Factor Analysis Techniques for the Assessment of Water Quality: A Case Study of Okun River, Ilorin, Kwara State

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Abstract

Okun River caters for diverse needs. Resulting from rapid industrialization and urbanization, the quality of the river is significantly affected. The study of impact of discharged industrial wastewaters into Okun River was carried out. Physicochemical properties such as temperature, turbidity, conductivity, total suspended solids, total dissolved solids, colour, odour, pH, total hardness, chloride, and concentrations of heavy metals (chromium, manganese, iron, copper, zinc and cadmium) were assessed. The mean concentrations of heavy metals and the physicochemical parameters determined were compared with standards and tolerance limit. Cr was not detected in all the samples while Mn, Fe, Cu, Zn and Cd concentrations varied from 0.10-3.47 mg/L, 2.64-9.65 mg/L,0.37-3.79 mg/L, 0.22-1.53 mg/L and 0.00-0.03 mg/L respectively. The mean values of pH, temperature, conductivity, turbidity, TSS, TDS, total hardness and chloride ranged between 6.33-7.77, 25.0-29.0 ºC, 325-815 mS/cm, 14.80-209.33 NTU, 733.33-1033.33 mg/L, 133-395.67 mg/L, 137.50-962.50 mg/L and 11.52- 49.04 mg/L respectively. The principal component analysis confirmed the heavy metals to be from anthropogenic and industrial origin.

Keywords: Industrial effluents, physicochemical parameters, water quality, heavy metals, component analysis

Introduction

Most organic industrial wastewaters are produced by factories producing (cosmetics, synthetic detergents, glue and adhesives, brewery and fermentation factories, pharmaceuticals, soaps, pesticides and herbicides, tanneries and leather factories, textile factories, organic dyes-stuffs, metal processing industries and oil refining industries) (Hanchang, 2009). Wastewater containing organic pollutants like pesticides, hydrocarbons, phenolic compounds, plasticizers, fertilizers, oil and greases, pharmaceuticals, detergents contain large amount of suspended solids which reduces the rays of light available to aquatic organisms and also makes the aquatic habitat unsuitable for invertebrates after settling out (Akl *et al*., 2014). It has been observed that inorganic industrial wastewater produced in the coal and steel industry, in the non-metallic minerals industries, and industries for the surface processing of metals and in commercial enterprises contribute to the decadence of safety index of the environment (Hanchang, 2009).

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One of the most critical problems of developing countries is improper management of the large amount of waste products generated by various anthropogenic activities. The disposal of the wastes into the ambient environment especially water bodies has been observed to pose great challenge, and it has rendered these natural resources unsuitable for both primary and secondary usage (Aboyeji, 2013; Okoro *et al.,* 2018). Despite the environmental consequences of surface water pollution by industrial effluents, industrial effluents are still contaminating many river systems in developing countries, especially Nigeria (Etim & Onianwa, 2013). Industrial effluent contamination of natural water bodies has emerged as a major challenge in developing and densely populated countries like Nigeria. Estuaries and inland water bodies, which are the major sources of drinking water in Nigeria, are often contaminated by the activities of the adjoining populations and industrial establishments (Ikhajiagbe *et al*., 2014).

Most major industries have treatment facilities for industrial effluents, but this is not the case with small-scale industries, which cannot afford sustainable investments in pollution control equipment, as their profit margin is very slender (Singh, 2012). Hence, there are issues of these industrial wastes management, which later becomes menacing concern after accumulations. The heavy metals are very harmful, toxic and poisonous even in parts per billion (ppb) range. These toxic heavy metals released in aquatic environment may enter into the food chain through bio-magnification that may cause various health problems in humans (Akaninwor *et al.,* 2009). Ultimately, metallic components leach to groundwater, lead to contamination due to accumulation, and may cause series problems for living things. Another recent investigation reported that elevated levels of heavy metals in seafood are found from the areas having long-term uses of treated or untreated wastewater (Kisku *et al.,* 2016).

