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Evaluation of Four Anthropogenic Activity Impacts on Heavy Metal Quality of the Kumba River in the South West Region of Cameroon

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Abstract

Anthropogenic activities have contributed to pollution of water bodies through deposition of diverse pollutants amongst which are heavy metals. These pollutants, which at times are above the maximum concentration levels recommended, are detrimental to the quality of the water, soil and crops (plant) with subsequent human health risks. The objective of the work was to evaluate the impacts of human-based activities on the heavy metal properties of surface water with focus on the Kumba River basin. Field observations, interviews, field measurements and laboratory analyses of different water samples enabled us to collect the different data. The results show four main human-based activities within the river basin (agriculture, livestock production, domestic waste disposal and carwash activities) that pollute surface water. Approximately 20.61 tons of nitrogen and phosphorus from agricultural activities, 156.48 tons of animal wastes, 2517.5 tons of domestic wastes and 1.52 tons of detergent from carwash activities were deposited into the river each year. A highly significant difference at 1% was observed between the upstream and downstream heavy metal loads in four of the five heavy metals tested except for copper that was not significant. Lead concentrations were highest in all the activities with an average of 2.4 $mg \cdot L^{-1}$ representing 57.81%, followed by zinc with 1.596 $mg \cdot L^{-1}$ (38.45%) and manganese with 0.155 $mg \cdot L^{-1}$ (3.74%) for the different anthropogenic activities thus indicating that these activities highly lead to pollution of the Kumba River water. The level of zinc and manganese was significantly influenced at $\rho < 005$ by anthropogenic activities though generally the variations were in the order: carwash (3.196 $mg \cdot L^{-1}$) < domestic waste disposal (3.347 $mg \cdot L^{-1}$) < agriculture (4.172 $mg \cdot L^{-1}$) < livestock (4.886 $mg \cdot L^{-1}$) respectively and leading to a total of 14.04 tons of heavy metal pollutants deposited each day.

Keywords

Metal Properties, Human-Based Activities, Kumba River Basin, Surface Water

1. Introduction

Surface water sources especially the Kumba River are at the core of most anthropogenic activities within the Kumba River basin. Unfortunately, these activities tend to negatively affect the river water quality especially through heavy metal contaminations. Although rivers and streams account for a tiny amount of the total surface freshwater, they are not only a precious source of drinking water for people across the world, but also support growing crop, manufacturing, energy, transport, and natural habitats for many other organisms [1]. Agricultural activities use approximately 70% of this total freshwater consumption around the world and are a major contributor of non-point source pollution to aquatic environments [2]. Despite its importance, water from the different sources for over the years has been responsible for about 5% of death in low-income countries due to unsafe sanitation and poor water quality [3] that leads to several infectious diseases [4]. More and more surface water is significantly polluted all around the world, while the global demand for freshwater is estimated to increase by one-third by 2050 [5]. This deterioration of surface water bodies makes its evaluation a priority in order to control and mitigate the level of risk [6]. One of the main targets of Cameroon's vision 2035 is to intensify adaptation and mitigating measures against the effects of environmental management to ensure economic growth as well as sustainable and inclusive development.

Anthropogenic (industrial, agricultural and domestic) activities, considered as major reasons for this environmental degradation, are putting substantial pressure on the aquatic ecosystem [7]. The development of human activities without control on the environment is affecting human health and aquatic systems thereby causing irreversible changes [8]. A major environmental problem is the heavy metal contamination of surface water and soils [9]. Although heavy metals like Cu, Fe, Mn and Zn are considered useful micronutrients to plants [10], they become dangerous when they exceed the safety limits and can cause severe health hazards in humans [11]. With increasing anthropogenic activities, these biologically or chemically non-degradable metals in the environment [12], accumulate in the soils reaching dangerous concentrations over time [13]. This has led to growing global concern over the potential accumulation of heavy metals in agricultural soils due to rapid urban and industrial development and increasing reliance on agrochemicals [14]. Extensive application of pesticides and inorganic fertilizers as well as antibiotics, and organic wastes in livestock and fisheries have been proven to contribute greatly to heavy metal contamination in soils, surface water as well as ground water leading to deterioration of soil and water qualities

[15]. Seventy-three percent of active Cameroonians, in a population of over 26 million, are employed in the agricultural sector where farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies thereby posing demonstrated risks to aquatic ecosystems, human health and productive activities [2]. On average, less than 50% of domestic sewage in developing countries is not treated properly before discharging into receiving rivers and other surface waters, which can pose a high risk for both aquatic life and public health [2]. This is dangerous, considering that foods containing heavy metals when consumed can lead to several health damages ranging from infertility, coronary diseases, kidney failures, and respiratory problems [16].

The Kumba River basin is amongst the many river basins in Cameroon with a variety of services offered to the local population (agriculture, livestock production and butchery, carwash and motor mechanics, as well as laundry). This basin, where a lot of anthropogenic activities that pollute surface water bodies are carried out, has witnessed a constant production and dumping of wastes from diverse categories and origins aggravated by an influx of people due to internal displacement from the sociopolitical crisis plaguing the southwest region of Cameroon during the study period. Within the river basin, the water from these surface water bodies is used in the production of both crops and animals while others use it for laundry, as carwash points and in motor mechanic workshops. Among the pollutants within the area are heavy metals considered harmful to human health. Studies have related the presence of cadmium to the use of phosphorus fertilizers [17] [18] widely used in Cameroon. Most empirical studies [19] have focused on the different management practices and constraints that limit farmers from producing quality cocoa. Though they found out that farmers' management practices had a positive and significant relationship with cacao beans quality, nothing was done to verify the presence of heavy metals in other sources like water and the soil as well as agents of contamination in a bit to eliminate the presence of these dangerous heavy metals. The objective of the work was to evaluate the impacts of identified human-based activities on heavy metal properties of surface water with special focus on the Kumba River basin.

