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Effects of Textile Effluents on the Physico - Chemical Parameters and Heavy Metal Concentrations of River Kaduna

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Abstract
Industrial effluents contribute to the pollution of water bodies and this has been related to heavy disease load in communities relying on the water bodies. This study investigates the effects of textile effluents on the physicochemical parameters and heavy metal concentration of River Kaduna. Heavy metals (Cd, Ni, Pb, Zn, Cu and Fe) and physiochemical parameters (temperature, pH, electrical conductivity (Ec), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD)) were analysed from water samples collected from five (5) sampling stations within the period January to March, 2020. About 22km was covered along the course of the river and the average distance between the stations is about 4.4km.The result from the physiochemical parameters shows the water Temperature (26.55-28.20^{0}C), Ec (120.06-182.35), DO (0.41-9.89), BOD (0.17-0.40), COD (3.22-36.10) were below the WHO and FEPA permissible limit and Turbidity (8.66-16.72) was above the limit. The result from heavy metal analysis reveals; Cd (0.05-0.07), Ni (1.55-2.55), Pb (0.59-1.45), and Fe (0.35-0.55) were found to be above acceptable limits when compared to Standards Organization of Nigeria (SON) and World Health Organization (WHO) guidelines. The concentration of all the heavy metals were larger than their respective control values showing the impact of external factors which must be checked. The study concluded that River Kaduna water body is polluted with heavy metals due to effluent discharged by the textile companies and other human activities along the bank of the river.
Keywords: Textile effluents, physicochemical parameters, heavy metals concentration and River Kaduna.

Introduction

There is a growing interest around the pollution of natural water bodies by industrial wastes in emerging and heavily inhabited nations like Nigeria. This is because rivers are main source of waste removal and particularly wastes from industries close to the water body. Consequently, main sources of drinking water in the country are frequently polluted by the activities of the neighboring inhabitants and manufacturing companies [1].Textile manufacturing companies produce large amount of wastewaters and are frequently discharged to nearby water bodies where their toxins can possibly and harmfully affect aquatic life, fresh water deliveries, and eventually, human wellbeing. Some of the identified effects of textile effluents on humans include; skin irritations, allergic reactions, cancer, inhibited sperm motility and respiratory difficulties [2].

Wastewater produced by the industries is one of the sources of contamination. Polluted air, soil, and water by wastewaters from the industries are related to weighty disease load and this could be part of the reasons for the recent shorter life expectancy in the country when matched with the advanced countries [3, 4].

Wastewaters produced from textile companies contain diverse pollutants, mostly heavy metals. The incessant release of sewage and resultant rise in concentration of heavy metals in diverse partitions of the environment can result to bioaccumulation of heavy metals in plants and animals. Heavy metals are not decomposable and as such accumulate in key organs in the body and over time begin to aggravate, leading to many indications of diseases. Consequently, unprocessed or incompletely processed textile waste can be detrimental to both aquatic and terrestrial life by badly affecting the normal ecosystem and long term health issues [5]. The pollution of surface water by heavy metals is a severe ecological setback as some of the heavy metals like Cadmium (Cd) and Lead (Pb) are toxic even at low concentrations, are non-degradable and bio-accumulate through food chain. However, some heavy metals such as Iron (Fe), Cupper (Cu) and Zinc (Zn) are essential micronutrients; they can be harmful to living organisms at higher concentration [6]. [7] stated that the occurrence of heavy metals in the environment, even in modest concentration, is harmful to human health as it produces many diseases of the central nervous system (Mg, Hg, Pb, As), the kidneys or liver (Hg, Pb, Cd, Cu) and skin, bones or teeth (Ni, Cd, Cu, Cr).

Heavy metal contamination of riverine and other aquatic environment may affect man directly or through his supplies of water, agricultural and other natural products; his physical items or properties or his opportunities for recreation and appreciation of nature. The Conservation of aquatic resources for ecosystem and human health is of utmost apprehension globally. It has thus become obvious that methods for managing aquatic resources must be carried out within the ecosystem dynamics in order that their exploitation for human uses remains sustainable [6, 8].

