land Use Change in Kumba

To determine the extent of water quality change within the study area we considered the evolution of the land use pattern within the metropolis. To this we used the supervised interactive classification technique in “Semi-Automatic Classification” SCP plugin on QGIS 3.2. We obtained and used images for the interval as shown on table 3.

Table 3. *Images acquired and used in the study.*

S/N	Platform	Sensor	Cell size (m)	Date of acquisition	Satellite owner
1	Landsat 5	ETM+	30	2007/01/29	USGS
2	Landsat 7	OLI/TIRS	30	2015/12/29	USGS
3	Landsat 9	OLI/TIRS	30	2023/01/16	USGS

TM: Thematic Mapper, ETM+: Enhanced Thematic Mapper Plus, OLI/TIRS: Operational Land Imager/Thermal Infrared Sensor, USGS: US Geological Survey

From the analysis of the different Landsat images, the results show that, the metropolis has been growing in terms of size, housing density and land use diversity. The results of the urban expansion of Kumba and the accompanying land use types are as shown on figure 3.

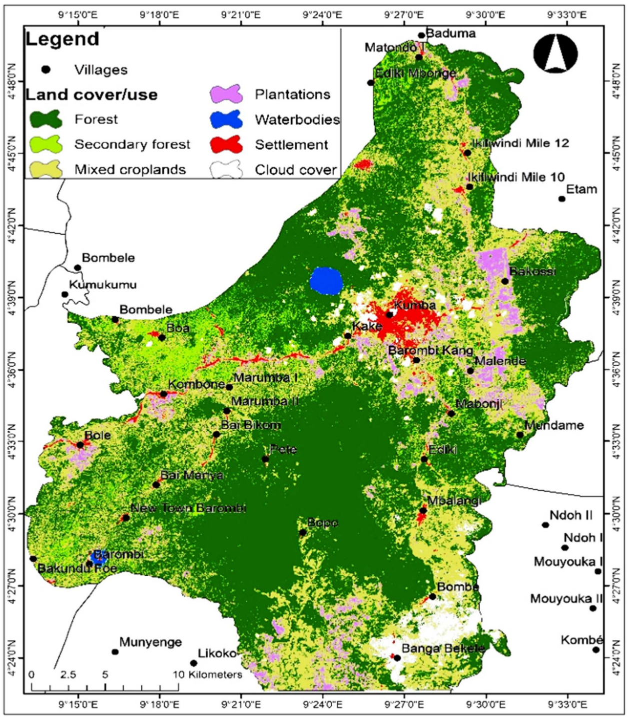

Figure 3. Land cover/use map of 2007 Source: Landsat 7 (2007).

