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Seasonal assessment of the physico-chemical properties of surface water and sediments in the vicinity of a scrap metal recycling industry in Southwestern Nigeria

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The study assessed the seasonal variations in the physico-chemical properties of surface water and sediments in some villages located around a scrap metal recycling industry in Ile-Ife. This is with a view to monitor the impact of the industry on the quality of surrounding water. The three water bodies (one river, one stream and one pond) identified in the area were sampled every other month for ten months. Water and sediment were sampled from the water bodies and their physico-chemical properties were determined using standard methods. Highest and least pH values: 7.15 ± 0.29 and 6.27 ± 0.26 were recorded in river and pond water sample, respectively during dry season, while the least pH values: 5.64 ± 0.09 were recorded in sediment samples from the river during wet season. Fe in water was highest in pond during dry season with (0.10 ± 0.01) mg/L. Stream sediment recorded higher values of Fe (1.02 ± 0.05) mg/kg, Zn (0.48 ± 0.01) mg/kg and Pb (0.09 ± 0.01) mg/kg than in stream water samples, while the values of pH, Mn, Cd and Cr (6.95 ± 0.03, 0.67 ± 0.11, 0.11 ± 0.02, 0.17 ± 0.03)mg/L respectively in stream water were higher than in stream sediment samples. In River, Fe and Zn values were higher in sediment (0.63 ± 0.04 and 0.52 ± 0.01)mg/kg respectively than in water samples, while in the pond pH, Mn, Cd and Cr were higher in water (6.51 ± 0.12, 0.71 ± 0.07, 0.09 ± 0.01 and 0.22 ± 0.03)mg/L respectively than in sediment samples. The study concluded that the scrap metal recycling industry has impact on the surrounding water bodies as the values of cadmium, lead and iron significantly exceeded the national and international standards.

Key words: Physico-chemical, standards, sediment, scrap metal, seasonal, surface water.

INTRODUCTION

Iron and Steel Industry is a major source of gaseous emission and particulate matter. The emissions

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eventually dissolve into surface water bodies with the attendant health implications. The rapid development in today's industrialized world has led to heavy metal pollution problem. Wastewater from non- ferrous metal ore mining and smelting, electroplating and other industrial production process, is an important pollution source of heavy metal (Wang and Chen, 2015; Ning et al., 2011). Also, activities ranging from residential to commercial and then to industrial are at a geometric increase owing to the constant increase in the world population. Industrial waste originate from manufacturing processes (Lkr et al., 2020), they are usually of a more variable character and must be examined on an industry-by-industry basis. Among these industries is the metal smelting industry which generates metals in general as major environmental pollutants and water pollutants. Iron and steel Industry is a major source of gaseous emission and particulate matter. The emissions eventually dissolve into surface water bodies with the attendant health implications. In Nigeria, the two main problems being contended with as regards water availability are the quantity (source and amount) and quality (Adeniyi, 2004). The quality of water is a reflection of the source environment and the activities of man. About one-third of the drinking water requirement of the world is obtained from surface sources like rivers, dams, lakes and canals (Jonnalagada and Mhere, 2001). The quality of water influences the health status of any populace, hence, analysis of water for physical, chemical and biological properties are very important (Chinedu et al., 2011).

The Iron – Smelting Plant is located close to some villages where the residents rely primarily on untreated water bodies for their domestic activities. There is therefore the need for the seasonal assessment of the physico-chemical properties of surface water and sediments in the villages within the vicinity of the scrap metal recycling industry. These involve the determination and assessment of the physicochemical properties of some surface water bodies in the villages, hence this study.

MATERIALS AND METHODS

Study area

The study was conducted around the Scrap Metal Recycling Industry, located at Fashina Village in Ile-Ife, Ife Central Local Government, Osun State. The coordinates of the Industry lies on latitude 7°29'44''N and longitude 4°28'37''E. The terrain is slightly undulating, and the altitude is between 235 and 255 m above sea level.

The study was carried out in 3 villages located around the Scrap Metal Recycling Industry (Figure 1). The land-use consists of a mosaic, principally of degraded tropical forest, arable land and built-up areas. The climate is tropical with the raining season extending from April to October while the dry season lasts from October to March (USAID, 2002). In recent decades, the region has been witnessing rapid population growth and land-use conversion due to urbanization. Human activities have impacted on the physical environment, especially when it comes to water resources, their quantity, and quality.

Sampling sites/points

The study was carried out on surface water bodies in three villages around the industry. Three water bodies were identified for sampling. A Global positioning system (GPS) handset was used to determine the grid coordinates of the sampling stations (Table 1). The four sampling stations were: One stream named Yagbo, one river named Awosun, and one pond. Ten sampling points (five on the stream, three on the river and two on the pond) were established. Ten water samples were collected from the ten sampling points. Sediment samples were also collected at sites corresponding to those of water sampling. Sampling was carried out six times for a period of ten months, covering both the dry and wet seasons. At each sampling site, water samples were collected using clean, properly washed and rinsed 2-litre plastic bottle containers. All possible sources of contamination were taken into consideration while performing the analysis.

Some parameters were determined in the field. They included water and ambient air temperature using a thermometer while pH values were determined using a pH meter. The electrical conductivity and Total Dissolved Solids (TDS) values of the samples were taken immediately after collection using a Jenway Conductivity meter. Magnesium ion, calcium ion, dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) were analyzed using titrimetric methods described by Golterman et al. (1978) and Nayar (2020). Turbidity was determined using nephelometric method as stipulated by APHA (2012). Potassium ion and sodium ion were analyzed using flame emission spectrophotometer as described by Golterman et al. (1978). Nitrate was determined spectrophotometrically as described by Ademoroti (1996). Heavy metals were analyzed using atomic absorption spectrophotometer (Golterman et al., 1978).