Incidentally, crops like Amaranthus, sugarcane, sorrel, banana, sweet potato, garden egg and tomato are grown along the bank of the River Kaduna and are irrigated by the water from the river. Consumption of these crops by man leads to serious health hazard because of their ability to bioaccumulate these metals.

The major aim of this research is to identify and examine the level of the following heavy metals: Cadmium (Cd), Lead (Pb), Nickel (Ni), Zinc (Zn), Copper (Cu) and Iron (Fe) in River Kaduna and its physiochemical parameters (temperature, pH, electrical conductivity (Ec), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD).

The objectives of this research are to determine the concentrations of the above named six heavy metal pollutants in the surface waters of River Kaduna, to determine the levels of the above named seven physicochemical parameters of the surface water of River Kaduna, to compare the level of concentration of the heavy metals and physicochemical parameters with W.H.O recommended permissible limits for inland waters and to determine the relationships between the physicochemical parameters and heavy metals concentration in River Kaduna.

Materials and methods

Study area

The study area was River Kaduna in Kaduna State. Kaduna state shares common boundaries with Niger, Zamfara, Katsina, Kano, Plateau and Nassarawa states (Fig. 1). To the south-west, the state shares common boundary with Federal Capital Territory (FCT), Abuja. Kaduna lies on longitude 7°25/ east of the Greeenwich meridian and latitude 10°30/ north of the equator. The whole land structure of the state is mostly undulating plateau with parts of the state like Zaria town, Kagoro and Kwoi areas having protruding hard resistant granite rocks as a result of weathering of previously existing Precambrian rocks through the ages [9]. River Kaduna takes its source from Kujama Hills in Jos Plateau and flows for about 210km before reaching Kaduna town and stretches down 100km into the Shiroro Dam project areas where it finally empties into River Niger [10]. It cuts across the city, dividing it into north and south areas. The North houses mostly the commercial centres and residence areas while the South is the industrial area [11]. Kaduna South LGA houses all the major industrial establishments in the town e.g. Cocacola, Nigeria Bottling Company, Peugeot Nigeria Plc, National Fertilizer Company and so on. The Makera and Kakuri zones contain the grossly polluting textile mills. The general drainage pattern, settlement distribution pattern and the 5 sampling sites are shown in Fig. 2. The River has a strong seasonal flow pattern. Its mean annual discharge is estimated at 4.925 billion m^3 [12].This dicharge falls considerably during the dry season especially during the months of January to March. On the other hand, the 4 principal wastes – contributing drains downstream of Kaduna South have a combined average discharge of over $0.5m^3\ sec^{-1}$ during the workdays of the dry season. It has been suggested that excluding runoffs, waste dilution in the river kaduna exceeds a ratio of 200:1 during the rainy season, while during the dry season, the river kaduna carries as much waste as freshwater [12]. In addition to climatic factors, the flow regime of the river system depends upon topography, surficial geology, soil and vegetation cover of the drainage area. The drainage pattern is mostly dendritic. It is navigable in the dry season and sometimes carries as much waste as freshwater [13].Five sampling stations were chosen along the river as shown in Fig. 2. Station 1 was located within the Gamji Park. Little discharge of sewage and refuse from the scanty residential areas and the park was observed. Station 2 was located about 500m from the railway bridge behind Ahmadu Bello Stadium. The river at this point receives discharges from residential areas, hospitals, police station and barracks. Station 3 was located by the Western by-pass bridge to Zaria (Nasarawa bridge). River receives drainage from the Kakuri, Nasarawa, Rafindadi and Makera rivulets that receives drainage from the various heavily polluted industrial establishment located in Kaduna South. Station 4 and 5 were located downstreem at an average distance of 4km. The borehole water found in the residential area serves as control for the study.