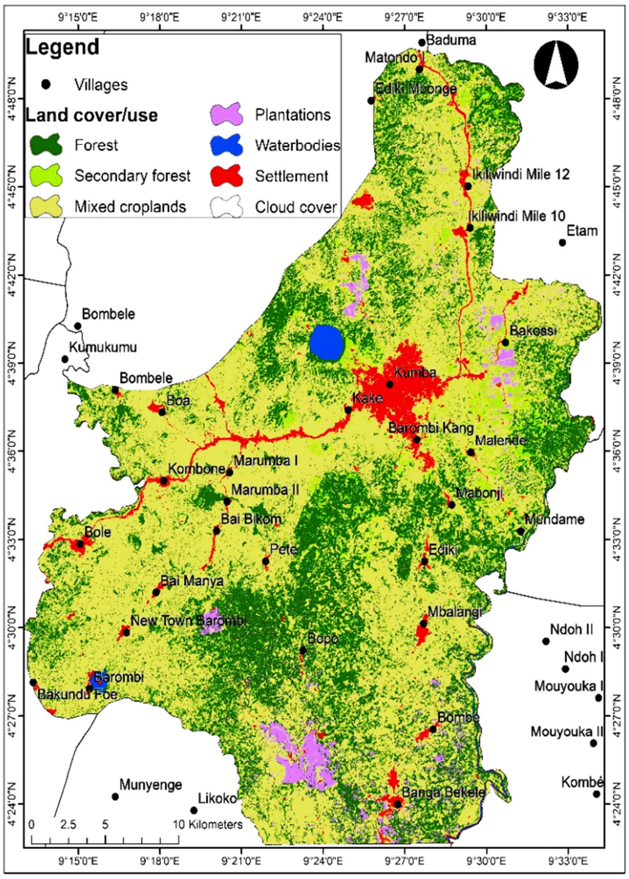

Figure 4. Land cover/use map of 2015. Source: Landsat 8 (2015).

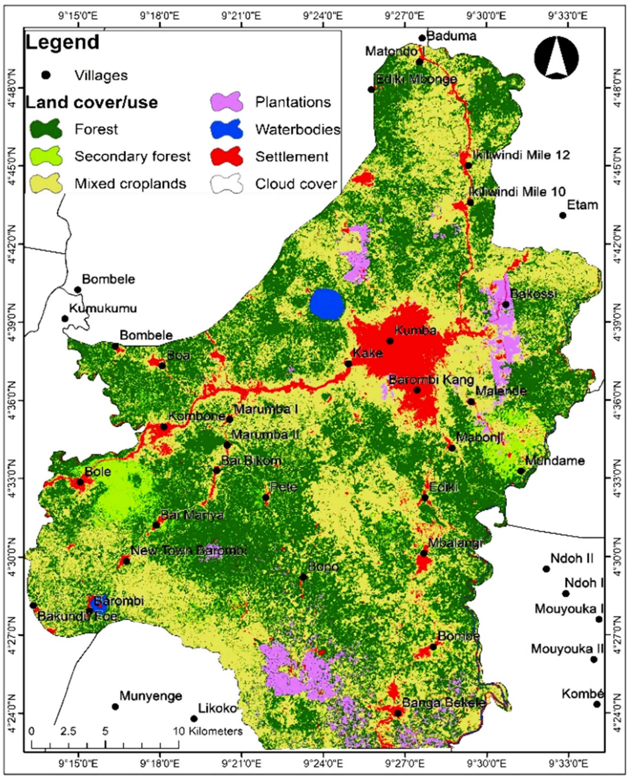

Figure 5. Land cover/use map of 2023. Source: Landsat 9 (2023)

The land cover and land use maps presented on figures 3, 4 and 5 show clearly that the city of Kumba has expanded significantly from 2007 to 2023 with largest changes noticed in urban land use activities like settlement expansion, mixed crop land and plantations. Table 4 Present the cumulative totals of the different land use activities in Kumba.

Table 4. Cumulative totals of land use and cover evolution (2007-2023) in Kumba.

Land cover/use	2007	2015	2023
Forest	59980.5	30527.37	47484.45
Secondary forest	4392.63	3290.49	2959.47
Mixed cropland	33,074.82	64,298.97	45,237.24
Plantations	3969.99	3,472.02	4,421.61
Settlement	1835.91	4522.32	5967.63
Water bodies	497.7	714.51	755.28

Source: field work and USGS data, 2023

The results on table 4 shows the land cover/use data for three different years (2007, 2015 and 2023) in terms of six categories: Forest, Secondary forest, Mixed cropland, Plantations, Settlement, and Water bodies. In 2007, the total area covered by forest was 59,980.5 hectares, which reduced significantly to 30,527.37 hectares in 2015, but has increased to 47,484.45 hectares by 2023. Secondary forests have shown some fluctuations over the years with a slight decrease from 4,392.63 hectares in 2007 to 3,290.49 hectares in 2015, and a further decline to 2,959.47 hectares in 2023. Mixed cropland saw a significant increase in land use from 33,074.82 hectares in 2007 to 64,298.97 hectares in 2015, followed by a decrease to 45,237.24 hectares in 2023. The area under plantations is relatively small, but it has shown a slight increase from 3,969.99 hectares in 2007 to 3,472.02 hectares in 2015 and then further increased to 4,421.61 hectares in 2023. Settlement areas have increased from 1,835.91 hectares in 2007 to 4,522.32 hectares in 2015, and 5,967.63 hectares in 2023. Finally, water bodies have also slightly increased from 497.7 hectares in 2007 to 714.51 hectares in 2015, and 755.28 hectares in 2023.