Heavy metals are defined subset of metallic elements having atomic weights between 63.546 gram and 200.590 gram and a specific gravity greater than 4.0, i.e. at least 5 times that of water. They exist in water in colloidal, particulate, dissolved phase with their occurrence in water bodies being of natural, or of anthropogenic origin and some of them are essential to sustain normal body functions. In addition, cobalt, copper, iron, manganese, molybdenum and zinc are needed at low levels as catalyst for enzyme activities. Heavy metals can also include the transition metals, some metalloids, lanthanides, and actinides and they have been associated with contamination and potential toxicity or eco-toxicity (Onwughara *et al*., 2011). The major anthropogenic sources of heavy metals are industrial wastes from mining sites, manufacturing and metal finishing plants, and domestic wastewater and run off from roads. Many of these trace metals, such as Mercury, Lead, Cadmium, Nickel, Arsenic, and Tin are highly toxic to humans. Some heavy metals such as Hg, Pb, As, Cd, Fe, Co, Mn, and Cr among others have been identified as harmful to aquatic ecosystem and human health (AbdulJameel *et al*., 2012; Okoro *et al.*, 2013; Okoro *et al.,* 2017).

Treatment of all kinds of wastewater before their discharge into the environment is important in order to avoid pollution. Large quantities of untreated solid and liquid wastes are discharged without control into streams and rivers, particularly those flowing through towns, cities and villages. In this way, water that should be a blessing to life becomes a carrier of poisons, toxicants and pathogens leading to dreadful diseases that cause death. Many diseases and premature deaths can be prevented by adequate care of our environment (Olaniyi *et al*., 2012).

This study was carried out to investigate the impacts of industrial effluents on the water quality of Okun river, using factor analysis and multivariate statistical techniques, respectively. In addition, it is to be noted that the comparison of the concentrations of each pollutant with national and international effluent standards will be performed. The physicochemical properties determination will show the extent of pollution of Okun River. Therefore, physicochemical properties such as Total Solid (TS), Total Suspended Solids (TSS), colour, Total Hardness, conductivity, alkalinity, acidity, odour, Total Dissolved Solids, Temperature (TDS), turbidity, and chloride among others were investigated in conjunction with determination of Cr, Cu, Mn, Zn, Fe and Cd.

Materials and Methods
Description of Study Area

Ilorin, the capital of Kwara state, Nigeria, is the study area for this investigation (Figure 1). It lies between latitude $8^0$24'N and $8^0$36N and between longitude $4^0$10'E and $4^0$36'E (Kolawole *et al.*, 2011). The city has a humid tropical climate, which is characterised by wet and dry season. Rainy season in the city begins towards the end of March and of October with two peak periods in June and September. Temperature is uniformly high throughout the year and open- air isolation can be very uncomfortable during the dry season (Oriola & Bolaji, 2012).

The city is mainly drained by river Asa and its tributaries are Aluko, Alalubosa, Okun, Osere, Agba and Atikeke forming the four drainage basins (Olabode *et al.*, 2014). Okun River among others is the river being investigated in this study. Okun River is located on the western part of Asa River. Land use pattern in the basins can be classified into built-up (paved) area, forest covered, farms and fallow area, area covered by grassland and bare surface area (Jimoh & Iroye, 2010).

Sampling

The water samples were collected from seven locations as shown in the table 1.

Table 1: Geographical location and position of sampling site.