Quality control and quality assurance

All determinations were based on approved standard methods with adequate quality assurance and quality control (QA/QC) measures. Some of the measures adopted were: performing blank analysis of distilled water with detection limit based on mean blank plus three times the standard deviation of replicate blank determination. Detection limit were 0.05 µg/L and 0.03 µg/kg for water and sediment respectively. Non-phosphate detergents were used to wash the DO and BOD bottles and rinsed with distilled water before use since phosphate can stimulate algal growth, the bottles were then thoroughly rinsed with the sample before final collection of the water; labelling of the bottles was done on the field using a marker to prevent sample mix up; the equipment used for the physicochemical water quality parameters were calibrated using the blanks and standards of known concentrations before each determination (Ademoroti, 1996); and the determination of physico-chemical water quality parameters were done within their individual holding time (Ademoroti, 1996).

RESULTS AND DISCUSSION

In the dry season as shown in Table 2, the least mean value for water temperature (24.00 ± 1.53°C) was found in the stream while least mean value for turbidity (12.35 ±

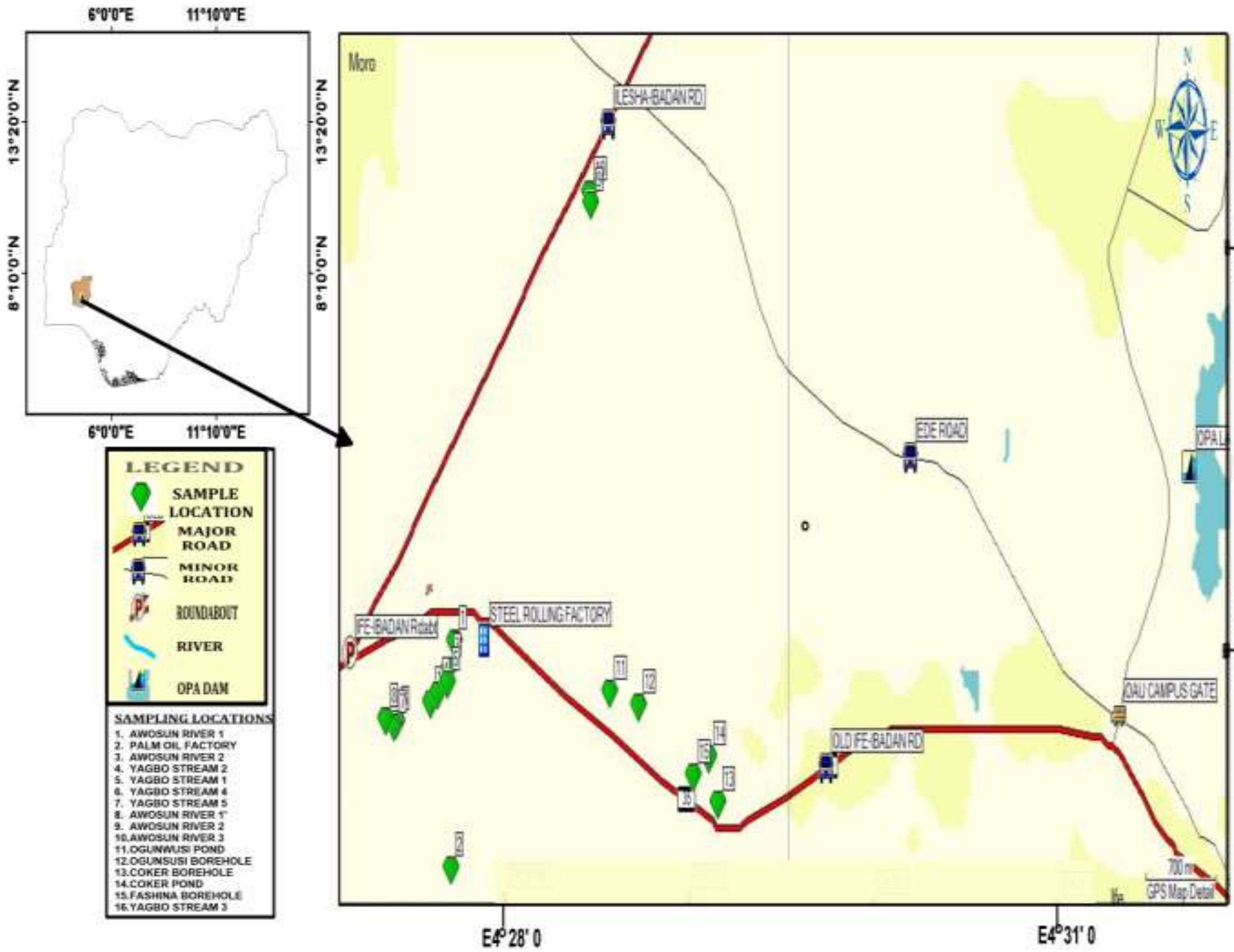

Figure 1. Map of study area showing sampling points.

Table 1. The geographical locations of water sampling stations.

S/N	Sampling Points	Grid Co-ordinates		Elevation (m) Amsl
		Northing	Easting	
1	Stream point 1	07° 29' 54.9"	004° 27' 41.7"	236
2	Stream point 2	07° 29' 53.5"	004° 27' 38.5"	231
3	Stream point 3	07° 29' 52.1"	004° 27' 36.1"	233
4	Stream point 4	07°29' 49.0"	004° 27' 25.2"	212
5	Stream point 5	07° 29' 48.6"	004° 27' 24.1"	214
6	River point 1	07° 29' 49.6"	004° 27' 21.6"	218
7	River point 2	07° 31' 06.3"	004° 28' 28.1"	228
8	River point 3	07° 31' 07.9"	004° 28' 27.7"	230
9	Pond point 1	07° 29' 43.9"	004° 29' 06.6"	245
10	Pond point 2	07° 29' 43.9"	004° 29' 06.6"	245

Amsl: Above mean sea level.

Table 2. Seasonal variation in physicochemical parameters of water samples in the water bodies.