3.2. Laboratory Results on Collected Water Samples

The results presented on tables 5 and 6 presents the laboratory analysis of the dry season and rainy season water samples collected from five different locations. The parameters measured include temperature, pH, electrical conductivity (EC), color, turbidity, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), ammonia (NH3), nitrate (NO-3), nitrite (NO-2), biological oxygen demand (BOD), chemical oxygen demand (COD), phosphate (PO3-4), copper (Cu), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and fecal coliform.

Comparing the results with the standards set by WHO/CAM STD, it is observed that several parameters in both seasons show ranges outside the recommended limits. For the dry season, Total Junction/Fiango and Buea Road samples showed high electrical conductivity (902 and 851 µs/cm), which exceeds the recommended limit of 1000 µs/cm, indicating salt levels in water that could be harmful to human health. Also, the Faecal coliform levels in Total Junction/Fiango (190.8 Mg/I) and Kumba town (108 Mg/I) were above the WHO/CAM STD limit of 50 Mg/I, indicating water contamination with bacteria that could cause diseases such as cholera and typhoid fever.

In the rainy season analysis, several parameters were found above the recommended limits, particularly in samples collected from Buea Road and Town Green. The conductivity levels (5568 and 7456 µs/cm) were much higher than the recommended range of 1000 µs/cm. The turbidity levels were also very high in samples from Buea Road (465 NTU) and Town Green (689 NTU), indicating high levels of suspended solids in the water. The Faecal coliform levels were also very high in samples from Buea Road (389 Mg/I) and Town Green (354 Mg/I), suggesting severe water contamination that requires urgent attention.

These results are crucial as they suggest that the quality of water in these areas is not safe for human consumption, and urgent measures should be taken to address water pollutants to safeguard public health.

Table 5. *Dry season laboratory analysis.*

S/N	1	2	3	4	5	6	7	8	9	10
PARAMETERS	**Temperature (°Celsius)**	**pH**	**EC(µs/cm)**	**Colour (TCU)**	**Turbidity (NTU µs/cm)**	**TSS (Mg/L)**	**TDS(Mg/L)**	**DO (Mg/L)**	**NH_3 (Mg/I)**	**NO^-_3(Mg/I)**
WHO/CAM. STD	(25)	6.5-9.5	≤1000	colourless	1-5	≤500	≤1000	7.5	<1.0	10
Meta qter	22.1	7.1	122	65	10	15	30	10.3	0.97	3.01
Kumba town	22.1	6.9	250	189	113.5	98	20	7.9	2.8	4.21
Total Junction/fiango	24.5	10.1	902	365	234	187	298	1.1	6.9	2.16
Buea Road	24.8	9.1	851	275	284	192	126	2.4	3.7	17.75
Town green	25.6	8.6	846	512	156.8	170	125	2.8	2.1	3.99
mean	23.82	8.36	594.2	281.2	159.66	132	119.8	4.9	3.294	6.24

Table 5. *Continued.*

S/N	11	12	13	15	16	17	18	19	20	21
PARAMETERS	**NO^-_2(Mg/I)**	**BOD (Mg/I)**	**COD(Mg/I)**	**PO^{3-}_4 (Mg/I)**	**CU (Mg/I)**	**Ca(Mg/I)**	**Mg(Mg/I)**	**Fe(Mg/I)**	**Zn(Mg/I)**	**Faecal Coliform (Mg/I)**
WHO/CAM. STD	1	10	40	≤5	0.1	-	≤50	≤0.3	5	0
Meta qter	0.05	13.3	22	1.35	0.04	0.83	3.71	0.75	0.13	130.5
Kumba town	0.06	20	18	3.51	0.11	1.5	4.73	0.12	1.43	108
Total Junction/fiango	0.04	298	126	9.76	0.59	2.25	2.47	2.17	2.76	190.8
Buea Road	0.023	352	571	7.92	0.96	1.98	2.35	3.95	1.97	104.7
Town green	0.94	315	396	5.43	0.62	0.09	4.2	2.78	1.34	106.8
mean	0.2226	199	502	5.594	0.464	2.93	3.492	1.95	1.526	128.16