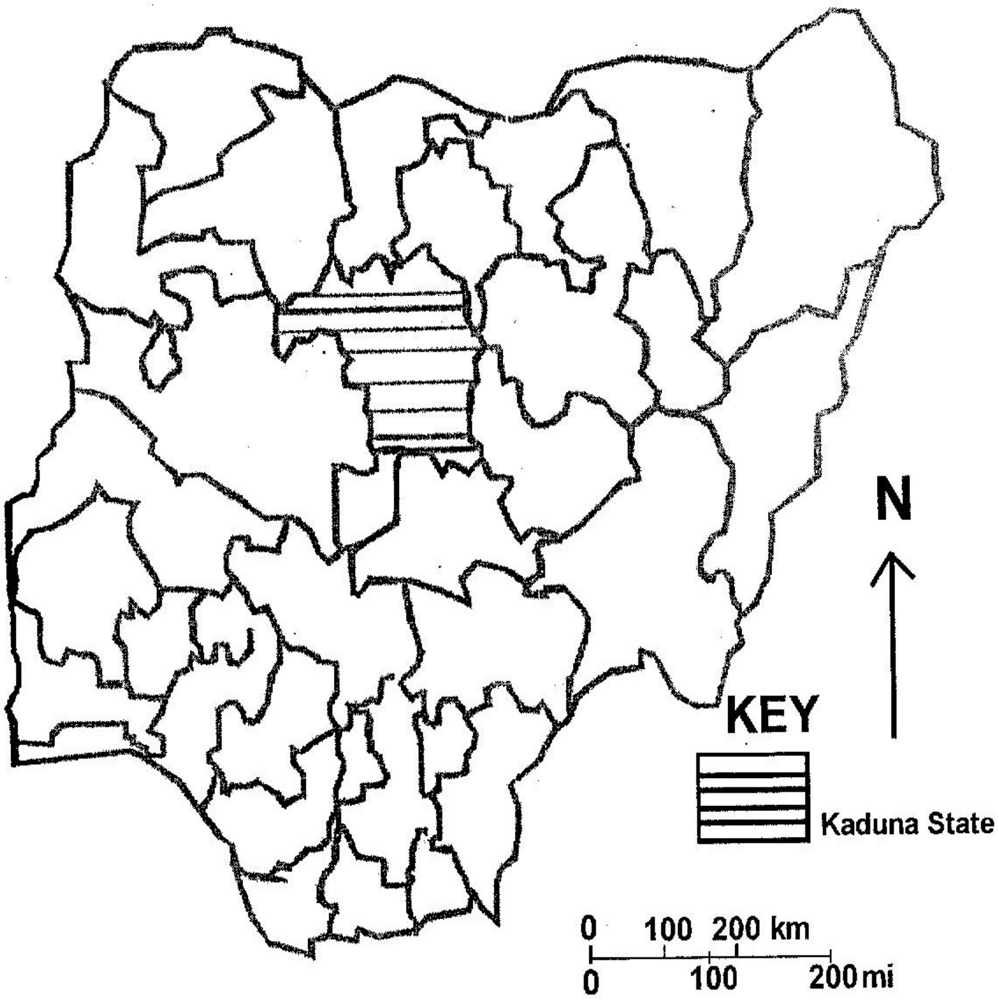

Figure 1: Map of Nigeria showing location of Kaduna State

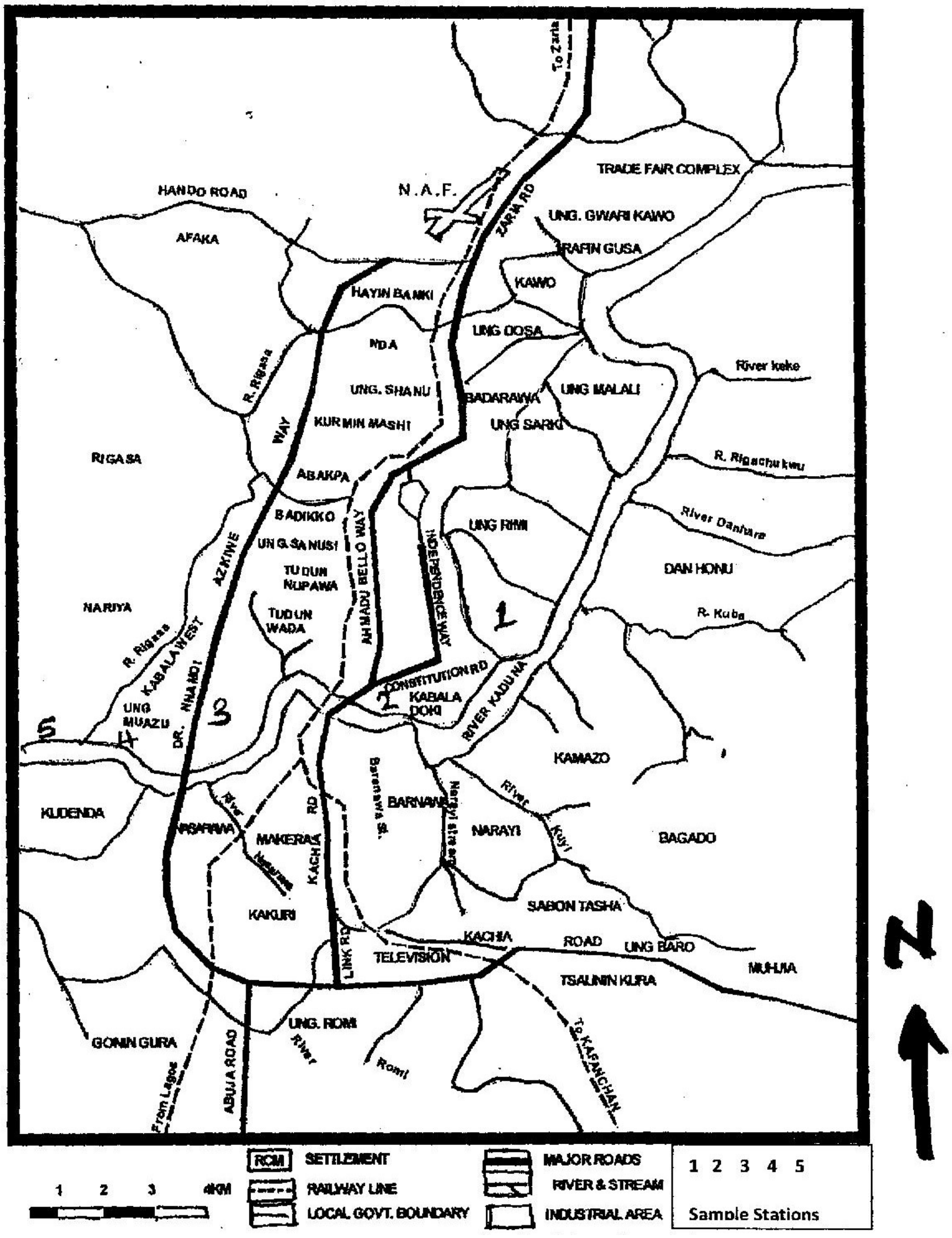

Figure 2: Settlement Distribution in Kaduna Town showing the 5 sampling stations along The Kaduna River

Source: [14].

Sample collection

Heavy metals (Cd, Ni, Pb, Zn, Cu and Fe) levels and physiochemical parameters (temperature, pH, electrical conductivity (Ec), turbidity, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD)) were analyzed from water samples collected from five (5) sampling stations within the period January to March, 2020. This is the period where the river water is most likely to contain the highest amount of contaminants [13]. About 22km was covered along the course of the river and the average distance between the stations is about 4.4km. A total of 45 water samples were collected. Samples were collected three times in a month from each sampling station for three months. The sampling time was between 9am to 11am. Water samples were collected from each sampling stations in pre-washed plastic bottles of 250ml as prescribed by the Standard methods for water and waste water analysis[15, 16]. The samples were collected by dipping the plastic bottles below the water surface at each of the selected sampling stations. Temperature, pH, Turbidity, Conductivity and Dissolved Oxygen were analyzed on the field while other samples were transported to the laboratory in the department of Biological Sciences, University of Abuja for analyses. Water samples for Biological Oxygen Demand (BOD) were collected in BOD bottles and transported in a cooled icebox to the laboratory.