Parameter	Yagbo Stream		Awosun River		Pond		Overall Mean		F	P	Nig.Std	WHO
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry				
Air Temp. (^{o}C)	26.67 ± 0.88^{ab}	25.00 ± 1.53^{a}	27.33 ± 0.67^{ab}	26.17 ± 1.01^{ab}	28.00±1.07^{ab}	30.67 ± 1.07^{ab}	26.67 ± 0.56	25.63±0.72	1. 804	0.095	NG	NG
Water Temp. (^{o}C)	25.33 ± 0.33^{abc}	24.00 ± 1.53^{a}	25.00± 0.00^{ab}	24.17 ± 1.74^{a}	27.25± 0.68^{abcd}	29.32± 0.36^{bcde}	26.58 ± 0.45	25.83 ± 0.73	8.813	0.000***	NG	NG
Turbidity(NTU)	45.01± 29.30^{a}	39.57 ± 23.18^{a}	168.06 ± 87.79^{b}	22.15 ± 2.18^{a}	19.42± 11.49^{a}	12.35± 4.97^{a}	75.50 ± 30.29	31.95± 12.71	2.915	0.009**	5	NG
pH	6.95±0.03cd	6.68± 0.22^{bcd}	7.02± 0.08^{d}	7.15± 0.29^{d}	6.15± 0.10^{abcd}	5.94± 0.32^{abc}	6.46± 0.18	6.78± 0.12	3.686	0.002**	6.5	NG
Acidity (mg/L)	12.00± 2.00^{a}	7.33± 2.40^{a}	10.00± 1.16^{a}	5.00± 1.00^{a}	8.17± 1.05^{a}	10.67± 3.60^{a}	9.25± 0.78	10.00± 2.85	0.733	0.667	NG	NG
Alkalinity (mg/L)	78.6± 7.75^{c}	72.00± 10.26^{bc}	37.33± 6.36^{a}	37.67± 1.67^{a}	42.33± 6.56^{a}	33.00± 3.13^{a}	44.15± 7.21	45.75± 5.58	3.192	0.005**	NG	NG
Conductivity (µScm^{-1})	139.10± 54.64^{ab}	140.80± 18.10^{ab}	80.57± 34.99^{a}	91.97± 5.28^{a}	141.13± 37.34^{a}	217.77± 37.24^{ab}	117.71± 18.99	144.25± 11.96	2.582	0.018*	1000	250
TDS (mg/L)	83.82± 32.94^{abc}	84.43± 11.00^{abc}	48.29± 21.05^{a}	55.13± 3.20^{ab}	85.59± 22.72^{ab}	130.07± 21.98^{abc}	70.70± 11.43	91.51± 10.40	2.520	0.020*	500	NG
DO (mg/L)	5.07± 0.35^{ab}	6.47± 0.41^{ab}	5.47± 0.81^{ab}	6.93± 0.48^{b}	4.40± 0.44^{ab}	5.60± 0.73^{a}	5.20± 0.22	6.35± 0.27	1.639	0.134	NG	NG
BOD(mg/L)	1.73± 0.27^{a}	3.00±1.00^{a}	1.60± 0.46^{a}	2.13± 0.53^{a}	2.67± 0.40^{a}	2.90± 0.72^{a}	1.80± 0.29	2.83± 0.33	0.763	0.650	6	NG
Ca^{2+} (mg/L)	36.11± 2.46^{ab}	19.39± 5.75^{ab}	12.50± 2.76^{ab}	21.70± 15.07^{ab}	15.93± 1.82^{a}	13.33± 3.55^{a}	25.31± 3.78	18.71± 3.81	1.804	0.095	NG	NG
Mg^{2+} (mg/L)	1.39± 0.01^{a}	1.75± 0.46^{a}	1.24± 0.55^{a}	1.39± 0.06^{a}	1.25± 0.02^{a}	1.85± 0.52^{a}	1.33± 0.22	1.70± 0.21	1.011	0.446	0.20	NM
Na^{+} (mg/L)	8.70± 0.92^{a}	6.21± 1.74^{a}	7.77± 1.35^{a}	5.33± 1.91^{a}	17.35± 2.36^{a}	19.54± 4.83^{a}	9.77± 1.17	5.98± 1.32	1.647	0.132	200	200
K^{+} (mg/L)	2.60± 0.21^{a}	2.32± 0.73^{a}	3.28± 0.27^{a}	4.40± 0.64^{a}	10.83± 2.81^{a}	12.69± 1.99^{a}	5.90± 1.28	5.48± 0.83	1.377	0.228	NG	NG
Cl^{-} (mg/L)	5.95± 0.83^{ab}	4.18± 0.34^{a}	9.50± 4.25^{ab}	6.33± 0.67^{ab}	18.11± 5.30^{ab}	21.15± 5.23^{ab}	11.91± 1.94	9.94± 2.31	2.402	0.026*	250	250
SO_4^{2-} (mg/L)	9.11± 0.59^{ab}	11.33± 4.22^{ab}	17.33± 7.90^{b}	7.56± 2.34^{a}	10.56± 1.14^{ab}	13.77± 1.52^{ab}	13.83± 2.37	11.33± 1.58	1.390	0.222	100	500
NO_3^{-} (mg/L)	2.94± 0.14^{a}	3.28± 0.22^{ab}	4.10± 1.41^{abc}	3.69± 0.14^{ab}	4.39± 0.70^{ab}	6.17± 0.51^{ab}	4.25± 0.46	4.64± 0.40	3.546	0.002**	50	50

P<0.05=* Significant difference; P<0.01=** Highly significant difference; P<0.001=*** Very highly significant difference; Mean values with the same alphabets as superscripts along the row are not statistically significantly different; NG = No guideline value; NM = Not Mentioned; Nig.Std = NSDQW, 2007