2. Materials and Methods

2.1. The Study Area

The study was carried out in the Kumba River basing where the river flows from its source (Lake Barombi Mbo) through a forest to Kumba Town area where most anthropogenic activities that pollute the river water begin to Barombi Kang where the river exits Kumba covering a distance of 11 km. The basin is located between longitudes 9˚23'' and 9˚29'' east of the Greenwich Meridian, and Latitudes 4˚36'' and 4˚40'' north of the Equator along the Cameroon volcanic line at the northwestern edge of the Douala Basin. Kumba has a hot and humid equatorial climate with two seasons: a short dry season of about 4 months (December to March) and a long rainy season (April to November). Annual rainfall ranges from 2298 mm to 3400 mm with an approximate average annual temperature of 27˚C. A wide variety of soils exist in the river basin including: Kumba Town; gravelly soils (brick red) around Buea Road; and laterites (brick red) in almost every part of the town [20].

In the basin, there are carwash points, farms, cattle slaughter house, motor mechanic workshops, piggeries and poultries, etc.

2.2. Determination and Assessment of Human-Based Activities and Their Impact on Water Quality

The rapid assessment method for evaluation of the weighted contribution of anthropogenic pollution developed by [21] was used to collect both qualitative and quantitative data on demographic situation and human activities within the Kumba River basin through interviews, discussions, observations and weighing of samples. The area along the Kumba River bed was divided into five sections/zones and 60 respondents were randomly chosen per section for a total of 300 respondents based on the proximity of their residence to the river and the length of time spent within the area. Only inhabitants who lived within 100 m away from streams and the Kumba River on both sides (where most activities take place) and who had spent at least one year at the time of data collection were considered. The most important human-based activities that polluted the Kumba River and streams were evaluated amongst the identified activities within the study area and classified into major groups described by [22] and the most groups considered for further analysis.

2.3. Estimation of the Pollutants Load Generated by Each Activity

2.3.1. Motor Mechanic/Carwash (Industrial) Activities

Site observation and discussions with carwash point owners enabled us to identify the carwash points along the river bank, the types and amounts of detergents they used when cleaning the cars and where they disposed of the wastewater. The record books were consulted to estimate the mean number and types (sizes) of vehicles washed per day. The contents of the detergents were gotten from the manufacturer information on the labels. To determine the level of contamination of the river water through washing of vehicles at carwash points, the quantity of each element contained in the detergent used $\left(Qe_i\right)$ and the total daily contamination of the river water due to carwash activity $\left(C_{cw}\right)$ was calculated based on Equations (1) and (2) developed by Nkobe in 2024.

$$Qe_i = \sum_{i=1}^{n}\left[\omega * \frac{e_i}{100}\left(aX + bY + cZ\right)\right] \quad (1)$$

$$C_{cw} = \sum_{e=1}^{e=n}\left(Qe_i\right) \quad (2)$$

where:

Qe_i = quantity of pollution per element in detergent type;

ω = weight of a packet of detergent;

e_i = proportion of elements contained in the detergent type;

a, b, c = average numbers of vehicle type 1, 2, 3 washed per day;

X, Y, Z = proportions of detergent packet used in washing vehicle types 1, 2, 3.

2.3.2. Livestock Production and Butchery Activities

The pollutant loads generated from livestock fences were estimated based on the common operational practice of animal rearing. The remains from animal feed as well as the feces were weighed daily with a scale balance and the volume estimated with a bucket whose volume is known and initial weight (W_1) estimated. The empty bucket was then filled with the remains, reweighed (W_2) and the difference in weight ($W_2 - W_1$) noted (representing the weight and volume of the remains). The same procedure was repeated for wastes from slaughtered animals. The wastes weight and volume were converted per fenced and slaughtered animal, and used as a unit to extrapolate for the number of animal types censored along the river bed.

2.3.3. Solid Wastes Disposal

A total of 5 inhabitants per river basin section for a total of 5 sections (25 persons) ready to deposit their wastes were intercepted and the wastes sorted and weighed followed by questioning on the frequency of deposition and the household sizes. The average of these wastes per person was used to extrapolate for the total population of the study area. Then dumps of wastes along the river bed were sorted, estimated, categorized and classified.

2.3.4. Agricultural Activities

The surface area of the river basin and areas occupied by different crops grown were estimated using a Garmin GPS and the farmers questioned on the use of inorganic fertilizers and pesticides, the types and quantity of fertilizers applied, and frequency of application. The produce obtained per year were weighed per unit area and extrapolated. Water samples were collected at each tributary leading to the Kumba River and tested for their physicochemical properties. Calculation of Total Nitrogen (TN) and Total Phosphorus (TP) loads was based on the fertilizers (N, P) quantities required for crop production within the limits of the drainage system and estimation of the losses of these fertilizers into the drainage network. TN and TP losses [$TN_{leaching}$ and $TP_{leaching}$ (kg N/ha/year)] through soil leaching were calculated using the regression model developed by De Willigen [23] shown in Equations (3) and (4).

$$TN_{leaching} = \left(0.0463 + 0.0037\left(\frac{P}{C * L}\right)\right) * \left(N_f + \alpha * N_{om} - N_u\right) \quad (3)$$

$$TP_{leaching} = \left(0.0463 + 0.0037\left(\frac{P}{C * L}\right)\right) * \left(P_f + \alpha * P_{om} - P_u\right) \quad (4)$$

where,

P is the annual precipitation (mm/year);

C is the clay content (%);

L is the layer thickness or rooting depth (m);

N_f and P_f are the minerals and manure TN and TP (kgN/ha);

α is the decomposition rate;

N_{om} and P_{om} are the amounts of TN and TP in soil organic matter (kg N/ha).

N_u and P_u are the TN and TP uptake by harvested crop and crop residues removed from the field (kg N/ha per year).

The following values were used for each variable shown in Equations (3) and (4):

1) An annual precipitation of 3000 mm [24] and an average clay content of 42.3% [25] were used in subsequent calculations.

2) The Nitrogen and Phosphorus in soil organic matter were calculated using Equations (6) and (7) by De Willigen [23]

$$N_f = \rho * L * TN \text{ in soil} \tag{5}$$

$$P_f = \rho * L * TP \text{ in soil} \tag{6}$$

where ρ is the bulk density (kg/m^3) of the soil. The bulk density used in subsequent calculations is 1790 kg/[26], while the total TN concentration and total TP in soils in cacao farms within the study area are 0.00004 kg N/kg and 0.00006 kg P/kg, respectively [25].