S/N	Samples	Study area	Lattitude (°N)	Longitude (°E)	Activity
1	OC	Olorunsogo Cottage	8,47374N	4,51472E	Car wash
2	SW	Saw Mill	8,47124N	4,52321E	Saw mill
3	OE	Oko Erin	8,47562N	4,53843E	Dump site
4	OS	Off Stadium	8,47444N	4,55244E	Farming
5	GS	Global Soap	8,47248N	4,53019E	Soap industry
6	TP	Tuyil Pharmacy	8,47601N	4,55244E	Pharmaceutical industry
7	UN	Unity road	8,47901N	4,55881E	Farming, Poultry
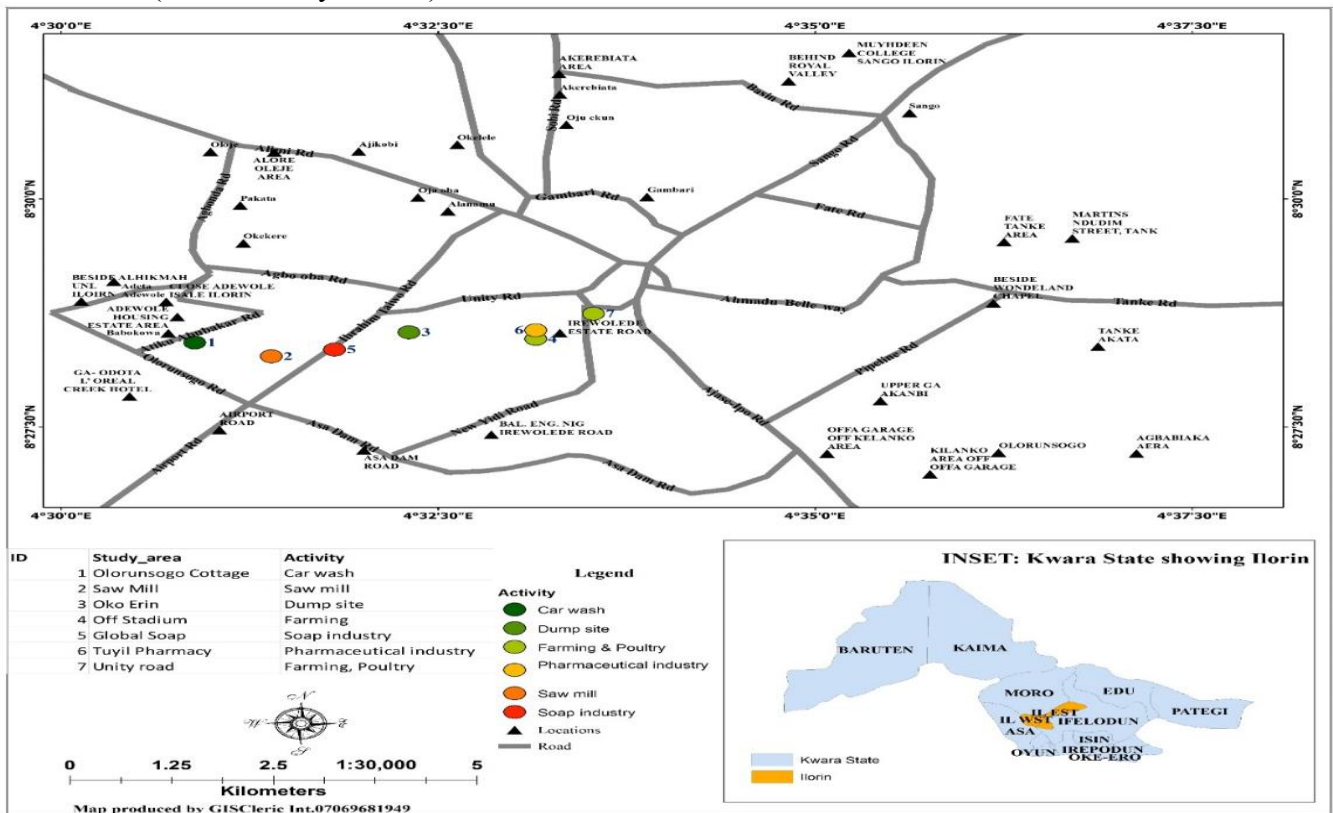
Figure 1: Map Showing the Sample Site.

Sample digestion

A 50 mL aliquot of well-mixed acidified sample was transferred to a 50 mL centrifuge tube and placed into Mod Block. A 2 mL of concentrated HNO_3 and 1 mL of concentrated HCl was added. The sample was covered with a ribbed watch glass (plastic) and heated at 90º C until the volume was reduced to 15 mL. A 15 mL of distilled water was then used to dilute the samples to 30 mL which were analysed (Hagedorn 2008).

Determination of physicochemical parameters
Turbidity

This was determined using a standardized Hanna H198703 Turbidimeter. The samples were poured into the measuring bottle and the surface of the bottle was wiped with tissue paper. The bottle was then inserted into the turbidimeter and the reading was obtained (Emmanuel & Chukwudi, 2013). Values were recorded in NTU i.e. Nephelometric Turbidity Unit.

