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Hydrochemical Appraisal of Isebo River in Ibadan South-Western Part of Nigeria

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Author's contribution

This whole work was carried out by the author OA.

Original Research Article

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ABSTRACT

Aims: To investigate the hydrochemical regime of Isebo River in Ibadan, South-western Nigeria with respect to its chemical quality status for drinking purposes due to its proximity to an industrial area and to also give recommendations based on the findings.
Methodology: Ten water samples were collected from the river while five raw effluent samples were also collected from the discharge points of the polluting industries in order to assess their chemical composition and toxicity levels in the laboratory. Concentrations of heavy metals, such as, Iron (Fe), Copper (Cu), Zinc (Zn), Chromium (Cr), Cadmium (Cd), Nickel (Ni) and Lead (Pb) were determined using Inductively Coupled Plasma (ICP) and Optical Electro-Spectrometer (OES) analytical procedures respectively. Physico-chemical parameters such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Temperature (T), the acidity and basicity levels (pH) of both the effluent and water samples were determined in the field using a Symphony SP80PC portable instrument.
Results: The output of the chemical analyses revealed mean concentrations in the order of abundance of toxic heavy metals in effluent samples as Fe>Zn>Cu>Cr>Ni>Pb>Cd while that of water sample analysis data is given as Fe>Zn>Cu>Ni>Cr>Pb>Cd. The coefficient of determination R^2= 0.9784 and 0.9809 of EC and TDS obtained for effluent and water samples respectively, shows a good positive correlation coefficient between the two parameters while temperature and pH varied anomalously.
Conclusion: The mean values of heavy metals in effluent and water samples are generally higher than the background values and the threshold of permissible contaminant levels established by the World Health Organization (WHO) respectively and

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this could lead to serious health hazards. Therefore, it is recommended that environmental monitoring and state-of-the-art effluent treatment facilities should be put in place by the polluting industries to prevent further pollution of the river and vulnerability of man to potential health hazards.

Keywords: Isebo River; raw effluents; heavy metals; pollution; environment; health hazards.

1. INTRODUCTION

Water is essential for human existence. Life on earth depends on air, water and food amongst other essential life sustaining resources. However, if the environment is polluted, it can lead to diseases and chronic ailments that could result to death. In view of this, water pollution study has been a global environmental stake from antiquity. Industrialization and socio-economic growth have always been in conflict with environmental sustainability, this is because the rapid expansion of the industrial sector has led to the discharge of significant quantity of toxic waste into the environment, thus creating environmental degradation and health hazards. An industrial area in Ibadan, South-western part of Nigeria was mapped out for environmental assessment due to indiscriminate disposal of raw effluents into the environment which is presumably contributing to the contaminant load of the nearby river which may affect the well-being of inhabitants and give rise to environmental nuisance. Many researchers have carried out a number of studies on toxic heavy metals and anthropogenic inputs have been attributed to their presence in effluent samples. The research carried out by [1] on toxic metals in effluent samples corroborates the study carried out by [2] that heavy metals such as Mercury (Hg), Arsenic (As), Nickel (Ni), Iron (Fe), Lead (Pb), Chromium (Cr), Zinc (Zn), Copper (Cu) and Cadmium (Cd) are prominent components of industrial effluents. Global environmental monitoring efforts geared towards environmental assessment reveals that heavy metals have become increasingly significant within the framework of environmental pollution research [3,4,5]. Some chemical substances have been shown to cause widespread health hazards in humans as a result of exposure through drinking water when they are present in excessive quantities [6].

The carcinogenicity of heavy metals has been studied by various researchers. The carcinogenic properties of some heavy metals and their persistence in the environment is of serious concern because they are not biodegradable and can transform from one oxidation state or organic complex to another [7,8]. Environmental scientists have dedicated massive research efforts to the study of heavy metals in water and the environment at large due to their mutagenic and carcinogenic properties since they have direct exposure to humans and other organisms [9]. The results of recent research conducted by [10] show the concentration of some heavy metals in the effluents discharged by some of the pharmaceutical companies in Lagos, South-western Nigeria. The regular monitoring of toxic heavy metals in effluents, animals, plants and other agricultural produce is expedient in order to prevent their excessive build-up in the food chain [11].