Table 6. *Rainy season laboratory analysis.*

S/N	1	2	3	4	5	6	7	8	9	10
PARAMETERS	**Temperature (^{0}Celsius)**	**PH**	**EC(µs/cm)**	**Colour (TCU)**	**Turbidity (NTU µs/cm)**	**TSS (Mg/L)**	**TDS(Mg/L)**	**DO (Mg/L)**	**NH_3 (Mg/I)**	**NO^-_3(Mg/I)**
WHO/CAM. STD	Ambient (25)	≤9	≤1000	colourless	≤5	≤500	≤1000	7.5	<1.0	10
Meta qter	19	9	100	115	789	124	1500	13.8	0.9	6
Kumba town	20.3	8.4	150	253	324	245	1245	19.9	1.5	4
Total Junction/fiango	19.4	9	723	456	367	372	3346	6.7	0.45	8
Buea Road	20.8	9.8	644	576	465	543	5568	15	1.6	24

S/N	1	2	3	4	5	6	7	8	9	10
PARAMETERS	**Temperature (^{0}Celsius)**	**PH**	**EC(µs/cm)**	**Colour (TCU)**	**Turbidity (NTU µs/cm)**	**TSS (Mg/L)**	**TDS(Mg/L)**	**DO (Mg/L)**	**NH_3 (Mg/I)**	**NO^-_3(Mg/I)**
Town green	20	9.1	567	673	689	513	7456	10	1.9	8
mean	19.9	9.06	436.8	414.6	527	359	3823	13.1	1.27	10

***Table 6.** Continued.*

S/N	11	12	13	14	15	16	17	18	19	20
PARAMETERS	**NO^-_2(Mg/I)**	**BOD(Mg/I)**	**COD(Mg/I)**	**PO^{3-}_4(Mg/I)**	**CU(Mg/I)**	**Ca(Mg/I)**	**Mg(Mg/I)**	**Fe(Mg/I)**	**Zn(Mg/I)**	**Faecal Coliform(Mg/I)**
WHO/CAM. STD	1	10	40	≤5	0.1	-	≤50	≤0.3	5	0
Meta qter	0.5	128	89	3.5	0.5	0.6	5	3	0.5	234
Kumba town	0.5	15	67	1.4	0.3	1	7	3	1	213
Total Junction/fiango	0.5	336	269	8	0.5	1	3	3	3	340
Buea Road	0.5	456	271	9	1	1	4	3	2	389
Town green	0.5	334	196	7	1	0.5	4	3	2	354
mean	0.5	254	178	5.8	0.66	1.82	4.6	3	1.7	306

3.3. Discussion

The results on tables 5 and 6 shows the physical, chemical and biological parameters of the studied river in both the wet and dry season, (2022-2023). The results further reveals that cations and anions concentrations are higher during the dry season compared with the wet season. To further show the impacts of urban activities on the Kumba river we used the Duncan's test as shown on table 7. The Duncan's statistical test was used because of its flexibility to compare means of groups and identify significant differences in water quality parameters of different areas with WHO standards as well as identify areas that need more attention in terms of water quality management. The Duncan's test results presented on table 7 presents the results of the chemical analysis of water samples to verify the link between the analyzed water quality values and the pollution of the Kumba river.