Determination of limnological parameters

Temperature was measured *in situ* using hand held mercury thermometer. pH was measured using pH Meter (HI 9024). Conductivity was measured using HACH Conductivity Meter. Turbidity was measured using a Microprocessor Turbidity Meter. Dissolved oxygen was determined on the field with a portable dissolved oxygen meter (SWH 00745). To determine BOD, water samples were incubated in BOD bottles for 5 days at 20°C. Dissolved oxygen meter was used to measure the DO levels. The difference between the initial DO on day one and the DO after 5 days of incubation gives the BOD (APHA, 1998).

Analyses of heavy metals

Analysis of water samples was carried out according to [15] and [16]. Water samples were digested with 12ml concentrated HNO_3. 100ml of water sample was put in a beaker, 5ml concentrated HNO_3 was added and then heated on a hot plate to bring it to slow boiling until it evaporates to about 20ml. Another 5ml concentrated HNO_3 was added and the content was heated to obtain gentle refluxing action until the digestion was completed as indicated by a clear solution. 2ml concentrated HNO_3 was again added to rinse the beaker and wash glass and then added to the flask. The filtrate was cooled and diluted to the 100ml mark of volumetric flask. Portions of the filtrate was then taken and analyzed for the various metals using Atomic Absorption Spectrometer (AAS) (Pye Unicam SP9). Metals analyzed were cadmium, nickel, lead, copper, zinc and iron. Cadmium, nickel and lead are non-essential elements while copper, zinc and iron are essential elements.

Statistiscal analysis

Descriptive statistical analysis was carried out using STATA 15 software. The relationships between the concentration of different physicochemical parameters and heavy metals were analyzed by Pairwise correlation coefficient.

Results and Discussion

Limnological parameters

The mean distribution ranges of temperature, pH, electrical conductivity, turbidity, dissolved oxygen, biological oxygen demand and chemical oxygen demand for all stations studied on River Kaduna compared with [17] and [18] guidelines were as shown in Table 1 and Table 2 shows the mean ranges for each station. The lowest temperature of 26.55±0.35°C was recorded in Station 3 and the highest temperature of 28.20±0.616°C was recorded in Station 5. The mean temperature value for all the stations was 26.91±0.16°C. The lowest pH of 6.55±0.50 was recorded in Station 1 and the highest pH of 7.95±0.56 was recorded in Station 3. The mean pH value for all stations was 6.77±0.15. The lowest electrical conductivity value of 120.06±0.330 µs/cm was recorded in station 1 while the highest value of 182.35±1.20 µs/cm was recorded in station 4. The mean Ec for all stations was 161.33±6.82µs/cm. The mean turbidity values ranged from 8.66±0.167 NTU in station 1 to16.72±0.289NTU in station 5.The mean Turbidity value for all stations was 13.54±0.71NTU. The lowest dissolved oxygen value of 0.41±0.06mg/l was recorded at Station 3 and the highest value of 9.89±0.21mg/l was recorded in Station 1. The mean DO value for all stations was 3.77±0.88mg/l. The lowest BOD value of 0.17±0.01mg/l was recorded at Station 1 and the highest value of 0.40±0.32mg/l was recorded in Station 3. The mean for all Station value for BOD was 0.29±0.02mg/l. The lowest value of 3.22±0.16mg/l for Chemical Oxygen Demand (COD) was recorded at Station 1 and the highest value of 36.10±0.46mg/l was recorded at Station 3. The mean for all stations value for COD was 21.77±2.88mg/l.