Electrical conductivity

The Electrical conductivity of the water samples was determined using the conductivity sensor, which was dipped into 20 mL of water samples in a beaker. It is necessary to correct the readings for changes in temperature so the conductivity meter was adjusted to compensate for temperature changes and correct the readings to a standard 25°C (Emmanuel & Chukwudi, 2013).

pH

The pH of the water samples was determined using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 4 and 9 (Emmanuel & Chukwudi, 2013).

Chloride

The sample (25 mL) was measured and diluted to 50 mL with distilled water. The pH of the sample was adjusted to 7.5 with H_2SO_4 followed by 1 mL 0.1M $KCrO_4$. The sample was titrated with 0.0141M $AgNO_3$ standard solution until the colour changed from yellow to faint red. Reagent was titrated blank using only distilled water without the sample (Olaniyi et al., 2012).

Total Hardness

The sample (20 mL) was placed in different clean 250 mL conical flask. To this were added 2 mL of ammonium chloride in concentrated ammonia buffer (NH_4CL/conc.NH_3) and 2 drops of Eriochrome Black T indicator. This was titrated against 0.01 M EDTA solution until there was a colour change from violet to blue (Olaniyi et al., 2012).

Results and Discussions
Heavy Metals

It can be established from Table 2 and graphical representations (Figure 2) that the concentrations of metals varied in the order of Fe > Mn > Cu > Zn > Cd > Cr in Table 2. The order of magnitude of pollution in the sampling locations for Iron is 5 > 1 > 3 > 2 > 6 > 4 > 7; Copper is 2 > 1 > 6 > 3 > 4 > 7 > 5, Manganese is 1 > 5 > 2 > 3 > 6 > 7 > 4; Zinc is 7 > 2 > 6 > 5 > 3 > 1 > 4 and Cadmium is 1 > 5 > 6 > 7 > 4 > 2 > 3 respectively.

From Table 2, it can be deduced that Chromium was not detected at all the sampling points in Okun River. Similar result was obtained on surface and ground waters concentrations of metal elements and their suitability for fish culture in central Cross-River State (Ada et al., 2012). The absence of chromium might be due to the absence of significant geological distribution of minerals in the sites (Adefemi & Awokunmi, 2010; Ada et al., 2012). Except for locations 1 and 5, Cd was detected at all sampling locations with mean values that ranged between 0.01 mg/L and 0.03 mg/L. All the obtained values of the heavy presented in Table 3 exceeded WHO (2008) and USEPA (2009) standard limits of 0.003 mg/L and 0.005 mg/L respectively but were within the permissible limit set by FEPA (2001) except the value obtained at location 3. A corresponding trend was also obtained on heavy metals concentration in surface water, sediments, fish and Periwinkles of Lagos lagoon (Aderinola et al., 2009). The cadmium present suggests the effect of pollution due to dyes and drug complexes, however there are few recorded cases of cadmium poisoning in human beings (Lokhande et al., 2011).

Table 2: Concentrations (mg/L) of Heavy metals in Okun River.

Study area	Heavy metals (mg/L)					
	Cr	Mn	Fe	Cu	Zn	Cd
1	ND	0.10 ±0.01	4.89 ±1.38	0.51 ±0.02	1.06 ±0.09	0.00 ±0.00
2	ND	0.80 ±0.01	7.50 ±7.49	0.37 ±0.09	0.55 ±0.28	0.02 ±0.01
3	ND	0.92 ±0.10	5.98 ±3.49	0.55 ±0.20	0.43 ±0.36	0.03 ±0.01
4	ND	3.47 ±0.16	9.00 ±6.32	0.91 ±0.98	1.53 ±1.53	0.02 ±0.01
5	ND	0.20 ±0.01	2.64 ±1.17	3.79 ±6.00	0.63 ±0.48	0.00 ±0.00
6	ND	1.19 ±0.25	7.89 ±5.70	0.70 ±0.59	0.63 ±0.34	0.01 ±0.01
7	ND	2.23 ±0.49	9.65 ±10.96	0.90 ±0.91	0.22 ±0.12	0.02 ±0.01

ND: Not detected.

Table 3: Concentrations (mg/L) of Heavy metals in examined water samples by regulatory bodies and past research work on surface water.