The effluent samples were collected from the points of discharge of the confectionery, paints, pharmaceutical, agrochemical and bottling companies in the study area. The pharmaceutical company was producing prescription medicines, vaccines and some healthcare products. The agrochemical company was producing pesticides and herbicides while the confectionery company was producing chocolates, sweets and biscuits. The paint company was producing emulsion and coating for interior usage while the bottling company was producing non-alcoholic drinks.

The indiscriminate disposal of untreated industrial effluents into the drains at the study sites has been posing environmental nuisance to the inhabitants and tends to degrade the chemical quality of River Isebo and the aesthetic integrity of the environment at large. The discharge from these industries flows through the open channels in the cities and the raw effluents enters River Isebo, thereby polluting the water resource. This study reveals the nature of chemical composition, toxicity levels of effluents, the presumed impacts on water quality and the potential health risks posed to the public and the environment.

2. MATERIALS AND METHODS

The topographical map of Ibadan (sheet 261 N.E.) on a scale of 1:25,000 was utilised as a base map. A mobile Global Positioning System (GPS) was used to determine the coordinates of the area which lies within Longitude 3º56'E and 3º59'E, and Latitude 7º23'N and 7º25'N as shown in Fig.1. River Isebo drains South-East while the drainage system of the area is sub-dendritic to dentritic and is controlled by the topography. This implies that the study area is underlain by homogeneous resistant rock which is characteristic of a Basement Complex setting. The Basement Complex form part of the African Crystalline Shield [12] while [13] classified the rocks of the Basement Complex of Nigeria into five main groups, such as, Migmatite gneiss complex, Charnokitic rocks, Schist, Older granites and Unmetamorphosed dolerite dykes.

The effluent discharge points and Isebo river course were mapped out for sampling programme. Raw effluent samples were collected from the drains of the polluting companies while water samples were collected from the downstream region for onward chemical analyses in the laboratory. Samples were collected into sterile 250 ml PyrexR bottles at the point where the effluents were being discharged by the companies into the environment and then stored in a refrigerator at 2-8ºC before conveyance to the laboratory for chemical analyses. A total of 5 effluent samples were collected at peak production periods and were denoted with EF-01 to EF-05 while 10 water samples were collected from the river and were denoted with W1 to W10 respectively.

Water and raw effluent samples were analysed to determine the concentrations of toxic heavy metals using Inductively Coupled Plasma (ICP) and Optical Electro-Spectrometer (OES) methods respectively. The ICP-OES analytical procedures have been described by [14,15] analytical procedures. Accuracy and instrument detection limits for measured heavy metals were estimated by taking replicate measurements of the calibrated blank (1% nitric acid) in accordance with 85-115% of the Environmental Protection Agency set limit [15] and accuracy of 0.1 for Cd, 1.5 for Pb, 0.5 for Ni and 0.3 for Cr and Cu respectively. A Symphony SP80PC portable instrument was employed in determining the physico-chemical parameters *In situ* which includes temperature, EC, TDS and pH. Accuracy was 1% for EC, ±0.1ºC for temperature and ±0.05 for pH. The colour of effluent and water samples obtained was determined by visual observation in the field.