***Table 7.** Duncan's test on Physico-Chemical Analysis of Water Samples from Four Areas Compared with WHO Standards.*

Chemical Propriety	Buea Road	Meta quarter	Total Junction/fiango	Town green	WHO
Electrical conductivity (µS/cm)	505.25+43.56	705.59 +27.0	708.00+304.60	689.10+146.43	750 (µS/cm)
Temperature (oC)	19.85+2.36	24.9 + 3.59	26.00+2.75	27.53+1.31	15°C
Turbidity (Mg/L)	23.5+6.34	20.9 +15.9	24.77+11.34	48.57+3.31	1-5
pH	4.55+2.3	5.99 +1.92	8.37+0.48	6.43+1.63	5.5-8.5
Total dissolved solids (Mg/L)	685.85+50.13	630.59 + 330.9	921.43+54.90	903.43+79.58	500
Total suspended particles (Mg/L)	13.15+7.99	13.97+ 9.75	9.77+2.99	28.53+19.82	50
Chlorine (Mg/L)	248+55.7	369.9+293.9	395.53+209.56	568.43+126.46	200
Sulphate (Mg/L)	54+6.0	50.61+35.33	58.43+5.87	62.37+3.46	200
Phosphate (Mg/L)	39.0 +22.0	44.43+27.53	36.60+25.34	37.63+16.99	0.3
Nitrates (Mg/L)	23.9+21.52	37.10+24.51	35.77+12.50	22.43+8.06	50
Sodium (Mg/L)	157.9+37	172.67+113.16	173.90+67.41	229.77+40.60	200
Iron	4.9+2.5	3.68+3.23	3.57+1.35	4.39+0.69	0.3
E coli cfu/100ml	9.5+2.95	15.40+8.79	18.43+5.53	25.69+4.83	0
BOD (Mg/L)	37.0 + 34.0	43.99+33.04	39.97+24.61	36.83+14.74	10
COD (Mg/L)	15.9 +5.07	13.59+8.69	16.43+4.91	18.69+3.99	10-20
Total coliforms (cfu/100ml)	61.0 +47.23	10.99+6.76	68.50+50.49	88.50+35.61	0
DO (Mg/L)	7.0 +1.59	6.98+4.17	13.40+7.54	7.35+2.54	6

The means and SD with * are significantly different ($p < 0.05$), using Duncan's test
Source: field work, 2023

The results examined different aspects and resulted with significant differences.

Water volume reduction and high discharge of domestic wastes are two factors that can increase electrical conductivity due to the presence of organic contents and other particulate matter in the effluent that disintegrate into electrolytes. The results on table 5 reveals that, a strong positive correlation exists between electrical conductivity and TDS, likely as a result of the deposal and decay of organic wastes matter in the river channel. Higher levels of electrical conductivity suggest water pollution. The electrical conductivity values in the studied localities were below the WHO maximum permissible limit of 750 µs/cm, but they indicate pollution in the water samples. The results suggest that as water volume decreases and domestic waste increases, electrical conductivity increases, but the pollution may not have significantly affected the salt content. This result is similar to the findings [2, 8, 15, 16]. The results further reveal that, the temperature values ranged from 19.875+2.46 to 27.83+1.61°C in different areas, with the least values recorded in Buea Road segment and the highest in town green. The temperature values were generally within the WHO standard of 25°C, except for Buea Road which recorded a much lower results. According to the findings, the recorded temperature values remained below the maximum permissible limit set by the World Health Organization (WHO), which is below 40°C. also the findings reveal that, the turbidity values in Buea Road, Meta quarter, Total Junction/fiango, and Town green were far above the acceptable limits set by WHO. Buea Road had the highest turbidity with values of 22.75+6.48, while Meta quarter and Total Junction/fiango had values of 21.00+16.52 and 24.67+11.24, respectively. Town green had the highest turbidity value of 48.67+3.21. Overall, the results suggest that the turbidity values were far above the acceptable limits set by WHO, indicating a high level of pollution in the water samples. This results confirms the findings of [10, 17]. The ph in the same vein revealed that, the values ranged from 8.4+9.8 to 6.9+10, with Total Junction/fiango having the most basic value and Kumba town having the lowest at 6.9. The values were within the acceptable range set by WHO, despite notable variations in the recorded values. The pH levels observed are unlikely to result in acidosis or other related illnesses. [18]. The presence of microorganisms in the water may be due to various urban activities. As for the TDS, the values ranged from 685.85+50.13 to 903.43+79.58 mg/L, the results indicate that the TDS level at Town Green was the highest among the recorded values, while the lowest level was observed in Kumba town. During the rainy season, the results revealed notable disparities in the total dissolved solids (TDS) when compared to the permissible limits set by the World Health Organization (WHO), which range from 500 to 1000 mg/L. These findings imply that factors such as runoff, waste discharge, and various urban activities are contributing to the poor quality of the river water. This has also been reported by [2, 16].