Table 1: Summary Statistics of Physicochemical Parameters of River Kaduna Compared with FEPA and WHO Guidelines

Parameter	Unit	Mean	SD	Minimum	Maximum	Guideline	
						[17]	[18]
Water Temp	^0C	26.91±0.16	0.63	26.55	28.20	30	30
Ph		6.77±0.15	0.59	6.55	7.95	6.5-8.5	6.5-8.5
Electrical Conductivity	μs/cm	161.33±6.82	26.42	120.06	182.35	240	250
Turbidity	NTU	13.54±0.71	2.74	8.66	16.72	10	5
Dissolved Oxygen	Mg/l	3.77±0.88	3.42	0.41	9.89	10	10
Biological Oxygen Demand	Mg/l	0.29±0.02	0.093	0.17	0.40	10	10
Chemical Oxygen Demand	Mg/l	21.77±2.88	11.16	3.22	36.10	40	40

Table 2: Mean Values of the Physicochemical Parameters at the Five Sampling Stations in River Kaduna

Stations	Water Temp. (^0C)	Ph	Ec (μs/cm)	Turbidity (NTU)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	26.56±0.233	6.55±0.505	120.06±0.330	8.66±0.167	9.89±0.21	0.17±0.01	3.22±0.16
2	27.15±0.231	6.56±0.326	141.89±4.014	12.35±0.500	5.89±0.54	0.24±0.01	14.65±0.51
3	26.55±0.351	7.95±0.568	179.61±1.062	15.49±0.530	0.41±0.06	0.40±0.32	36.10±0.46
4	27.10±0.233	6.87±0.203	182.35±1.201	15.33±0.333	1.80±0.05	0.33±0.04	30.33±0.49
5.	28.20±0.616	6.93±0.881	182.0±0.577	16.72±0.289	1.26±0.14	0.31±0.14	25.89±0.58

Heavy metals concentration in surface water sample

The mean distribution ranges of heavy metals (Cd, Ni, Pb, Zn, Cu and Fe) for all the five stations studied on River Kaduna compared with values from control experiment, [17] and [18] guidelines were as shown in Table 3. Table 4 shows the mean values for each sampling station. Cadmium concentration is between 0.051±0.004mg/l and 0.070±0.007mg/l with the highest value recorded at station 3. The mean concentration of Cadmium for all stations was 0.059±0.003 mg/l . Nickel concentration was between 1.55 and 2.55mg/l with the highest value recorded at Station 2. The mean concentration of Nickel for all stations was 1.75±0.115 mg/l. Lead concentration ranges between 0.590±0.020mg/l and 1.450±0.017mg/l with the highest concentration at station 1. The mean concentration of Lead for all stations was 0.939±0.102 mg/l. The concentration of zinc showed the highest value of 0.153±0.145 mg/l at Station 3. The mean concentration value of zinc for all stations was 0.120±0.009 mg/l. The concentration of copper was between 0.050±0.010 and 0.090±0.005mg/l with the highest value recorded at station 2. The mean concentration value of copper for all stations was 0.073±0.003 mg/l. Iron concentration was between 0.350±0.017 and 0.553±0.014mg/l. The highest value of iron concentration of 0.55mg/l was observed at Station 3 and 5. The mean concentration value of Iron for all stations was 0.430±0.272mg/l.

Table 3: Summary Statistics of Heavy Metals Concentration in Surface Water Samples of River Kaduna

Heavy Metals	Units	Mean	SD	Minimum	Maximum	Heavy metal (control)	Guidelines	
							[19]	[20]
Cadmium	Mg/l	0.059±0.003	0.014	0.051	0.074	0.0011±0.0001	0.003	0.003
Nickel	Mg/l	1.75±0.115	0.444	1.550	2.550	0.0043±0.0008	0.020	0.020
Lead	Mg/l	0.939±0.102	0.399	0.590	1.455	0.0053±0.0012	0.010	0.010
Zinc	Mg/l	0.120±0.009	0.035	0.090	0.153	0.0063±0.0012	3.000	5.000
Copper	Mg/l	0.073±0.003	0.012	0.050	0.090	0.0040±0.0011	1.000	2.000
Iron	Mg/l	0.430±0.272	0.105	0.350	0.550	0.0050±0.0005	0.300	0.300

Table 4: Mean Values of the Heavy Metals Concentrations at the Five Sampling Stations in River Kaduna