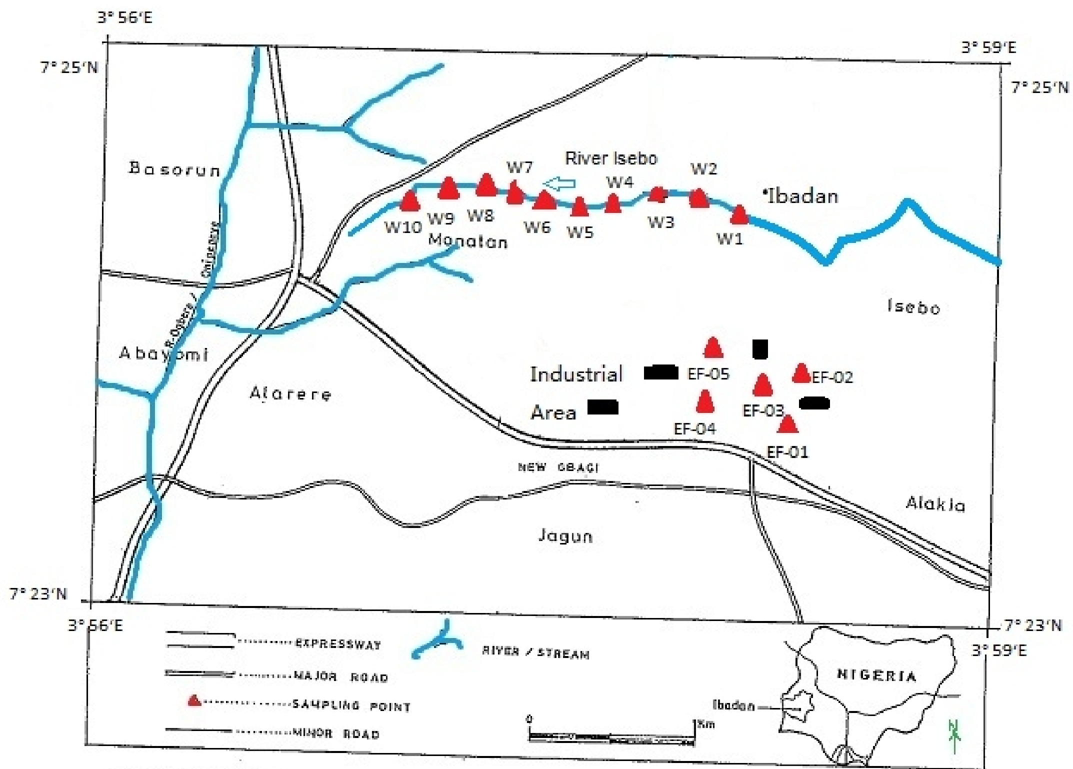

FIGURE 1: LOCATION AND DRAINAGE MAP OF THE STUDY AREA SHOWING SAMPLE POINTS

3. RESULTS

The results obtained from chemical and statistical analyses of effluent and water samples are reported in Tables 1 to 6 and depicted graphically in Figs. 2 to 7 respectively.

Table 1. Heavy metal concentrations in effluent samples (mg/l)

Sample	Zn	Fe	Cu	Ni	Pb	Cr	Cd
EF-01	10.8	12.0	7.7	4.5	0.7	4.6	0.8
EF-02	8.9	11.2	6.3	5.8	0.8	5.4	0.7
EF-03	12.0	14.4	8.9	6.6	1.0	6.0	0.9
EF-04	6.8	10.2	5.0	3.9	0.8	4.9	0.6
EF-05	5.6	8.0	4.0	4.4	0.9	5.0	0.4

3.1 Chemical Analysis OF Effluent Samples

Table 2 represents some statistical data obtained for the heavy metals in various effluent samples while Fig. 3 is the graphical representation.