3) The decomposition rate in Equations (3) and (4) for nitrogen is assumed to be 1.6% per year [23], and for phosphorus, is assumed to be 1.9% per year [27]. The total fertilizer used per unit area of crops was obtained from Food and Agriculture Organization (FAO) report of 2005 [28] where fertilizer consumption is expected to have been increased by about 30% since 2004. [29] stated that well-decomposed Farm Yard Manure (FYM) may contain nitrogen from 1.2% to 2.0% and phosphorus from 0.5% to 0.7%. The amounts of nitrogen and phosphorus applied to each crop from FYM were calculated by multiplying the amount of FYM by 0.02 and 0.007, respectively. The amounts of nitrogen and phosphorus in FYM application were calculated using Equations (7) and (8).

$$TN \text{ in FYM}(\text{t/ha}) = \text{Total amount of FYM applied}(\text{t/ha}) * 0.02 \tag{7}$$

$$TP \text{ in FYM}(\text{t/ha}) = \text{Total amount of FYM applied}(\text{t/ha}) * 0.007 \tag{8}$$

2.4. Collection and Preparation of Samples and Analysis

The monitoring was carried out over a period of eight months within two climatic seasons (rainy and dry seasons). Ten sampling stations were identified in total within the five sections of the river basin (one station situated at 10 m upstream and another 10 m downstream of the anthropogenic activities within each section). Water samples were collected using the method described by [30]. Three water samples were collected at each point (one on each side of the river close to the banks and one in the middle) in 50 cl acid-washed high density polyethylene (HDPE) bottles. Each sample was collected at a depth of 20 - 50 cm below the water table. The samples were bulked, labeled and stored at < 4˚C in a flask containing ice blocks before onward transportation to the soil and water science laboratory of University of Dschang in Cameroon where analysis was carried out. These water samples were collected during three different periods of the year (dry season, end of dry season/beginning of the rainy season, and during the heavy rainy season) for a total of 30 water samples. Soil samples were collected at 5 different points along transects within agricultural activity sites during the farming period at 0 - 25 cm, air-dried and homogenized (bulked) after passing through a 2 mm sieve to form a sample for analysis.

The analytic methods used to determine heavy metals content in samples complied with the procedures and methodologies recommended by the American Public Health Association notably atomic absorption spectrometry [31]. All samples of water were digested in the presence of aqua regia (mixture of concentrated nitric acid HNO_3 with hydrochloric acid HCl (1:3)) overnight at room temperature. Then, the mixture was boiled for 2 hours according to the standard method NF ISO 11466 [32]. After cooling, the digested samples were filtered using membrane (0.45 mm), the filtrate was diluted to 50 mL with de-ionized water and kept at room temperature for further analysis. Determination of the heavy metals in the filtrate of samples was achieved by using UNICAM Atomic Absorption Spectrophotometer (AAS). The standard solutions were prepared by diluting a stock solution containing 100 ppm of single element AAS grade standard with distilled water. The standard solutions for the heavy metals were used to construct the calibration curves with the help of AAS. The AAS was calibrated for all the metals by running different concentrations of standard solutions. Average values of three replicates were taken for each determination. All glassware was acid-washed using 10% nitric acid before use.

2.5. Estimation of Kumba River Flow Rate

The width of the river and streams within the river basin was measured at three points along each section of the river or stream. The width was segmented at 1 m distance and the different heights of the water in the segments of the river or stream were measured. The Simpson’s rule [33] was used to determine the cross-sectional area of the drains, while the floating method (through a floater placed on the river bed and allowed to float through a predetermined distance three times whose times in seconds have been noted with a stop watch and the average calculated) was used for the flow speed. To have the flow, speed was simply multiplied by the cross-sectional area obtained through the Simpson’s rule.

2.6. Assessment of the Effect of Anthropogenic Activities on Heavy Metal Quality on the River

The difference in heavy metal loads between upstream and downstream values indicates the contribution of anthropogenic activities. As a measure to control pollution of the river water, the anthropogenic origins of heavy metals were identified and their contributions on river water quality evaluated. The heavy metal concentrations of the river resulting from anthropogenic activities were compared with the maximum concentrations that support aquatic life.

2.7. Statistical Analysis

The Student t-test enabled us to determine the levels of significance between the upstream and downstream pollutions while Analysis of Variance (Tukey test) permitted us to assess the level of significance amongst the anthropogenic activities and amongst the heavy metals.

3. Results

3.1. Human-Based Activities within the River Basin

Farming dominated the activities carried out within the basin (23%) followed by trading (22%), domestic solid waste disposal (19%), livestock production (17%), car washing (10%), motor mechanic (6%) and butchery activities (3%). It should be noted that 28% of respondents carry out their different activities alongside livestock production like pigs. There is a cattle market at the Buea road especially on every Wednesday. Also close to this cattle market are two butchering houses where animals are killed on a daily basis, with the blood and other by-products emptied into the Kumba River and streams. The different human activities taking place along the banks of the Kumba River (**Figure 1**) vary from one section of the river watershed to another.

3.2. Estimates of the Pollutants Load Generated by Each Activity

3.2.1. Pollutant Load Generated by Carwash Activities

Then mean number of automobiles washed per day in the three main carwash points directly linked to the Kumba River and its tributaries were identified within the study area (denoted CW1, CW2 and CW3 respectively). The three carwash points received an average of 248 automobiles per day 65 of which are cars, 5 are trucks and 178 motorcycles. The ingredients that constitute a sachet of detergent used in washing the automobiles include anionic surfactant, sodium tripoly phosphate, sodium percarbonate, sodium carbonate, sodium silicate, carboxy methylcellulose and sodium sulphate. These elements are in the proportions (e_i): surfactants (30%), sodium (20%), carbonate (20%), phosphate (10%), sulphate (10%) and silicate (10%) respectively. The following were used for the calculations: a = 5, X = 2.5, b = 65, Y = 1, c = 178, Z = 1/2, ω = 25 g, respectively.

The level of contamination of the river water by the detergent through washing of vehicles at carwash points estimated using Equations (1) and (2) are expressed in **Table 1**

A mean daily contamination of the Kumba River by detergent used in washing these automobiles stands at 4.163 kg/day though the element contaminations ranged from 0.416 kg to 1.249 kg. Anionic surfactant was highest (1.249 kg/day

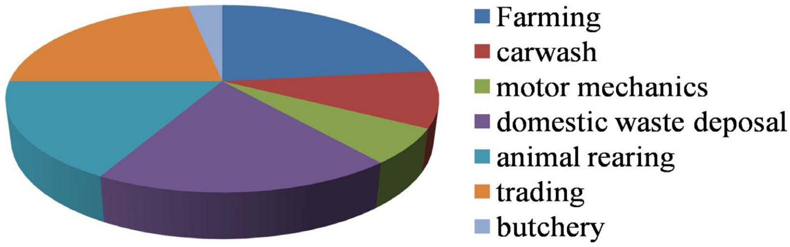


Figure 1. A proportional representation of different activities within the Kumba River basin.