4.97 NTU) was found in the pond. The highest mean value for water temperature (29.32 ± 0.36°C) was recorded in the pond during the dry season. Turbidity's highest mean value was found in the river (168.06 ± 87.79 NTU) during the wet season (Table 2). The water temperature values were very highly significantly different (P<0.001) across the water bodies. The higher water temperature recorded during the dry season could be attributed to direct heat from sunlight impacting the water. This finding is in agreement with Abowei (2010) who reported that higher surface water temperature during dry season is expected, as heat from sunlight increases water temperature. It may also be due to low relative humidity and reduction in the amount of suspended particles in the air environment. However, turbidity showed a high significant difference (P<0.01) between the river and other water bodies (Table 2). The higher wet season turbidity could be attributed to input of silt, and increase in abundance of phytoplankton and organic matter with run-off. Phytoplankton biomass influences water transparency. The seasonal variation of pH in the water samples showed that the highest mean value of 7.15 ± 0.29 was found in river during the dry season, while it was least (5.94 ± 0.32) in the pond during the dry season (Table 2). There was a high significant difference (P<0.01) in pH across the three water bodies (Table 2). The higher pH value recorded during the dry season in the present work could be due to increased photosynthesis and evaporation of water. Photosynthetic assimilation of dissolved inorganic carbon can increase pH (Khan and Chowdhury, 1994). Table 2 also revealed that all the water bodies except the river showed pH in acidic medium in both seasons. The highest acidic pH value of 5.94 ± 0.32 was found in the pond in dry season, while the least acidic pH of 6.95 ± 0.03 was recorded in the stream during the wet season. The acidic pH of surface water bodies can be caused by several factors, including agricultural activities and acid rain (Iyama et al., 2019).

According to Ugbaja and Ephraim (2019) the acidic nature of the water samples is a possible reflection of the presence of high levels of free CO_2 in the waters. An important problem associated with acidic nature of surface water is that these water favour the mobility of non-biodegradable and hazardous trace elements within them (Ephraim and Ajayi, 2015).

For magnesium ($Mg^{2+)}$, potassium (K^+), sodium (Na^+), chloride (Cl^-) and nitrate (NO_3^-) ions, the highest mean values of 1.85 ± 0.52, 12.69 ± 1.99, 19.54 ± 4.83, 21.15 ± 5.23 and 6.17 ± 0.51 mg/L were recorded in the pond during the dry season respectively (Table 2). The least values for K^+ and Cl^- (2.32 ± 0.73 and 4.18 ± 0.34 mg/L) were recorded in the stream during the dry season, while the least value for NO_3^- (2.94 ± 0.14 mg/L) also occurred in the stream but in the wet season. Least value for Mg^{2+} 1.24 ± 0.55 mg/L occurred in the river during the wet season (Table 2). Higher levels of Cl^- and NO_3^- in the dry season than in wet season is probably due to dilution effect, and demonstrate an increase in the discharge of the respective components into the water body with time (Ugbaja and Ephraim, 2019).

Calcium ion (Ca^{2+}) had its highest mean values of 36.11 ± 2.46 mg/L in the stream and Sulphate ion (SO_4^{2-}) had its highest mean values 17.33 ± 7.90 mg/L in the river occurring during the wet season, while their least values 12.50 ± 2.76 and 7.56 ± 2.34 mg/L occurred in the river but during wet and dry seasons respectively (Table 2).

The highest mean values of Total Dissolved Solids (TDS) (130.07 ± 21.98 mg/L), Dissolved Oxygen (DO) (6.93 ± 0.48 mg/L) and Biochemical Oxygen Demand (BOD) (3.00 ± 1.00 mg/L) occurred during the dry season, in pond, river and stream respectively (Table 2). However, the least values of TDS (48.29 ± 21.05 mg/L) and BOD (1.60 ± 0.46 mg/L) occurred in the river during the wet season, while the least value for DO (4.40 ± 0.44 mg/L) was found in the pond during the wet season (Table 2). There was significant difference ($P<0.05$) in the values of TDS across the water bodies, while there was no significant difference ($P>0.05$) in values of DO and BOD across the water bodies (Table 2). Higher value of TDS in dry season is possibly caused by greater water evaporation often encountered during dry season (Ugbaja and Ephraim, 2019). High TDS value is also indicative of hard water and the presence of toxic minerals which emanated from some dissolved solids of organic origin (Iyama et al., 2019). According to Ephraim and Ajayi (2015), low BOD value is an indication of limited levels of organic matter decomposition requiring oxygen from the water.

Results of seasonal variations of heavy metals in the water bodies revealed that iron (Fe) concentration highest mean value of 2.76 ± 1.32 mg/L was recorded in the river during the dry season, while the least mean value of 0.28 ± 0.059 mg/L was found in the stream during the wet season (Table 3). There was a very highly significant difference ($P<0.001$) in the mean values of Fe when compared across the water bodies as shown in Table 3.

Iron is found in relatively high concentrations in fresh water ecosystems and in many respects can be viewed as master metal owing to their ability to influence the cycles of other biologically important elements through both microbial mediated and abiotic reaction (Nwineewii and Edem, 2014). Nwineewii and Edem (2014) also reported higher iron concentration in surface water during the dry season.

Zinc (Zn) had the highest mean value of 0.11 ± 0.018 mg/L in the stream during the dry season, while it was least (0.088 ± 0.0097mg/L) in the pond during the dry season (Table 3). There was no significant difference ($P>0.05$) in Zn concentration across the water bodies.