Regulatory Bodies/ Research work	Cr	Mn	Fe	Cu	Zn	Cd
WHO (2008)	0.05	0.1	0.3	2.0	5.0	0.003
USEPA (2009)	0.1	0.05	0.3	1.3	5.0	0.005
FEPA (2001)	0.05	5	20	<1.0	<1.0	<0.03
Aderinola et al., (2009)	0.06	0.09	1.41	0.20	0.53	0.35
Kar et al., (2008)	0.001-0.044	0.025-2.72	0.025-5.49	0.003-0.032	0.012-0.37	0.001-0.003
Ada et al., (2012)	---	0.17-1.27	0.43-2.93	0.76-0.97	0.31-1.28	ND
Present Study	ND	0.10-3.47	2.64-9.65	0.37-3.79	0.22-1.53	0-0.03

Concentration of Mn obtained ranged from 0.10 to 3.47 mg/L. Its mean concentration was ranked second highest after iron at all locations, except for location 5, where it was ranked fourth. These values exceeded the permissible limits set by WHO (2008) and USEPA (2009), but were lower than FEPA (2001) standard. All the values, except at locations 4 and 7, corresponded to the values obtained by Ada *et al*. (2012). The mean concentrations of Cu obtained varied between 0.37 and 3.79 mg/L. All the values were found to be much lower than the WHO (2008), USEPA (2009) standards and the permissible limit set by FEPA (2001) except at location 3 with a mean concentration of 3.79 mg/L, which deviated widely from all the standard limits set by all the regulatory bodies.

Table 4: Extracted Eigen vectors of heavy metals in Okun River.

	Coefficients of PC1	Coefficients of PC2
Cr	0	0
Mn	0.52439	0.37114
Fe	0.57606	-0.10852
Cu	-0.47763	0.39495
Zn	0.18794	0.79283
Cd	0.36017	-0.25675

Concentrations of Zn obtained in the s present study ranged from 0.22 mg/L to 1.53 mg/L. All the values obtained complied adequately with WHO

(2008) and USEPA (2009) standards as they were below the permissible limits of 5.0 mg/L set by these regulatory bodies. However, they exceeded the FEPA (2001) 1 mg/L permissible limit. This moderate level of Zn was attributed to the absence of heavy discharge from zinc-based fertilizer chemicals (Adefemi & Awokunmi, 2010; Ada *et al*., 2012; Kar *et al.,* 2008). The mean concentrations of iron obtained ranged from 2.64 mg/L to 9.65 mg/L and varied widely from one another. All the values deviated widely from WHO (2008) and USEPA (2009) standards but were below the permissible limit of 20 mg/L set by FEPA (2001). Concentration of iron was the highest among all the metals assessed, except at location 5 where copper had a greater mean concentration. The high concentration of iron obtained at location 5 might be due to the soap effluents being released into the river at this point.

With respect to the principal component analysis for the heavy metal content of Okun River in Table 4, two PCs were extracted using the correlation matrix which reflected the process influencing the heavy metal composition of the river water (Boyacioglu *et al*., 2007). The sources of PC1 loading variables is the industrial and anthropogenic sources while the source of PC2 is loading represent geological and other pollution sources. The PCs extracted from the variables were retained with eigen values greater than 1.11 and the variance of the PCs are 40.49% and 18.59% respectively as presented in Figure 2 (Anazawa *et al*., 2004). PC1 is strongly correlated with Mn, Cd and Fe and negatively correlated with Cu. PC2 is strongly correlated with Zn, Cu, Mn while negatively correlated with Fe and Cd. Therefore, we can confirm from the statistical data that larger

percentage of the heavy metals are from industrial sources (Chu *et al*., 2018)