To examine the association between urban activities and the alteration in the quality of Kumba river water, we employed the Pearson correlation coefficient on table 8. The Pearson's correlation coefficient test was preferred in the analysis of the Physico-Chemical analysis of water samples to determine the relationship between different parameters. This test can provide valuable insights into the water quality in the area and identify the crucial parameters that determine suitability for human consumption.

The chemical and biological results from the water samples also indicate variations in the water quality. Similar results were obtained in studies conducted by other authors, who also measured various parameters to assess water quality. a similar study conducted by [19] in the Buea municipality reported electrical conductivity values ranging from 42.4 µS/cm to 1668 µS/cm. They attributed the high values to surface runoff and leachate from contaminated sites.

Another study by [20] in the Buea municipality recorded pH values ranging from 4.24 to 8.43 in their water samples, which is similar to the pH values obtained in this study.

Similarly, the recorded turbidity values in this study are consistent with the values reported by [9, 19], who measured turbidity values ranging from 6.40 NTU to 53.60 NTU and 10.49 NTU to 58.70 NTU, respectively.

In regard to the chemical parameters, the total dissolved solids (TDS) values recorded in this study are comparable to the TDS values reported by [19], who measured TDS values ranging from 766.67 mg/L to 1230.54 mg/L in water samples from the Buea municipality.

Similarly, the recorded concentrations of nitrates and phosphates are similar to the values obtained by [21] in their study in Kumba, where they measured nitrate concentrations ranging from 12.25 mg/L to 44.00 mg/L and phosphate concentrations ranging from 0.40 mg/L to 4.95 mg/L.

Table 8. *Pearson correlation coefficient test on relationship between water quality variables.*

	EC (µS/cm)	Temp (oC)	Turb(Mg/L)	pH	TDS (Mg/L)	TSP (Mg/L)	Ch (Mg/L)	Sul (Mg/L)	Pho (Mg/L)
EC (µS/cm)	1								
Temp (^{o}C)	.897**	1							
Turb(Mg/L)	.727*	.817*	1						
pH	.901**	.941**	0.671	1					
TDS (Mg/L)	.839**	.949**	.850**	.921**	1				
TSP (Mg/L)	0.244	0.486	0.620	0.364	0.463	1			
Ch (Mg/L)	.711*	.824*	.933**	.731*	.860**	0.550	1		
Sul (Mg/L)	.825*	.918**	.842**	.860**	.975**	0.419	.849**	1	
Pho (Mg/L)	.857**	.911**	0.707	.814*	.847**	0.239	.741*	.897**	1
Nit (Mg/L)	.746*	.776*	0.523	.820*	.802*	0.073	0.700	.842**	.865**
Sod (Mg/L)	.820*	.934**	.929**	.831*	.955**	0.517	.942**	.967**	.890**
Iron	.832*	.831*	.801*	.755*	.886**	0.329	.740*	.953**	.871**
Eco/100ml	.783*	.879**	.937**	.823*	.900**	0.626	.970**	.854**	.721*
BOD_5 (Mg/L)	.910**	.742*	0.580	.750*	.729*	0.016	0.574	.797*	.852**
COD (Mg/L)	.849**	.950**	.881**	.875**	.984**	0.479	.846**	.985**	.885**
TS (cfu/100ml)	0.350	0.433	0.579	0.354	0.460	0.361	0.374	0.322	0.153
DO (Mg/L)	0.605	0.644	0.499	0.697	0.695	-0.122	0.596	0.606	0.574