Among the water bodies, the highest mean values of manganese (Mn) (0.091 ± 0.004 mg/L), lead (Pb) (0.23 ± 0.031 mg/L) and cadmium (Cd) (0.095 ± 0.0071 mg/L) were recorded in the pond during the dry season, while the least values of Mn (0.046 ± 0.006 mg/L) and Pb (0.016 ± 0.00 mg/L) occurred in the stream in the wet season. However, the least value of Cd (0.088 ± 0.0038 mg/L) was found in the dry season in the stream (Table 3). There was no significant difference ($P>0.05$) in Mn and Cd concentrations, while there was a highly significant difference ($P<0.001$) in the concentration of Pb across the water bodies (Table 3). Comparison of values of selected parameters obtained in this study with National (Nigerian) and International (WHO) standards revealed that only Mg^{2+} was higher than national and international standards, while for other parameters such as Na^+, Cl^-, NO_3^-, and SO_4^{2-}, values obtained in this study were within national and international standards (Table 2).

Table 4 shows the comparison between the seasonal variation in selected physico-chemical parameters of water and sediment samples. In sediments, the highest mean value of pH was recorded in the river during the dry season (5.87 ± 0.07), while the least value was also obtained in the river during the wet season (5.64 ± 0.09) as presented in Table 4. The result of this study agrees with those of Olatunji et al. (2016) who also recorded acidic pH values in dry season of soils around a scrap metal recycling factory. Akinnifesi et al. (2005) attributed this to the fact that tropical soils are generally slightly acidic. Table 4 also reveals that the pH of water and sediment from the water bodies, with the exception of the water samples from the river, were all slightly acidic. Very highly significant difference ($P<0.001$) existed between pH of the water and sediment samples (Table 4).

For Na^+ and K^+, the highest mean values in sediments were found in the pond during the dry season (0.50 ± 0.02 and 0.42 ± 0.01cmol/kg) respectively, while the lowest mean values (0.47 ± 0.01 and 0.37 ± 0.01 cmol/kg)

Table 3. Seasonal variation in heavy metals parameters of water samples in the water bodies.

Parameter (mg/L)	Yagbo Stream		Awosun River		Pond		Overall Mean		F	P	Nigerian Standard	WHO
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry				
Cd	0.09± 0.0022^{a}	0.088± 0.0038^{a}	0.091± 0.0^{a}	0.089± 0.0035^{a}	0.092± 0.0026^{a}	0.095± 0.0071^{a}	0.089± 0.001	0.087± 0.002	0.430	0.912	0.003	0.003
Cr	0.058± 0.035^{ab}	0.0043± 0.0063^{a}	0.030± 0.024^{ab}	0.0057± 0.0008^{a}	0.0052± 0.0055^{a}	0.0023± 0.0048^{a}	0.067± 0.027	0.004± 0.0035	2.726	0.013*	0.05	0.05
Fe	0.28± 0.059^{a}	0.67± 0.11^{a}	1.06± 0.59^{a}	2.76± 1.32^{b}	0.33± 0.042^{a}	0.66± 0.42^{a}	0.47± 0.16	1.15± 0.40	6.223	0.000***	0.3	NG
Mn	0.046± 0.006^{a}	0.084± 0.006^{a}	0.047± 0.0055^{a}	0.087± 0.007^{a}	0.05± 0.0046^{a}	0.091± 0.004^{a}	0.11± 0.07	0.08± 0.002	0.733	0.677	0.20	0.5
Zn	0.094± 0.018^{a}	0.11± 0.018^{a}	0.095± 0.013^{a}	0.10± 0.021^{a}	0.092± 0.0065^{a}	0.088± 0.0097^{a}	0.10± 0.007	0.095± 0.009	0.668	0.733	3.00	3.00
Pb	0.016± 0.00^{a}	0.17± 0.029^{bc}	0.12± 0.098^{abc}	0.19± 0.044^{bc}	0.082± 0.057^{ab}	0.23± 0.031^{bc}	0.03± 0.03	0.17± 0.017	4.190	0.001**	0.01	0.01

P<0.05=* Significant difference; P<0.01=** Highly significant difference; P<0.001=*** Very highly significant difference; Mean values with the same alphabets as superscripts along the row are not statistically significantly different; NG = No guideline value; Nig.Std = NSDQW, 2007

Table 4. Seasonal variation in selected physico-chemical parameters of water and sediment samples.