The loading plot (Figure 2) and the correlation matrix (Table 5) helps to explain the level of correlation between the heavy metals. Mn, Fe; Cu, Fe; are strongly correlated and Mn, Zn; Mn, Cd; Fe, Cd; Cd, Mn; are moderately correlated while Mn, Cu; Fe, Cu; Cu, Cd; Zn, Cu; are negatively correlated. On the loading plots, when the two vectors are close, forming a small angle, the two vectors they represent are positively correlated. If they diverge at very large angles, they are negatively correlated the sources of PC1 loading variables is the industrial and anthropogenic sources while the source of PC2 is loading represent geological and other pollution sources (Chu *et al*., 2018).
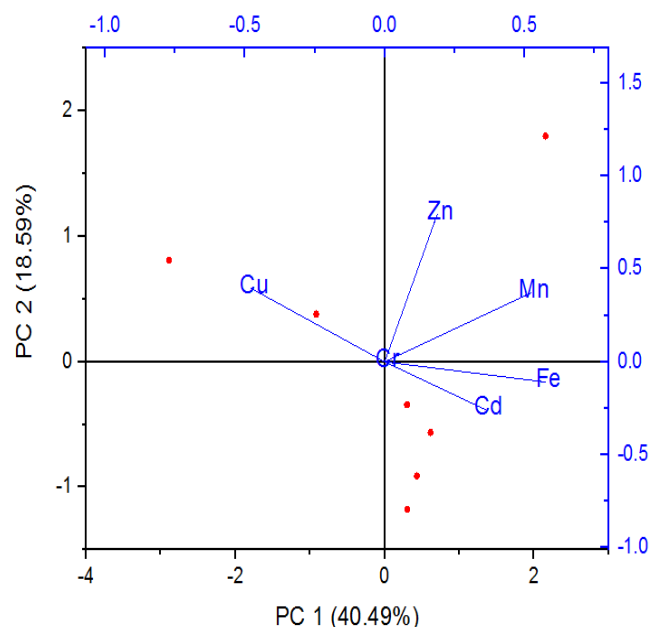

Figure 2: Bi-plot of Okun River heavy metals

Table 5: Correlation matrix of the heavy metals in Okun river.

	Cr	Mn	Fe	Cu	Zn	Cd
Cr	0	0	0	0	0	0
Mn	0	1	0.79909	-0.25815	0.37741	0.26396
Fe	0	0.79909	1	-0.65175	0.01591	0.25036
Cu	0	-0.25815	-0.65175	1	-0.05609	-0.44819
Zn	0	0.37741	0.01591	-0.05609	1	0.09665
Cd	0	0.26396	0.25036	-0.44819	0.09665	1

Physicochemical Parameters

All the water samples were coloured except samples gotten from points 1, 2 and 3 at Location 1 were colourless. However, the apparent colours observed varied between different shades of black, brown and yellow. The odours recorded for the samples were observed to be within four fruity, earthy, offensive and medicinal with the majority of the samples falling in the earthy category. Table 6 show the obtained Physiochemical parameters for the Okun River.

pH is a measure of the acidity or alkalinity of water and an extremely significant parameter in accounting for the toxicity of heavy metals. Thus, pH has a primary importance in deciding the quality of wastewater effluent. The pH values of the samples varied between 6.3 and 7.9 with the lowest value recorded at location 5 while the highest at location 2. All the values complied with both WHO (2008), USEPA (2009) and FEPA (2001) permissible limits for surface water (Adewoye, 2013). Many lake and rivers exhibit vertical temperature gradients as the sun warm the upper water while deeper water will remain cooler (Wahl & Peters, 2014). The mean temperature values ranged between 25 °C and 29 °C with the highest values recorded at locations 2 and 5. However, all the values complied with WHO (2008), USEPA (2009) FEPA (2001) permissible limits for surface water. These values are also similar to the values obtained on Asa River (Adewoye, 2013) Electrical conductivity (EC) in natural waters is the normalized measure of the water's ability to conduct electric current. Dissolved salts, such as sodium chloride and potassium chloride, mostly influence this. Most freshwater sources range between 0.001 to 0.1 S/m. The source of EC may be an abundance of dissolved salts due to poor irrigation management, minerals from rainwater run-off, or other discharges, presence of free CO_2 and level of hardness in the water (Adefemi & Awokunmi, 2010). The mean values obtained for conductivity ranged between 325.33 mS/cm and 815.67 mS/cm. The mean values were complied with only the USEPA (2009) standard limit, as other regulatory bodies are silent on permissible limits for conductivity in surface water.