Stations	Cadmium (mg/l)	Nickel (mg/l)	Lead (mg/l)	Zinc (mg/l)	Copper (mg/l)	Iron (mg/l)
1	0.051±0.004	1.550±0.152	1.450±0.017	0.116±0.020	0.070±0.010	0.350±0.017
2	0.053±0.008	2.553±0.057	0.590±0.020	0.150±0.015	0.090±0.005	0.350±0.017

3	0.070±0.007	1.550±0.104	1.353±0.014	0.153±0.012	0.070±0.010	0.553±0.014
4	0.060±0.010	1.553±0.145	0.650±0.076	0.090±0.011	0.073±0.003	0.350±0.028
5	0.060±0.010	1.550±0.020	0.650±0.057	0.090±0.005	0.073±0.006	0.550±0.000

The low temperature recorded between January and February could be attributed to the harmatten period conciding with the period of the research. Higher temperature values recorded in March could be due to increased solar radiation and dilution effect by effluent dischared from the textile factories as previously observed by [21] in Romi River in Kaduna who also recorded low temperature within the same period. Higher temperature negatively impact water quality by enhancing the growth of micro-organisms which may increase taste, odour, colour and corrosion problems [22, 23]. Temperature affects biological, chemical and physical activities in the water. Increase in temperature of water decreases solubility of gases such as O_2, CO_2, N_2 and CH_4[22]. The pH values for the five stations were within the WHO acceptable limits of 6.5 – 8.5 for inland water, which is in agreement with the observation of [21]. The World Health Organisation (WHO, 2010) recommends a pH value of 6.5 or higher for drinking water to prevent corrosion. A pH above 8.0 would be disadvantageous in the treatment and disinfection of drinking water with chlorine (UNICEF 2008; Oyem *et al.,* 2014). However pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most drainage basins of the world [24]. The higher electrical conductivity values observed in stations 3, 4 and 5 may be as a result of heavy metallic ions contained in the effluents discharged from the industries. They are however not above the WHO standard value of 250 us/cm for inland water. Electrical conductivity values obtained by [25] in a similar study on Rido River in Kaduna were above WHO standard. The high turbidity observed in sites 3,4 and 5 could be due to the discharge of large volume of industrial wastes and dyes from the textile factories. Observations in station 3, 4 and 5 during this period in particular indicated floating oils, grease, purple dyes on the river and pungent odour. The highest turbidity of 16.72 NTU recorded at station 5 may be due to the low speed observed at this portion of the river. The values of DO for all stations were below standard. This could be due to the effect of high level of pollution by domestic and industrial waste which depletes oxygen in water. Higher BOD observed in station 3, 4 and 5 during this period confirms this suggestion. This observation is in agreement with [21] and [25]. Higher Chemical Oxygen Demand (COD) was registered in stations 3, 4 and 5. This may be due to the high concentration of waste chemical from industries into River Kaduna. The concentration of COD is higher than BOD for all the five stations. This may be due to the fact that COD records values of oxygen depletion not only due to biological process but also due to the chemical oxidation of elements in water. COD in textile wastewater can be caused by formaldehyde based dyes, softeners and detergents [26]. Analysis of heavy metals in the surface water of the river and pipe borne water used in the control experiment show much variation. The concentration of metals in the pipe borne water were very low and donot show any significant relationship with the concentration of metals in the surface water of River Kaduna. This suggests that arthropogenic inputs contribute to the higher concentration of heavy metals in the surface water of River Kaduna. The concentration of cadmium, nickel, lead and iron in the surface water of River Kaduna for all stations were above the maximum tolerable limits set by SON and WHO. This suggests that sewage and refuse dumped in the river at station 1 and 2 and the industrial effluents discharged in station 3 could be responsible for high concentration of these metals. This is in agreement with the observation of [27] on the effects of effluents on River Rido in Kaduna. The concentration of zinc and copper were below the maximum tolerable limits set by SON and WHO. This is in agreement with similar study by [28]. The low concentration of zinc and copper indicates their low concentration in the sewage and refuse dumped in station 1 and 2 and the textile effluents discharged at station 3. Some heavy metals such as zinc, copper and iron are necessary for the proper functioning of the human body when their levels are low, absorption of excessive quantities of these metals is harmful. Some other metals such as cadmium, nickel and lead are not necessary for the human body and can cause serious threat to human health [27]. The statistical analysis was carried out using STATA 15 software. The relationships between the concentration of different physicochemical parameters and heavy metals were analyzed by Pairwise correlation coefficient and the result are shown in Table 5. The high correlation coefficient (near +1 or -1) means a good relationship between two variables and its concentration around zero means no relationship between them. It can be strongly correlated if r>0.7 whereas r values between 0.5 to 0.7 shows moderate correlation between two different parameters[29]. From Table 5, we can observe that Cadmium and Iron has positive correlation with all physicochemical parameters studied except DO which shows a strong negative correlation. A moderate negetive correlation (-0.6073) was observed between turbidty and