Parameters Unit (water;sediment)	Yagbo Stream				Awosun river				Pond					
	Water		Sediment		Water		Sediment		Water		Sediment			
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	F	P
pH	6.95±0.03^{cd}	6.68±0.22^{b}	5.67±0.03^{a}	5.86±0.04^{a}	7.02±0.08^{bcd}	7.15±0.29^{bc}	5.64±0.09^{a}	5.87±0.07^{a}	6.51±0.12^{de}	6.27±0.26^{e}	5.65±0.05^{a}	5.84±0.06^{a}	769.186	0.000***
Na^{+} (mg/L; cmol/kg)	8.70±0.92^{b}	6.22±1.74^{b}	0.48±0.01^{a}	0.49±0.01^{a}	7.77±1.35^{b}	5.33±1.91^{b}	0.49±0.02^{a}	0.49±0.03^{a}	9.50±1.20^{b}	9.88±3.87^{b}	0.47±0.01^{a}	0.50±0.02^{a}	10.488	0.000***
K^{+} (mg/L; cmol/kg)	2.60±0.21^{ab}	2.32±0.73^{ab}	0.37±0.01^{a}	0.41±0.01^{a}	3.28±0.27^{ab}	4.40±0.64^{bc}	0.38±0.01^{a}	0.42±0.01^{a}	6.78±1.77^{cd}	8.30±2.52^{d}	0.38±0.01^{a}	0.42±0.01^{a}	9.805	0.000***
Ca^{2+} (mg/L; cmol/kg)	16.41±1.12^{c}	8.81±2.61^{b}	0.14±0.003^{a}	0.13±0.003^{a}	8.93±1.97^{b}	15.50±10.77^{c}	0.14±0.003^{a}	0.14±0.01^{a}	7.37±0.74^{b}	7.23±1.91^{b}	0.13±0.003^{a}	0.14±0.004^{a}	21.186	0.000***
Mg^{2+} (mg/L; cmol/kg)	1.39±0.01^{a}	1.75±0.46^{a}	3.17±0.07^{c}	2.66±0.09^{bc}	1.24±0.06^{a}	1.39±0.06^{a}	3.10±0.22^{c}	2.32±0.42^{b}	1.25±0.02^{a}	1.65±0.24^{a}	3.03±0.11^{c}	2.40±0.26^{b}	11.120	0.000***
SO_4^{2-} (mg/L; cmol/kg)	9.11±0.59^{ab}	11.33±4.22^{ab}	10.17±0.33^{a}	11.43±0.21^{a}	17.33±7.90^{c}	7.56±2.34^{a}	10.20±0.79^{a}	12.41±0.41^{a}	8.45±2.41^{a}	14.66±2.63^{bc}	10.22±0.38^{a}	11.17±0.56^{a}	5.209	0.000***
Cl^{-} (mg/L; cmol/kg)	5.95±0.83^{a}	4.18±0.34^{a}	420.99±46.58^{b}	298.13±20.65^{b}	9.50±4.25^{a}	6.33±0.67^{a}	445.23±78.91^{b}	335.83±65.81^{b}	6.21±0.83^{a}	9.11±1.58^{a}	318.07±61.01^{b}	312.31±40.47^{b}	55.707	0.000***
NO_3^{-} (mg/L; cmol/kg)	2.94±0.14^{b}	3.28±0.22^{bc}	0.007±0.001^{a}	0.006±0.001^{a}	4.10±1.41^{c}	3.69±0.14^{bc}	0.008±0.002^{a}	0.004±0.007^{a}	3.65±0.43^{bc}	3.90±0.32^{c}	0.006±0.001^{a}	0.004±0.001^{a}	14.641	0.000***
Fe (mg/L; mg/kg)	0.09±0.002^{a}	0.09±0.003^{a}	1.02±0.05^{a}	0.66±0.04^{a}	0.09±0.0^{a}	0.09±0.004^{b}	0.52±0.17^{a}	0.63±0.04^{a}	0.09±0.004^{a}	0.10±0.01^{a}	0.86±0.02^{a}	0.61±0.03^{a}	3.897	0.000***
Zn (mg/L;mg/kg)	0.06±0.04^{a}	-0.004±0.01^{a}	0.44±0.01^{b}	0.48±0.01^{bc}	0.03±0.02^{a}	-0.01±0.0^{a}	0.45±0.02^{b}	0.52±0.01^{c}	0.01±0.01^{a}	-0.002±.003^{a}	0.86±0.06^{bc}	0.61±0.03^{d}	4.284	0.000***
Mn (mg/L;mg/kg)	0.28±0.06^{a}	0.67±0.11^{a}	0.42±0.01^{b}	0.43±0.02^{b}	1.06±0.59^{a}	2.76±1.32^{a}	0.42±0.03^{b}	0.43±0.02^{bc}	0.35±0.04^{a}	0.71±0.07^{a}	0.49±0.01^{bc}	0.59±0.01^{d}	5.998	0.000***
Pb (mg/L;mg/kg)	0.05±0.01^{a}	0.08±0.01^{cde}	0.09±0.01^{bc}	0.06±0.004^{ab}	0.05±0.01^{bcd}	0.09±0.01^{de}	0.07±0.03^{ab}	0.05±0.01^{ab}	0.05±0.01^{bc}	0.0±0.004^{e}	0.44±0.03^{bc}	0.50±0.03^{ab}	83.191	0.000***
Cd (mg/L;mg/kg)	0.09±0.02^{bc}	0.11±0.02^{bc}	0.10±0.01^{c}	0.07±0.01^{ab}	0.10±0.01^{bc}	0.10±0.02^{bc}	0.08±0.02^{abc}	0.06±0.003^{a}	0.08±0.01^{bc}	0.09±0.01^{bc}	0.08±0.01^{bc}	0.06±0.01^{ab}	199.242	0.000***
Cr (mg/L;mg/kg)	-0.02±0.03^{c}	0.17±0.03^{a}	0.006±0.001^{a}	0.009±0.002^{ab}	0.12±0.10^{c}	0.19±0.04^{a}	0.01±0.003^{ab}	0.003±0.003^{a}	0.08±0.05^{a}	0.22±0.03^{a}	0.10±0.01^{ab}	0.07±0.004^{a}	5.561	0.000***

P<0.001=*** Very highly significant difference; The first unit on the parameters is for Water Samples, while the second unit on the parameters is for Sediment Samples; For each water body, mean values with the same alphabets as superscripts along the row are not statistically significantly different.
Note: the unit in front of each parameter is indicated for water and sediment respectively that is (water units; sediment units).

were found during the wet season, but in the pond and stream respectively.

The mean value of Fe and Cd were highest in the stream during the wet season (1.02 ± 0.05 and 0.10 ± 0.01 mg/kg respectively), and lowest in the river during the wet and dry seasons (0.52 ± 0.17 and 0.06 ± 0.003 mg/kg) respectively as shown in Table 4. The finding of this study agrees with that of Owoade et al. (2014) who also found that Cd was higher in wet season than in dry season in their study of soils around a scrap metal recycling factory. This may be due to the effect of rainfall which may have facilitated surface runoff and leaching of heavy metals from soils (Yahaya et al., 2010). For Zn, the mean value was highest in the pond during the wet season (0.86 ± 0.06 mg/kg) and least in the stream during the wet season (0.44 ± 0.01 mg/kg). This agrees with the study of Olatunji et al. (2016) who recorded higher Zn value in wet season in soil in the vicinity of an iron smelting plant, and attributed it to the fact that heavy metals are more readily available during the rainy season than during the dry season.