Monitoring of TSS is an important criterion for assessing the quality of water. Surface water may contain suspended solid matter consisting of particles of many different sizes. These small solid particles cause the liquid to appear turbid. The values obtained for turbidity ranged from 14.80 to 209.33 NTU. The highest value was recorded at location 5 while the lowest at location 6. All the values exceeded the permissible limit set by FEPA (2001). All these values, except for values recorded at locations 2 and 5, corresponded to the values obtained for Asa River (Adewoye, 2013). The sources of total suspended solids include erosion, storm water runoff, industrial discharges, micro-organisms, and eutrophication. Many fish species are sensitive to prolonged exposure to TSS.; The mean values obtained for TSS varied between 1033.33 and 733.33 mg/L, with the highest value recorded at location 1, while the lowest value was obtained at location 6. All the values correspond to the WHO (2008) standard of 1000 mg/L.

Table 6: Levels of Physicochemical Parameters of water from Okun River.

Study area	Parameters							
	pH	Temp (°C)	ECS (mS/cm)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	Total Hardness (mg/L)	Chloride (mg/L)
1	6.70	25.0	325.67	15.42	1033.33	133.00	137.50	11.52
	±0.1	±0.0	±13.05	±9.43	±115.47	±4.36	±12.50	±2.35
2	7.77	28.7	506.33	64.43	1000.00	228.33	962.50	28.36
	±0.15	±0.6	±5.51	±6.83	±100.00	±2.08	±62.50	±0.89
3	7.23	27.0	421.33	16.17	866.67	204.67	187.50	21.57
	±0.06	± 0.0	±40.38	±2.40	±115.47	±2.08	±0.00	±3.58
4	6.63	27.7	815.33	21.70	766.67	395.67	233.33	49.04
	±0.06	±0.6	±10.02	±2.86	±28.87	±1.15	±14.43	±0.51
5	6.33	29.0	384.67	209.33	1000.00	170.33	195.83	10.64
	±0.06	±0.0	±7.09	±34.53	±0.00	±2.08	±40.18	±0.89
6	6.50	28.3	525.00	14.80	733.33	242.00	204.17	16.16
	±0.10	±0.6	±3.61	±2.08	±57.74	±1.73	±19.09	±2.12
7	6.57	26.0	535.00	18.07	850.00	243.67	198.50	23.93
	±0.06	±0.0	±6.24	±5.51	±0.00	±0.58	±20.48	±0.89

Total dissolved solids (TDS) content in water is a measure for salinity. A large number of salts are found dissolved in natural waters, the common ones are carbonates, bicarbonates, chlorides, sulphates, phosphates, and nitrates of calcium, magnesium, sodium, potassium, iron, and manganese, etc. A high content of dissolved solid elements affects the density of water and osmoregulation of freshwater organisms, reduces solubility of gases (like oxygen) and utility, of water for drinking, irrigational, and industrial purposes. The values obtained for TDS ranged between 133 mg/L and 397 mg/L. The highest values were recorded at location 4 while the lowest values were recorded at location 1.

Total hardness is the sum of calcium and magnesium hardness, in mg/L as $CaCO_3$ (Campbell & Peterson, 2010). High levels of hard-water ions such as Ca^{2+} and Mg^{2+} can cause scaly deposits in plumbing, appliances, and boilers. These two ions also combine chemically with soap molecules, resulting in decreased cleansing action. Total hardness values obtained ranged between 137.50 /L and 967.50 mg/L. The highest values were recorded at locations 2 while the lowest values between were recorded at locations 1. Values below 200 mg/L obtained at all points locations 1, 3 and 5 complied with WHO (2008), USEPA (2009) and FEPA (2001) standards, while values above 200 mg/L obtained at locations 2, 4 and 6 failed to comply with all the standard limits. Chloride values obtained ranged between 10.64 mg/L and 49.04 mg/L. The highest values were recorded at location 5 while the lowest value were recorded at Locations 5. High chloride content has a corrosive effect on metal pipes and structures and is also harmful to trees and plants.