Table 1. Level of contamination of Kumba River water by detergent at carwash points within the study area.

Qei	Level of detergent contamination		
	Mean Daily quantity	Mean Weekly contamination	Mean Yearly contamination
Surfactant (kg)	1.249	8.743	454.636
Sodium (kg)	0.833	5.831	303.212
Carbonate (kg)	0.833	5.831	303.212
Phosphate (kg)	0.416	2.912	151.606
Sulphate (kg)	0.416	2.912	151.606
Silicate (kg)	0.416	2.912	151.606
Total	**4.163**	**29.141**	**1515.878**

corresponding to 454.636 kg/year) followed by sodium and carbonate depositions (0.833 kg/day corresponding to 303.212 kg/year each) and then phosphate, sulphate and silicate respectively with 0.416 kg/day (corresponding to 151.606 kg/year) each. Extrapolating the detergent contamination of the river, it can be seen that a total of 1.52 tons of detergent is deposited into the river yearly from carwash activities within the study area.

3.2.2. Pollutant Load Due to Agricultural Activities

Crop cultivation is practiced on a total of 58.18 hectares of land out of the 200 ha considered for the study: 25.11 ha in Kumba Town area, 8.52 ha in Metta quarter and Ntoko street area, 6.51 ha in Preventive and Lower Fomenky area, 8.96 ha in Kumba Mbeng area and 9.08 ha in Danny Cash area while the remaining 141.82 ha of the river basin is occupied by habitats and forest. The majority (45.7%) of the farmland is occupied by maize followed by plantain (14.9%), vegetables (11.9%), cassava (11.7%), cocoa (11.1%) and yam (4.7%). Vegetables grown involve African leafy nightshade locally known as huckle berry or njamanjama (*Solanum scabrum*), amaranths locally referred to as green or folong (*Amaranthus* spp), waterleaf (*Talinum triangulare*), pumpkin leaves (*Curcubita maxima*) and bitterleaf (*Vernonia amygdalina*). Different crop types are grown within the study area and the surface areas occupied are summarized in **Table 2**. From discussions held with the over 79 farmers met on their farms within the defined

Table 2. Surface area occupied by different crop types grown within the study area.

Crop type cultivated	Surface area occupied by crops within identified areas (ha)					Total area occupied by crop
	KTA	MQ/NSA	PA/LFA	KMA	DCA	
Maize	12.34	3.40	2.87	4.94	3.01	26.56
Vegetables	1.08	2.05	1.43	1.14	1.20	6.90
Cassava	3.89	0.76	0.25	1.07	0.85	6.82
Plantain	2.55	1.88	1.65	1.33	1.26	8.67
Yam	1.03	0.43	0.31	0.48	0.51	2.76
Cocoa	4.22	0.00	0.00	0.00	2.25	6.47
Total	25.11	8.52	6.51	8.96	9.08	58.18

KTA = Kumba Town Area, MQ = Metta Quarter, NSA = Ntoko Street area, PA = Preventive Area, LFA = Lower Fomenky Area, KMA = Kumba Mbeng Area, DCA = Danny Cash Area.

study area (100 m wide on both sides of the river), only two out of the six crop types cultivated receive fertilizer application (maize and vegetables).

However, only maize received inorganic fertilizer (NPK 20-10-10 and urea) at an average rate of 225 kg·ha^{-1} while vegetables received organic fertilization from farm yard manure like cow, pig and fowl dung at an average rate of 25 t·ha^{-1}. However, due to the Russian-Ukraine war, only 47.9% of the total maize area received fertilizer during the period of data collection. Also, the farmers attest using herbicides to weed their farms before cultivation and to suppress grass in some farms like cocoa and plantain farms sprayed four times a year. Total nitrogen and phosphorus content in the soil (Table 3) were 12.17 tons and 8.44 tons respectively. Of this quantity, 41.74% (5.08 tons) of TN and 29.74% (2.51 tons) of TP found in the soil within the Kumba River basin leached into the river. These amounts are high and thus may partially account for the overgrowth of algae and water plants (eutrophication) registered within the study area.

3.2.3. Pollutant Load Due to Livestock Production and Butchery Activities

Many pig styles, poultries and cow butchery houses exist within the study area but a few are stationed close to the Kumba River. Table 4 summarizes the type and number of livestock linked directly to the river.

A total of 596 animals were censured within the 8 months of the study period, 84 of which are pigs while 512 cattle were slaughtered cattle (4 per day for 4 days per week and 32 weeks of the study) where 156.48 tons of their wastes and wastewaters were deposited into the Kumba River. The Kumba Mbeng area deposited the greatest proportion of animal wastes in the river followed by Danny Cash Area.

3.2.4. Pollutant Load Due to Domestic Waste Disposal Activities

The waste dumps according to origin of the wastes, the type of wastes and number

Table 3. Fertilizer application rates on agricultural land within the Kumba River basin.

Crop	Area	Rate of fertilizer (kg/ha)	% fertilizer applied	Qty of fertilizer (kg/ha)		Total (tons) in soil		Total leached in tons	
				N_f	P_f	TN_{soil}	TP_{soil}	TN_{lea}	TP_{leac}
Maize	26.56	225	47.9	112.5	56.25	8.88	3.76	2.71	1.84
Huckle berry	4.14			500	175	1.69	1.51	1.60	0.35
amaranth	1.38	25 tons of farm yard manure	2 for N and 0.7 for P	500	175	0.56	0.50	0.53	0.12
Waterleaf	0.48			500	175	0.20	0.17	0.19	0.04
Cassava	6.82					0.55	1.61	-	-
Yam	2.76	100 tons of FYM	2 for N and 0.7 for P	2000	700	0.22	0.65	0.04	0.13
Cocoyam	0.96					0.08	0.23	0.01	0.03
Total						12.17	8.44	5.08	2.51
Percentage leached into river (%)								41.74	29.74

Table 4. Estimates of livestock wastes deposited in the Kumba River during the study period.