Comparison of the results between water samples and sediment samples revealed that, in the stream, the recorded mean values of Mg^{2+}, SO_4^{2-}, Cl^-, Fe, Zn and Pb were higher in sediment samples (3.17 ± 0.07, 11.43 ± 0.21, 420.99 ± 46.58, 1.02 ± 0.05, 0.48 ± 0.01 mg/kg and 0.09 ± 0.01 mg/kg respectively) than in water samples (Table 4). The higher levels of Mg^{2+}, Cl^-, Fe and Pb in sediment in the stream occurred in wet season, while the higher values of $SO_4^{2-}$and Zn in sediment in the stream occurred in the dry season. A very highly significant difference (P<0.001) existed between the water and sediment mean values of Mg^{2+}, Cl^-, Fe and Pb in the stream as shown in Table 4. On the other hand, the mean values of pH, Na^+, Ca^{2+}, NO_3^-, Mn, Cd and Cr in the stream were higher in water samples (6.95 ± 0.03, 8.70 ± 0.92, 2.60 ± 0.21, 16.41 ± 1.12, 3.28 ± 0.22, 0.67 ± 0.11, 0.11 ± 0.02 and 0.17 ± 0.03 mg/L respectively) than in sediment samples (Table 4). The higher value of pH recorded in water samples in this study occurred in wet season, while the higher values of Mn, Cd and Cr occurred in dry season (Table 4). There was a very highly significant difference (P<0.001) between the water and sediment mean values of pH, Na^+, Ca^{2+}, NO_3^-, Mn, Cd and Cr in the stream (Table 4). Higher values of Na^+, K^+ and NO_3^- in water could be due to the fact that they are soluble in water, and may be present in highly soluble form in water samples.

In the River, Mg^{2+}, Cl^-, Fe and Zn Mean ± S.E values were higher in sediment samples (3.10 ± 0.22, 445.23 ± 78.91, 0.63 ± 0.04 and 0.52 ± 0.01 mg/kg respectively) than in water samples (Table 4). However, Mg^{2+} and Cl^- were higher in wet season, while Fe and Zn were higher in dry season, in the sediment samples as shown in Table 4. There was also a very highly significant difference (P<0.001) between the water and sediment mean values of all the parameters listed above in the river (Table 4). However, the mean ± S.E values of pH (7.15 ± 0.29), Na^+ (7.77 ± 1.35mg/L), K^+ (4.40 ± 0.64 mg/L), Ca^{2+} (15.50 ± 10.77 mg/L), SO_4^{2-} (17.33 ± 7.90 mg/L), NO_3^- (4.10 ± 1.41 mg/L), Mn (2.76 ± 1.32 mg/kg), Pb (0.09 ± 0.01 mg/kg), Cd (0.10 ± 0.02 mg/kg) and Cr (0.19 ± 0.04 mg/kg) in the river were higher in water samples than in sediment samples (Table 4). The recorded higher values of Na^+, SO_4^{2-}, NO_3^- and Cd in the water samples occurred in the wet season, while for pH, K^+, Ca^{2+}, Mn, Pb and Cr, the higher values occurred in the dry season (Table 4). There was a very highly significant difference (P<0.001) between the water and sediment mean values of all the parameters listed above in the river (Table 4). The high probability for solubility, and the form in which they are present may be responsible for the higher values of Na^+, K^+ and NO_3^- in the water samples than in the sediment samples. Ionic compounds with NO_3^- are known to form soluble cations.

In the pond, the mean ± S.E values of Mg^{2+}, Cl^-, Fe, Zn and Pb were higher in the sediment samples (3.03 ± 0.11, 318.07 ± 61.01, 0.86 ± 0.02, 0.86 ± 0.06 and 0.50 ± 0.03 mg/kg respectively) than in the water samples as presented in Table 4. The higher values in sediment obtained for all the parameters occurred in the wet season, except for Pb which occurred in the dry season (Table 4). There was a very highly significant difference (P<0.001) between the mean values of the parameters listed above in water and sediment samples in the pond (Table 4). It was also revealed from Table 4 that the mean ± S.E values of pH, Na^+, K^+, Ca^{2+}, SO_4^{2-}, NO_3^-, Mn, Cd and Cr in the pond were higher in water samples (6.51 ± 0.12, 9.88 ± 3.87, 8.30 ± 2.52, 7.37 ± 0.74, 14.66 ± 2.63, 3.90 ± 0.32, 0.71 ± 0.07, 0.09 ± 0.01 and 0.22 ± 0.03mg/L respectively) than in sediment samples as shown in Table 4. Except for the mean value of pH and Ca^{2+} which were higher in wet season, all other parameters listed above were higher in dry season. There was a very highly significant difference (P<0.001) between the mean values of the parameters listed above in water and sediment samples in the pond (Table 4).

Across the water bodies, pH, Na^+, K^+, Ca^{2+}, SO_4^{2-}, NO_3, Mn, Cd and Cr were higher in water samples than in sediment samples (Table 4). On the other hand, Mg^{2+}, Cl, Fe and Zn were higher in sediment samples than in water samples as shown in Table 4. SO_4^{2-} was higher in water samples in river and pond, while it was higher in sediment sample in the stream. For Pb, higher concentration was recorded in sediment samples in stream and pond (Table 4). According to Eddy et al. (2004), high load of heavy metals in sediment could be due to the fact that sediment acts as a sink or reservoir for heavy metals. Metals interact with organic matter in the aqueous phase and so settle down thereby resulting in a high concentration of metals in sediment (Begun et al., 2009). High concentration of Zn and Pb in soils is indicative of Pb being the primary anthropogenically derived pollutant trace metal in a given soil environment. The higher concentration of Cr in water samples than in sediment samples across the water bodies may be due to the unstable nature of Cr^{6+} which is the most unstable form of the metal. Salami et al. (2014) attributed low Cr concentration in the soil around a scrap metal recycling factory to the fact that most of the paints in the scraps have peeled off before they were brought to the factory for recycling, and possible conversion to Cr^{6+} due to the presence of organic matter content. Cr^{6+} is very unstable under normal soil condition (Salami et al., 2014). Availability of Cr^{6+} depends on pH and texture of the soil. When compared with national and international standards, parameters such as Pb, Cd and Fe were higher, while Mn, Zn and Cr were within the national and international standards.