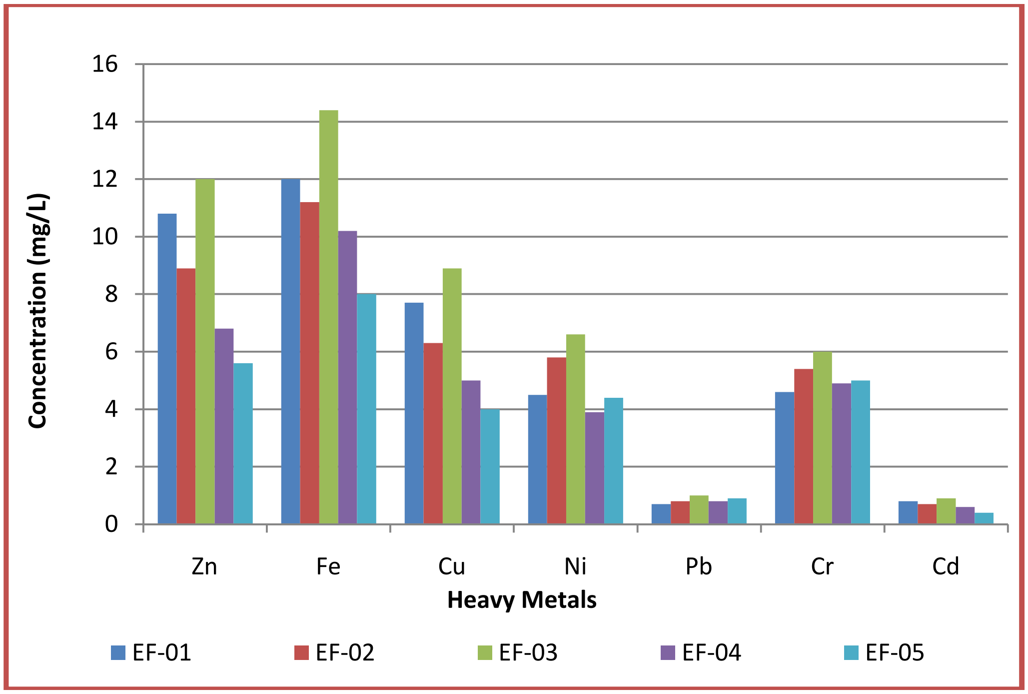

Fig. 2. Heavy metal distribution in effluent samples

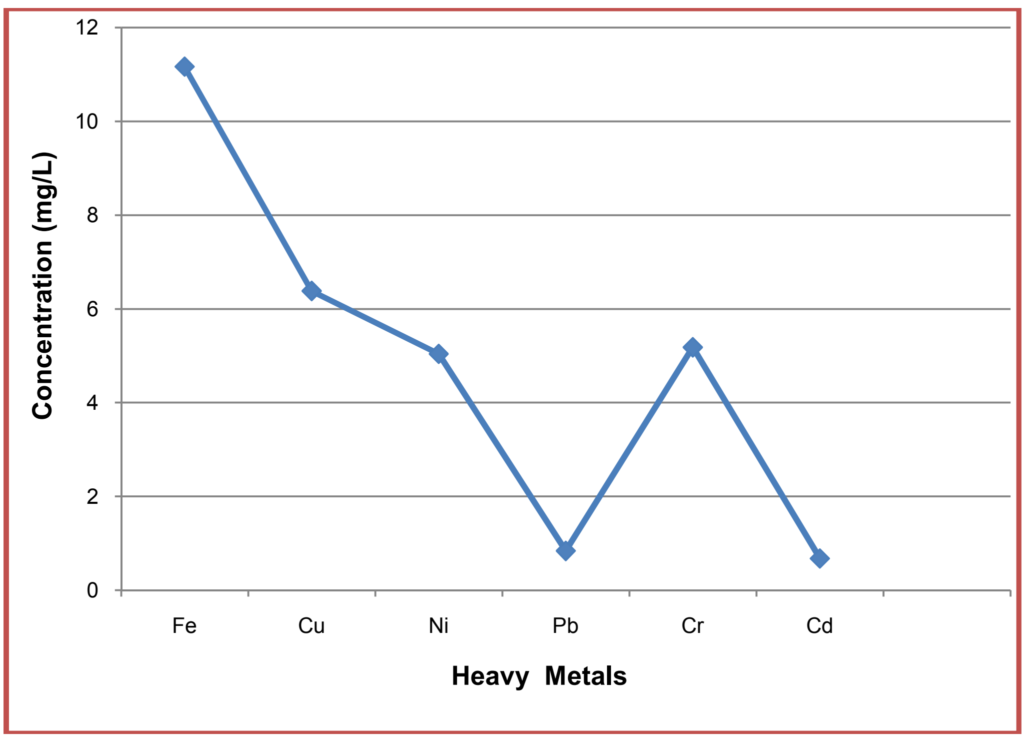

Fig. 3. Average Concentration of Heavy Metals in Effluent Samples

Table 2. Some statistical data obtained for heavy metals in effluent samples (mg/l)

Parameters	Zn	Fe	Cu	Ni	Pb	Cr	Cd
Average	8.82	11.16	6.38	5.04	0.84	5.18	0.68
Minimum	5.6	8.0	4.0	3.9	0.7	4.6	0.4
Maximum	12.0	14.4	8.9	6.6	1.0	6.0	0.9

In Table 3 and Fig. 4, the physico-chemical parameters of effluent samples measured *in situ* and a graphical illustration of the relationship between EC and TDS in form of linear regression plot are shown appropriately.