Livestock type	Livestock wastes deposited into the Kumba River water (in tons) within 8 months of study					Total livestock reared or butchered
	KTA	MQ/NSA	PA/LFA	KMA	DCA	
Piggery 1	5.472	6.384	4.560	3.648	2.736	25
Piggery 2	2.736		3.648	7.296	13.680	30
Piggery 3			2.736		23.712	29
Butchery 1				39.936		256
Butchery 2				39.936		256
Total livestock	8.208	6.384	10.944	90.816	40.128	596

of waste dumps per area within the study area are summarized in **Table 5**. On average, about 15.2 kg of wastes per household of 4 persons giving approximately 9.5 tons (7.126 m^3) of wastes generated by the over 2500 inhabitants of the river basin and deposited into the river daily for a total of 2517.5 tons (1888.125 m^3) per year. According to estimates, approximately 41.58 tons (31.186 m^3) of wastes were found deposited along the banks of the river with about 5.3% increase daily for a potential waste deposition of 625.57 tons (469.178 m^3) per year.

3.3. Kumba River and Its Flow Rate

The cross-sectional area of river varied from 3.262 m^2 with flow velocity of 0.18 m/s leading to a flow rate of 0.58716 m^3/s (35.2296 m^3/h or 845.5114 m^3/day) during the dry season to a cross-sectional area of 20.447 m^2 with a flow velocity of 0.32 m/s leading to a flow rate of 6.54304 m^3/s (23554.944 m^3/h and 565318.656 m^3/day respectively) during the wet season. At the moment of water sample collection, the cross-sectional area was 10.9633 m^2 with a flow velocity of

Table 5. Estimates of solid wastes dumped into and along the banks of the Kumba River within the study area.

Waste dump	Unit of measurement	Estimate of domestic waste dumps along the bank of the Kumba River (weight in tons and volume in m^3)					Total waste dump weight and volume
		KTA	MQ/NSA	PA/LFA	KMA	DCA	
Dumps along bank	Weight	12.020	4.380	16.230	4.750	4.200	41.58 t
	Volume	9.015	3.285	12.173	3.563	3.150	31.186 m^3
Dump into river	Weight	2.702	1.043	3.620	1.126	1.009	9.5 tons/day
	Volume	2.027	0.782	2.715	0.845	0.757	7.126 m^3

0.26 m/s leading to a flow rate of 2.8505 m^3/s corresponding to 10261.68 m^3/h and 246280.32 m^3/day respectively.

3.4. Effects of Anthropogenic Activities on Heavy Metal Concentration

Generally, the results suggest that anthropogenic activities contribute to pollution of the river water (Figure 2). Average pollutant load differences of 4.170 $mg·L^{-1}$, 4.887 $mg·L^{-1}$, 3.347 $mg·L^{-1}$ and 3.196 $mg·L^{-1}$ between upstream and downstream measurements for agricultural, livestock production, domestic waste disposal and carwash/motor mechanic activities respectively were registered though the difference varied from one sampling site to another.

From the Student t-test carried out between upstream and downstream anthropogenic activity sites, a highly significant difference at 1% ($|t| = 19.93$) was observed between the upstream and downstream heavy metal loads amongst the four anthropogenic activities within the study area. This indicates that these activities highly lead to pollution of the Kumba River water. The order of contaminations (Figure 3) was livestock production > agriculture > domestic waste disposal > carwash/motor mechanic activities. On average, each anthropogenic activity contributed to an increment in pollutant load of 3.90025 $mg·L^{-1}$ leading to a total of 15.601 $mg·L^{-1}$ brought into the river through the four anthropogenic activities.

3.5. Variation of Individual Heavy Metal Loads Due to Anthropogenic Activities

Lead produced the highest pollutant load for all the anthropogenic activities in the Kumba River within the study period followed by zinc and manganese. No change was also observed in copper. Figure 4 presents the detailed variations of the different heavy metals tested resulting from anthropogenic activities.

Highly significant differences at 1% significance level were observed from upstream to downstream each anthropogenic activity site in the individual heavy metals except for copper in which no change was registered. These differences indicate that all the anthropogenic activities highly lead to pollution of the Kumba River. Considering the different anthropogenic activities (Figure 5), the manganese pollution was in the order: carwash > livestock > agriculture > domestic activities; for Iron pollution: domestic > agriculture > livestock = carwash