Conclusion

This study has been able to document the physicochemical quality of water and sediment from surface water bodies around a Scrap Metal Recycling Industry. Across the threei water bodies, Fe and Zn were higher in sediment samples than in water samples while pH, Mn, Cd and Cr were higher in water samples than in sediment samples. Generally, the majority of the detected parameters did not exceed the national and international standards. However, detected levels of heavy metals like cadmium, lead and iron significantly exceeded the national and international standards. The high levels of these heavy metals may be due to the impact of the Scrap Metal Recycling Industry.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abowei JFN (2010). Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. Advance Journal of Food Science and Technology 2(1):36-40.

Ademoroti CMA (1996). Environmental Chemistry and Toxicology. Foludex Press Limited, Ibadan pp. 44-47

Adeniyi IF (2004). The Concept of Water Quality In: Ife Environmentalist, Official Bulletin of Nigerian Society for Environmental Management (NISEM) OAU. 1(1):2.

Akinnifesi TA, Asubiojo OI, Amusan AA (2005). Effects of fungicide residues on the physico-chemical characteristics of soils of a major cocoa-producing area of Nigeria. Science of the Total Environment 38:6803-6812.

Alafara AB, Adekola FA, Folashade AO (2005). Quantitative leaching of a Nigerian iron ore in hydrochloric acid. Journal of Applied Science and Management 9(3):15-20.

American Public Health Association (APHA) (2012). Standard methods for the examination of water and wastewater. 20th edn, American Public Health Association, Washington DC.

Begun A, Ramaiah M, Harikrishna KI, Veena K (2009). Heavy metal pollution and chemical profile of Cauvery River water. E - Journal of Chemistry 6(1):47-52.

Chinedu SN, Nwinyi OC, Oluwadamisi AY, Eze VN (2011). Assessment of Water quality in Cannanland, Ota, Southwest Nigeria. Agriculture and Biology Journal of North America. ISSN Print:2151-7517.

Eddy NO, Udoh CL, Ndibuke MO (2004). Heavy metals in sediments from Cross River at Oron. African Journal Environmental Science and Health 7:115-119.

Ephraim BE, Ajayi IO (2015). Compositional evaluation and quality status of surface water of Mbat-Abiati and Oberekkai creeks of Great Kwa River, Southeastern Nigeria. Advances in Applied Sciences Research 6(6):36-46.

Golterman HL, Clymo RS, Ohnstad M (1978). Methods for physical and chemical analyses of freshwater. IBP Handbook No. 8. Blackwell Scientific. Oxford.

Iyama WA, Edori OS, Ede PN (2019). Physicochemical assessment of surface water quality around the Sagbama Creek water body, Bayelsa State, Nigeria. Global Journal of Science Frontier Research: B Chemistry 19:1.

Jonnalagada SB Mhere G (2001). Water Quality of the Odzi River in the Eastern Highlands of Zimbabwe. Water Research 35:2371-2376. http://dx.doi.org/10.1016/S0043-1354(00)00533-9

Khan MAG, Chowdhury SH (1994). Physico-chemical Limnology of Lake Kaptai, Bangladesh. Tropical Ecology 35(1):35-51.

Lkr A Singh, MR Puro N (2020). Assessment of water quality status of Doyang River, Nagaland, India, using Water Quality Index.Applied Water Science 10:46

Nayar R (2020). Assessment of Water Quality Index and Monitoring of Pollutants by Physico-Chemical Analysis in Water Bodies: A Review. International Journal of Engineering Research and Technology 09(01).

Ning L Liyuan Y Jirui D Xugui P (2011). Heavy Metal Pollution in Surface Water of Linglong Gold Mining Area, China. Procedia Environmental Sciences 10:914-917. doi:10.1016/j.proenv.2011.09.146

NSDQW (2007). Nigerian Standard for drinking water and wastewater. Standard Organisation of Nigeria/Nigerian Industrial Standards.NIS 554:1-30.

Nwineewii JD, Edem CA (2014). Determination and toxicological effects of some heavy metals in surface water from the Niger delta, Nigeria. IOSR Journal of Applied Chemistry (IOSR - JAC) e - ISSN: 2278-5736. 7(5):32-36.

Olatunji OA, Komolafe ET, Oke SO (2016). Seasonal variation in physicochemical properties of soil within the vicinity of an iron smelting factory – implication on standing vegetation. Notulae Scientia Biologicae 8(2):220-225

Owoade OK, Awotoye OO, Salami OO (2014). Ecological vulnerability: seasonal and spatial assessment of trace metals in soils and plants in the vicinity of a scrap metal recycling factory in Southwestern Nigeria. Environmental Monitoring and Assessment 186(8).

Salami OO, Awotoye OO, Owoade OK (2014). Markers of environmental health: nickel and chromium levels in soil and vegetation around a steel recycling facility in Southwest Nigeria. British Journal of Applied Science & Technology 4(7):1060-1070.

Ugbaja AN, Ephraim BE (2019). Physicochemical and bacteriological parameters of surface water quality in part of Oban Massif, Nigeria. Global Journal of Geological Sciences 17:13-24

USAID (2002). Nigeria Environmental Analysis, USAID BIOFOR IQC No. LAG-I-00-99-00013-00

Wang J Chen C (2015). The current status of heavy metal pollution and treatment technology development in China. Environmental Technology Reviews 4(1):39-53. doi:10.1080/21622515.2015.1051136

Yahaya MI, Ezeh GC, Musa YF, Mohammed SY (2010). Analysis of heavy metals concentration in road sides soils in Yauri, Nigeria. African Journal of Pure and Applied Chemistry 4(3):022-030.