	Nit (Mg/L)	Sod (Mg/L)	Iron	E co/100ml	BOD (Mg/L)	COD (Mg/L)	TS (cfu/100ml)	DO (Mg/L)
EC (µS/cm)								
Temp (°C)								
Turb(Mg/L)								
pH								
TDS (Mg/L)								
TSP (Mg/L)								
Ch (Mg/L)								
Sul (Mg/L)								
Pho (Mg/L)								
Nit (Mg/L)	1							
Sod (Mg/L)	.785*	1						
Iron	.759*	.898**	1					
Eco/100ml	0.662	.934**	.743*	1				
BOD_5 (Mg/L)	.798*	.730*	.882**	0.588	1			
COD (Mg/L)	.765*	.969**	.936**	.877**	.766*	1		
TS (cfu/100ml)	-0.095	0.386	0.269	0.484	0.059	0.460	1	
DO (Mg/L)	0.646	0.604	0.458	0.599	0.468	0.618	0.495	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: field work, 2023

The results of the correlation analysis on Table 6 shows that, a strong positive relationship between different urban activities and changes in the physico-chemical and biological characteristics of the water samples. The results suggest that these relationships could be used to control the rate of deposition of toxic wastes into the river. The study revealed a highly significant correlation between electrical conductivity and temperature, a very high relationship between electrical conductivity and turbidity, and significant relationships between electrical conductivity and pH, total dissolved solids, chlorine, and sulfate. Most of the variables were highly correlated with electrical conductivity, except for total coliform and total suspended particles. The correlation analysis indicates that human activities in the study sites have a direct impact on water quality parameters, leading to potential health risks for local communities. These risks include the increased likelihood of diarrhea and skin infections.

4. Conclusion

The study analyzed the relationships between land use patterns and water quality of the Kumba river. Samples were collected in both the dry and rainy season then laboratory tested for variations in their characteristics vis-à-vis urban land use and land cover within the metropolis. Urban land uses were found to have stronger relationships with water quality parameters as parametres such Electrical conductivity, total dissolved solids, and chemicals in the water were strongly correlated with at least one land use parameter and varied with seasons. Overall, all water quality parameters showed negative correlations with river flows, indicating that parameter concentration increases when river flow decreases. The study suggests that appropriate land use and water use management can modify water quality, particularly the dry season. Further investigations and complete spatial and temporal sampling are needed to better understand the complex relationship between land use and water quality in surface water.

Abbreviations

µS/cm: Micro-Siemens Per Centimeter
BOD: Biochemical Oxygen Demand
BOD: Biochemical Oxygen Demand
BUCREP : Bureau Centrale de Recensement et des Etudes de Population
Cfu: Colony Forming Unit
Cl: Chlorine
COD: Chemical Oxygen Demand
COD: Chemical Oxygen Demand
DDT: Dichlorodipheny-trichloroethane
DO: Dissolved Oxygen
EC: Electrical Conductivity
Fe: Iron
FAO: Food and Agricultural Organisation
HCl: Hydrogen chloride
KCC: Kumba City Council
KDH: Kumba district hospital
mg/l: Milligram per litre
ml: Milliliter
MgCl: Magnesium Chloride
Na: Sodium
NO_3: Nitrate
Nm: Nanometre
NTU: Nephelometric Turbidity Units
pH: Potential of Hydrogen
PO_4: Phosphates
TDS: Total Dissolved Solids
TSS: Total Suspended Solids
TDD: Tethramethyle-diamino-diphenylmethane
VSS: Volatile Suspended Solids
WHO: World Health Organization

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Conflicts of Interest

The authors declare no conflicts of interest.

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