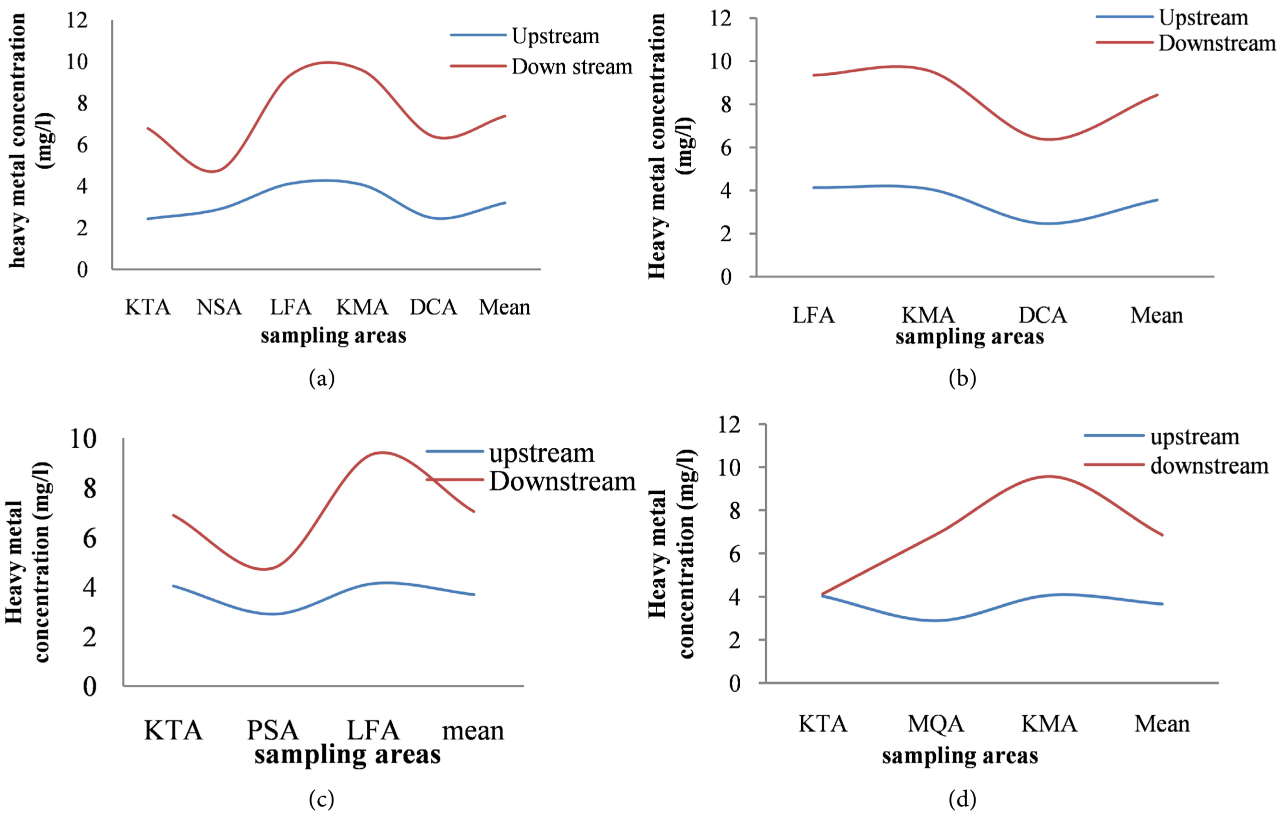


Figure 2. Effect of anthropogenic activities on heavy metal load of the Kumba River water. a = agriculture activities, b = livestock activities, c = domestic waste disposal activities, d = carwash and motor mechanic activities.

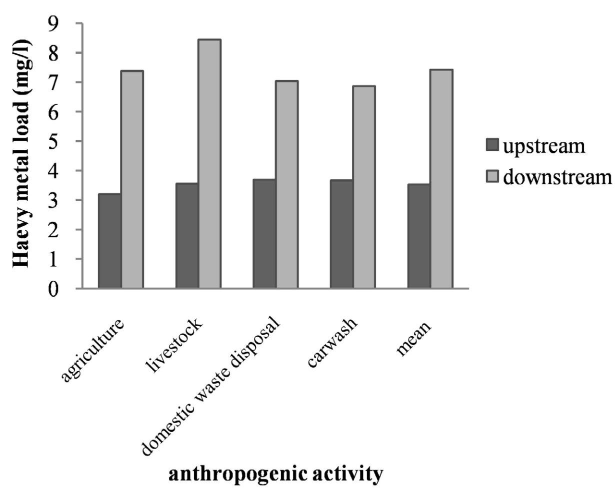


Figure 3. Heavy metal pollution of Kumba River by anthropogenic activities.

activities; for zinc pollution: livestock > agriculture > carwash > domestic activities; and finally for lead: livestock > agriculture > domestic wastes > carwash activities.

Livestock production sites produced the highest heavy metal pollutant load (Table 6). Generally, the human-based contaminations were in the order:

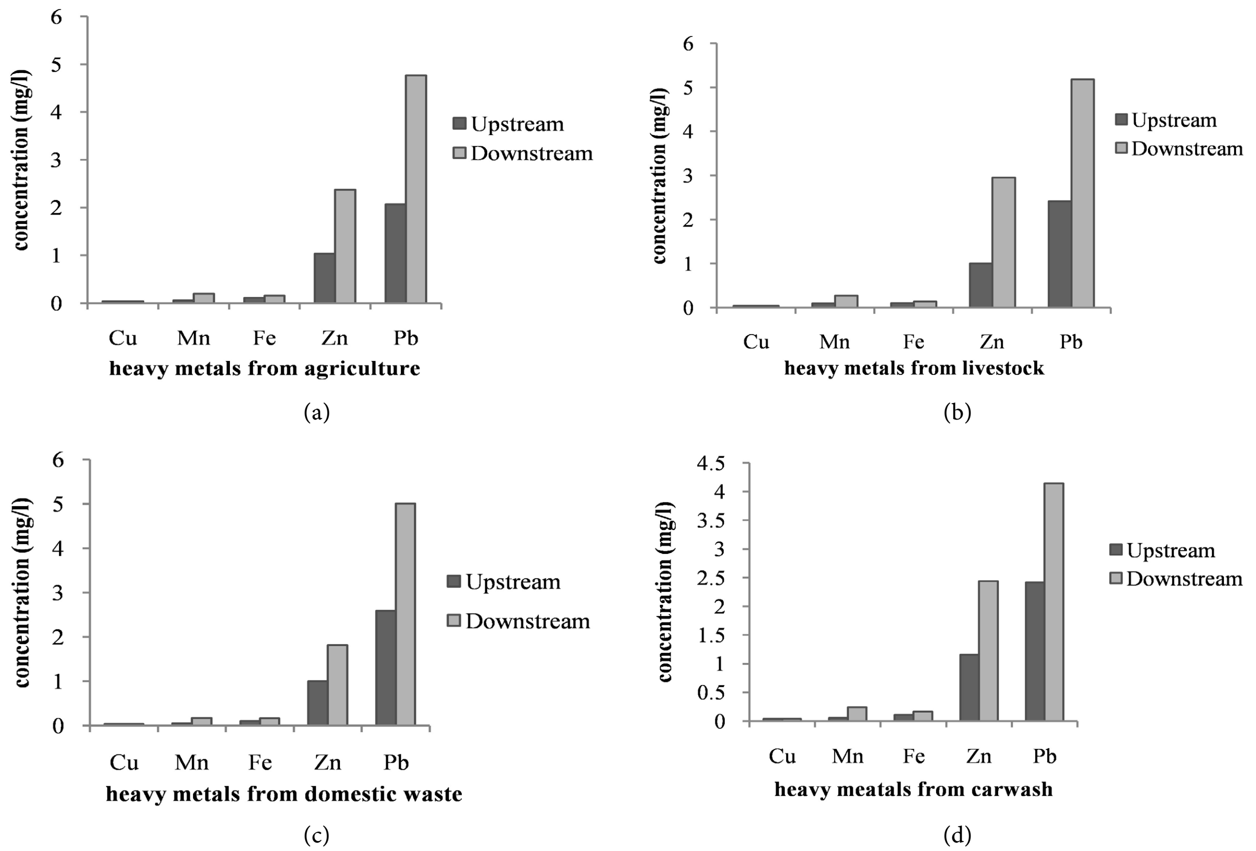
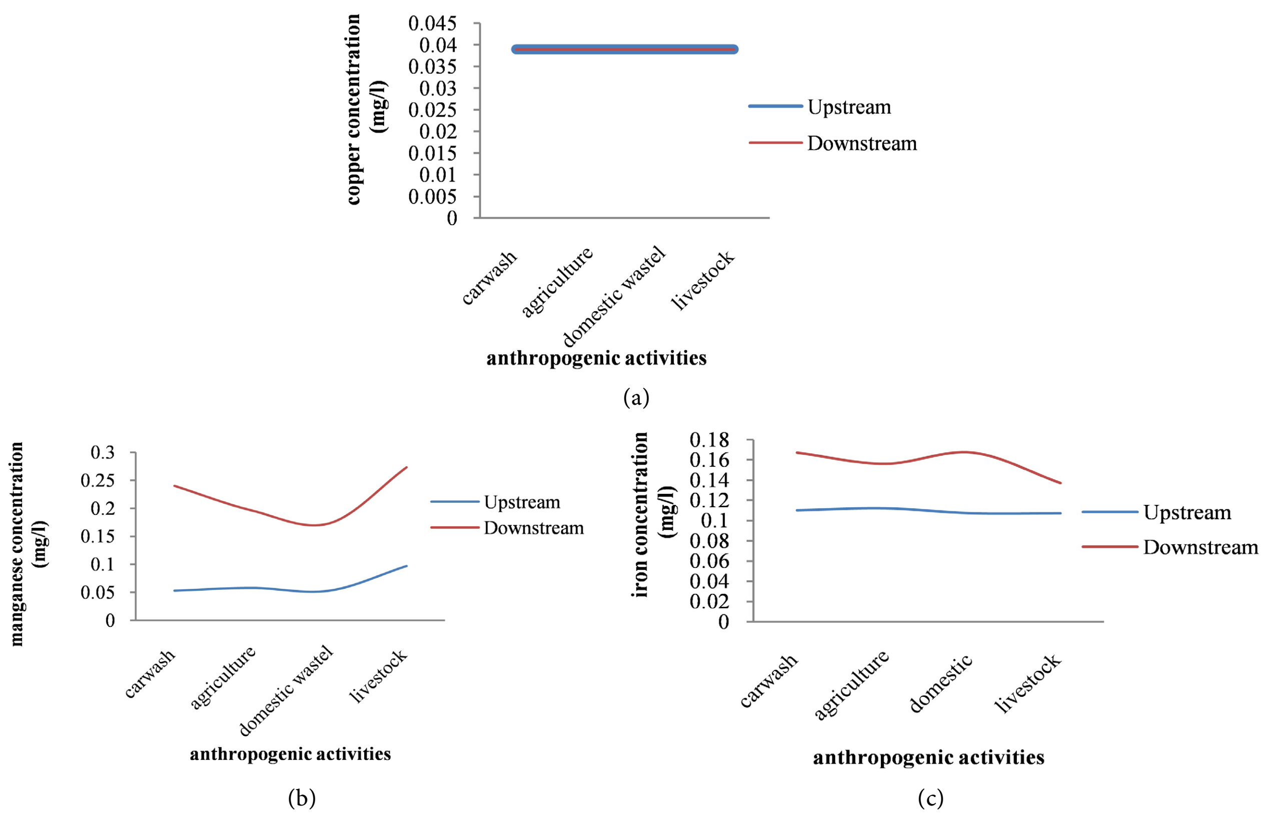


Figure 4. Individual heavy metal load in Kumba River resulting from anthropogenic activities.



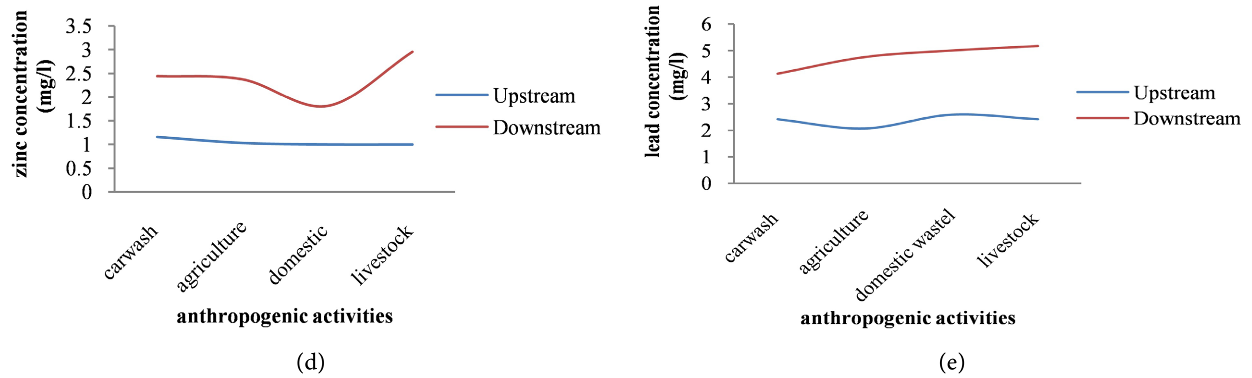


Figure 5. Individual heavy metal pollution of the Kumba River by anthropogenic activities.

Table 6. Increment in heavy metal concentrations of the Kumba River due to anthropogenic activities.