nickel. These results indicate that physicochemical properties directly impact the concentration levels of Cadmium, Iron and nickel. Positive significant relationships exists between Cadmium-Iron (0.7638), nickel-copper

(1.0000), Zinc-copper (0.6071). Significant positive correlation between the heavy metals themselves suggests similar and identical origin of the heavy metals, and indicating that the anthropogenic activities could enhance the concentration of these elements.

Table 5: Correlation Analysis Between Physicochemical Parameters and Heavy Metal Contents of the Surface Water of River Kaduna.

	temp	ph	ec	turbid~y	do	bod	cod
temp	1.0000						
ph	0.7904	1.0000					
ec	0.6859	0.9675	1.0000				
turbidity	0.7681	0.9294	0.9614	1.0000			
do	-0.7137	-0.9757	-0.9874	-0.9230	1.0000		
bod	0.2664	0.7994	0.8649	0.7282	-0.8486	1.0000	
cod	0.5556	0.9261	0.9699	0.8673	-0.9788	0.9274	1.0000
cadmium	0.5726	0.8497	0.8009	0.6366	-0.8796	0.7725	0.8823
nickel	-0.3809	-0.4962	-0.2952	-0.2084	0.3460	-0.3469	-0.2986
lead	-0.2195	-0.2791	-0.4389	-0.6073	0.3066	-0.2647	-0.2903
zinc	-0.2108	-0.1946	-0.0725	-0.1871	-0.0033	-0.0496	0.0765
copper	-0.3809	-0.4962	-0.2952	-0.2084	0.3460	-0.3469	-0.2986
iron	0.8941	0.7348	0.6186	0.5953	-0.7098	0.2832	0.5878

	cadmium	nickel	lead	zinc	copper	iron
cadmium	1.0000					
nickel	-0.5345	1.0000				
lead	0.1748	-0.4589	1.0000			
zinc	0.1527	0.6071	0.1688	1.0000		
copper	-0.5345	1.0000	-0.4589	0.6071	1.0000	
iron	0.7638	-0.4082	0.1335	0.1166	-0.4082	1.0000

Conclusion

The introduction of textile effluents into River Kaduna greatly impairs the water quality of the river. In addition to the effluent discharge, sewage and refuse dumped at station 1 and 2 contributes significantly to the pollution of the River. Cadmium, nickel, lead and Iron had concentration levels that were above the permissible levels recommended by SON (2007) and WHO (2011). The exceptions were zinc and copper which had concentration levels that were within the permissible limits. The presence of these heavy metals in River Kaduna exposes the people in the area to anaemia, fatigue, musculoskeletal complaints, mood disturbances, neurological problems, high blood pressure, kidney and liver dysfunction, gastrointestinal, endocrine and immune system dysfunction. In order to meet the requirements of SON (2007) and WHO (2011) standards and regulatory guidelines, it is therefore recommended that effluents are properly treated before being discharged into water bodies. Sewage and refuse should also not be dumped directly into water bodies. The Kaduna Environmental Protection Authority (KEPA) should ensure that textile factories comply with Federal Environmental Protection Agency and National Standard Drinking water quality guidelines for industrial effluent discharge.

Declaration of conflicting interests

The authors declared no potential conflicts of interest

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