From Table 7, PC1 is strongly correlated with ECS, TDS, and Chloride and negatively correlated with turbidity and TSS. PC2 is strongly correlated with pH and total hardness while negatively correlated with none of the physiochemical properties. As described from above, therefore, we can confirm from the statistical data that larger percentage of the heavy metals are from industrial sources (Shen et al., 2019).
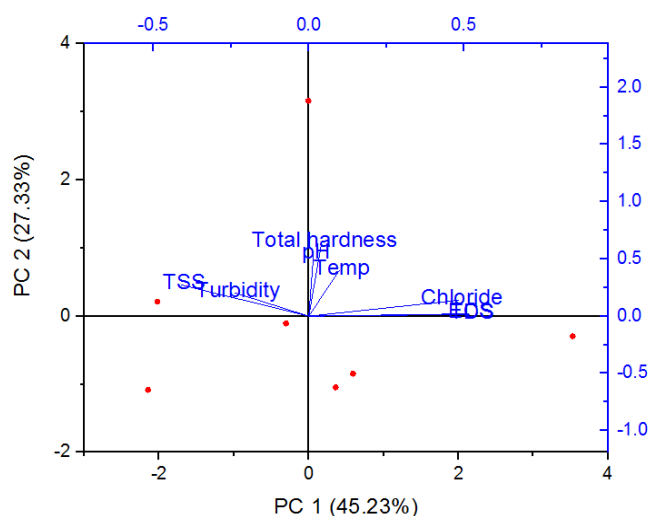
Figure 3: Bi-plot of the physiochemical properties of Okun River

The correlation matrix (Table 8) and the bi-plot (Figure 3) show the correlation relationship between the physiochemical properties. pH and total hardness are strongly correlated while pH with temperature, TSS and chloride are moderately correlated. In addition, a negative correlation was seen between pH and ECS, turbidity and TDS. The significantly positive correlations of temperature and turbidity; ECS and TSS; turbidity and THS; TDS and ECS; chloride and ECS indicates that these variables were influenced by anthropogenic and industrial sources (Shen et al., 2018; Shu et al., 2019).

Table 7: Extracted eigen vectors of the physiochemical properties of Okun river

	Coefficients of PC1	Coefficients of PC2
pH	0.01548	0.54038
Temp	0.0957	0.39832
ECS	0.5139	0.02024
Turbidity	-0.237	0.20304
TSS	-0.40865	0.27206
TDS	0.51748	0.01521
Total hardness	0.04125	0.64349
Chloride	0.48321	0.13919

Conclusion

The results of the analysis carried out showed that Okun River is highly polluted, mainly because of anthropogenic activities; especially industrial activities going on around the river. The water samples studied had manganese, copper and iron at high concentrations, which may bio-accumulate in living organisms, posing great environmental and health hazards to aquatic plants and animals, and eventually to man. Zinc and cadmium were also detected in low but potentially hazardous concentrations. On the other hand, the physicochemical properties of the water connote that the water is not fit for domestic and industrial uses. These facts show that Okun River water needs both primary and secondary treatment before it is safe for any form of consumption. Therefore, indiscriminate discharge of industrial effluent into Okun River should be discouraged and discontinued henceforth. The state Government through the State Environmental Agency can enact a law restricting the inhabitants against indiscriminate pollution of the river by the industrialists. The community as well should be vigilant and prosecute anyone caught causing the pollution.

Table 8: Correlation matrix of the physiochemical properties of Okun River

	pH	Temp	ECS	Turbidity	TSS	TDS	Total Hardness	Chloride
pH	1	0.13004	-0.05299	-0.22741	0.29554	-0.03907	0.81684	0.22451
Temp	0.13004	1	0.24358	0.59008	-0.12934	0.25435	0.45103	0.13458
ECS	-0.05299	0.24358	1	0.24358	0.59008	-0.12934	0.25435	0.45103
Turbidity	-0.22741	0.59008	-0.30006	1	0.48657	-0.30382	0.08618	-0.34738
TSS	0.29554	-0.12934	-0.69386	0.48657	1	-0.71735	0.3227	-0.48027
TDS	-0.03907	0.25435	0.99598	-0.30382	-0.71735	1	0.06946	0.93283
Total hardness	0.81684	0.45103	0.09475	0.08618	0.3227	0.06946	1	0.24626
Chloride	0.22451	0.13458	0.92827	-0.34738	-0.48027	0.93283	0.24626	1

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