Anthropogenic activity	Change in heavy metal content of water samples (mg·L^{-1})					Total pollutant (mg·L^{-1})
	Zn	**Cu**	**Mn**	**Pb**	**Fe**	
Agriculture	1.340	0.0	0.138	2.694	0.045	4.217
Livestock	1.950	0.0	0.176	2.760	0.04	4.890
Domestic waste	0.810	0.0	0.120	2.417	0.07	3.354
Carwash	1.283	0.0	0.187	1.726	0.04	3.200
Total	6.383	0.0	0.621	9.597	0.195	**15.796**
Mean per activity	1.596	0.0	0.155	2.400	0.049	**3.949**
Percentage change (%)	149.5	0.0	203.6	92.8	31.7	
MCL to support aquatic life	**0.0766**	**0.1**	**/**	**0.0058**	**0.20**	
MCL for irrigation water	**2.0**	**0.2**	**0.20**	**5.0**	**5.0**	

carwash (3.2 mg·L^{-1}) < domestic waste disposal (3.354 mg·L^{-1}) < agriculture (4.217 mg·L^{-1}) < livestock production (4.89 mg·L^{-1}) of heavy metal load respectively. However, considering the individual heavy metal loads, Lead (Pb) produced the highest pollution level (9.597 mg·L^{-1}) followed by Zinc (Zn) with 6.383 mg·L^{-1}, Manganese (Mn) with 0.621 mg·L^{-1} and Iron (Fe) with 0.195 mg·L^{-1} respectively. The concentration of copper (Cu) remained constant at 0.039mg/l along the river bed. This suggests that little or no human-based activity that leads to deposition of copper is taking place within the different areas in question. The order of increment of heavy metals due to anthropogenic activities is Cu (0%) < Fe (31.7%) < Pb (92.8%) < Zn (149.5%) < Mn (203.6%). Considering the individual anthropogenic activities, the increment in Pb concentrations were highest in all the activities with an average of 2.4 mg·L^{-1} followed by Zn (1.596 mg·L^{-1}) and Mn (0.155 mg·L^{-1}) respectively. Combining these results to the daily volume of the river, a total of 14.04 tons of heavy metals are deposited each day, 57.81% of which is lead, 38.45% of zinc and 3.74% of manganese respectively. The concentrations of zinc and lead from the different anthropogenic activities were generally above the maximum concentration levels of 0.0766 mg·L^{-1} and 0.0058 mg·L^{-1} respectively to support aquatic life thus partially accounting for the lack of fish production within the river.

4. Discussion

Human-based activities have accounted for the degradation of water quality in the world. [34] in their study on the impact of anthropogenic activities on surface water quality in Ecuador showed poor water quality, which may be due to several natural phenomena and anthropogenic activities that occur along the river bed, and which coincides with the results obtained in this present study. Generally, driven by the need to survive, alleviate poverty, unemployment, lack of means to start a business and educate children as well as heavy expenses at social programs, four main anthropogenic activities were identified within the study area that result to pollution of the surface water's physicochemical quality. These included agriculture, livestock production and butchery, domestic activities as well as carwash and motor mechanic activities. These activities are amongst some activities identified in an earlier research by [17], where they pointed out anthropogenic factors affecting water quality including impacts due to agriculture, use of fertilizers, manures and pesticides, animal husbandry activities, inefficient irrigation practices, deforestation of woods, aquaculture, pollution due to industrial effluents and domestic sewage, mining, and recreational activities causing elevated concentrations of heavy metals, grease & oils and nutrient loads. This research, like the studies carried out by [34] [35] [36] and [37] showed that the water quality in the five sections of the Kumba River downstream is of lower quality compared to upstream. Analysis of variance revealed that the change in zinc and manganese were significantly influenced by these anthropogenic activities at 5% ($p < 0.05$). The results indicated that the main causes of the deterioration of the Kumba River water quality are livestock production and agricultural activities. All four anthropogenic activity effluents highly significantly affected the heavy metal quality of the river water and could be used in controlling the heavy metal load. However, the domestic waste pollution of the river was statistically significant contrary to the other anthropogenic activities that were insignificant despite the changes. Generally, the level of heavy metal contamination was in the order livestock production and butchery activities > agricultural activities > domestic waste disposal activities > carwash and motor mechanic activities. This trend is similar to the results obtained by [17] for livestock production and agricultural activities.

Considering heavy metals, Zinc and Lead were the metals with most contamination with pollution levels higher in the dry season compared to the rainy season though not in the same trend. In comparison to the results obtained on the Saigon River by [38], the mean concentrations of heavy metals such as Cu, Zn, and Hg in the water body was detected at a slightly higher level in the dry season, while that of Pb in the river water were lower in the dry season. In addition of these differences being statistically significant, this pattern of heavy metal concentration is similar to a study on the occurrences of heavy metals in the

Kumba River. The order of the heavy metal pollutions was Pb > Zn > Mn > Cu > Hg during the dry season and Zn > Pb > Mn = Cu = Hg during the rainy season respectively and were below the maximum contamination levels for these metals respectively recommended by FAO. These orders are in contrast with a similar study on the Saigon River conducted by [1] who found out that the order was Cu > Zn > Pb > Cd > Hg with the presence of tested heavy metals in the surface water of the sampling sites found at lower levels than the limits according to the Vietnam regulation for surface water. However, comparing the average values of each metal to the maximum contamination levels defined by the United State Environmental Protection Agency (US EPA), the average concentrations of Zinc and Lead during both seasons are above the maximum concentrations to support aquatic life. These (coupled with the presence of surfactants from the detergents used in carwash activities) may partially account for the lack of fish that used to exist in the river and the death of fish in the river and lone fish pond situated at the periphery of Kumba at Barombi Kang in which the river water is used. Similar trends of Mn, Zn and Cu concentrations were detected in the samples of River Meme by [39]. Generally, zinc is seen to have an inverse correlation with all the other metals. Correlation between the different heavy metals suggests that as copper (Cu) contamination increases, manganese (Mn) and lead (Pb) tend to increase always and as manganese (Mn) increases lead (Pb) tends to increase always. There is thus need to regulate the anthropogenic activities within the river basin especially the direct washing of vehicles in the river water so as to permit fish production.

5. Conclusion

This study brings out the role played by anthropogenic activities within the Kumba River basin in the deposition of large quantities of pollutants of different categories into the surface waters. These anthropogenic effluents significantly affect the heavy metal quality of surface water within the basin, with a consequential effect on both the water environment and potential human health. The study suggests a check of these activities that cause negative impacts on the quality of surface water bodies as well as control of heavy metal quality of the water. The control of heavy metal loads in the river water could be accomplished through the control of human-based activities linked to particular metals within the river basin through protection of the streams and river by institution of legal sanctions and sensitization (education) of the inhabitants of the area regarding environmental protection as well as placement of trash cans within the basin.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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