Table 3. Physico-chemical parameters of effluent samples

Sample	EC (µmhos/cm)	TDS (mg/l)	Temp. (°C)	pH
EF-01	1552.8	1100.7	33	6.3
EF-02	1400.1	1009.8	29	5.9
EF-03	2446.2	2001.8	34	5.2
EF-04	780.3	544.2	31	7.8
EF-05	501.1	455.6	30	5.5

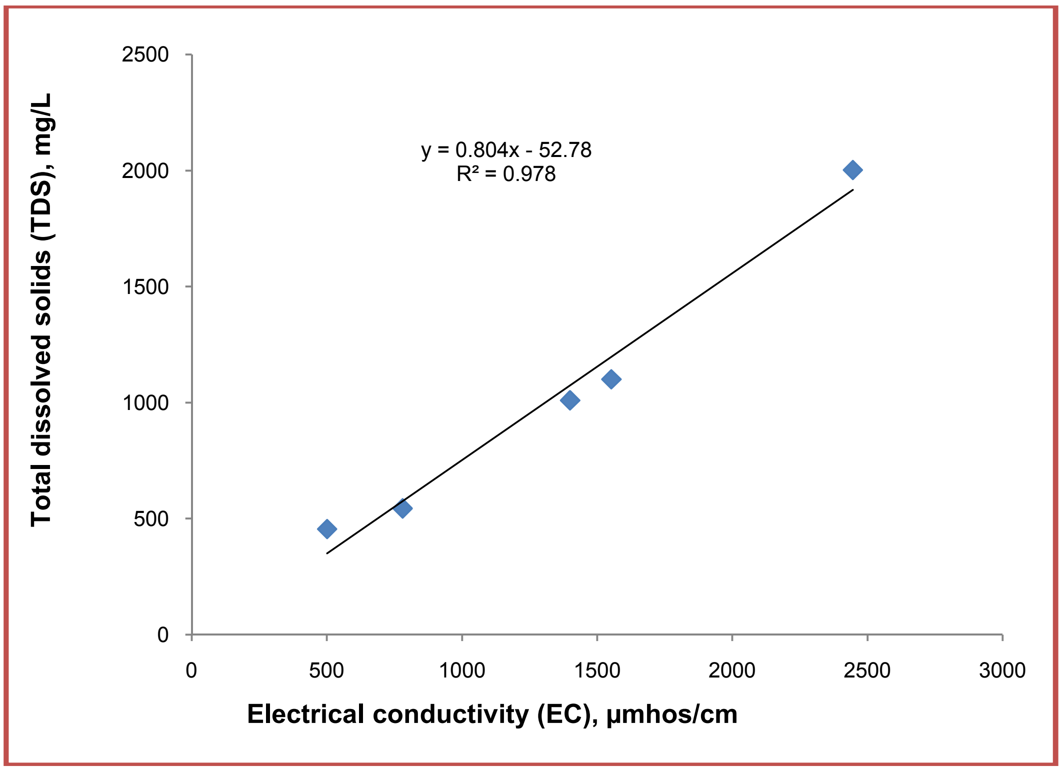

Fig. 4. Linear regression of EC and TDS of effluent samples

Table 4 and Fig. 5 present the chemical analysis data obtained for the water samples and its graphical representation.

Table 4. Heavy metal concentrations in water samples and WHO guideline values (mg/l)

Sample/ WHO Values	Zn 3.0	Fe 2.0	Cu 2.0	Ni 0.07	Pb 0.01	Cr 0.05	Cd 0.003
W1	4.1	8.0	5.2	2.1	0.5	0.6	0.4
W2	4.9	10.1	4.4	3.0	0.5	0.7	0.5
W3	7.0	12.4	6.9	3.9	0.8	1.5	0.8
W4	3.8	10.2	3.0	1.9	0.4	0.9	0.5
W5	3.6	8.0	3.0	1.4	0.2	0.5	0.2
W6	2.9	6.9	2.8	1.1	0.1	0.4	0.2
W7	4.0	7.7	3.8	0.9	0.3	0.2	0.1
W8	2.6	4.0	2.5	0.7	0.1	0.2	0.1
W9	3.3	3.8	2.4	1.2	0.1	0.3	0.2
W10	2.5	3.0	1.0	1.2	0.2	0.1	0.1

3.2 Chemical Analysis OF Water Samples

The results of some of the statistical parameters computed for heavy metals in water samples and the corresponding graphical illustration are presented in Table 5 and Fig. 6 respectively.

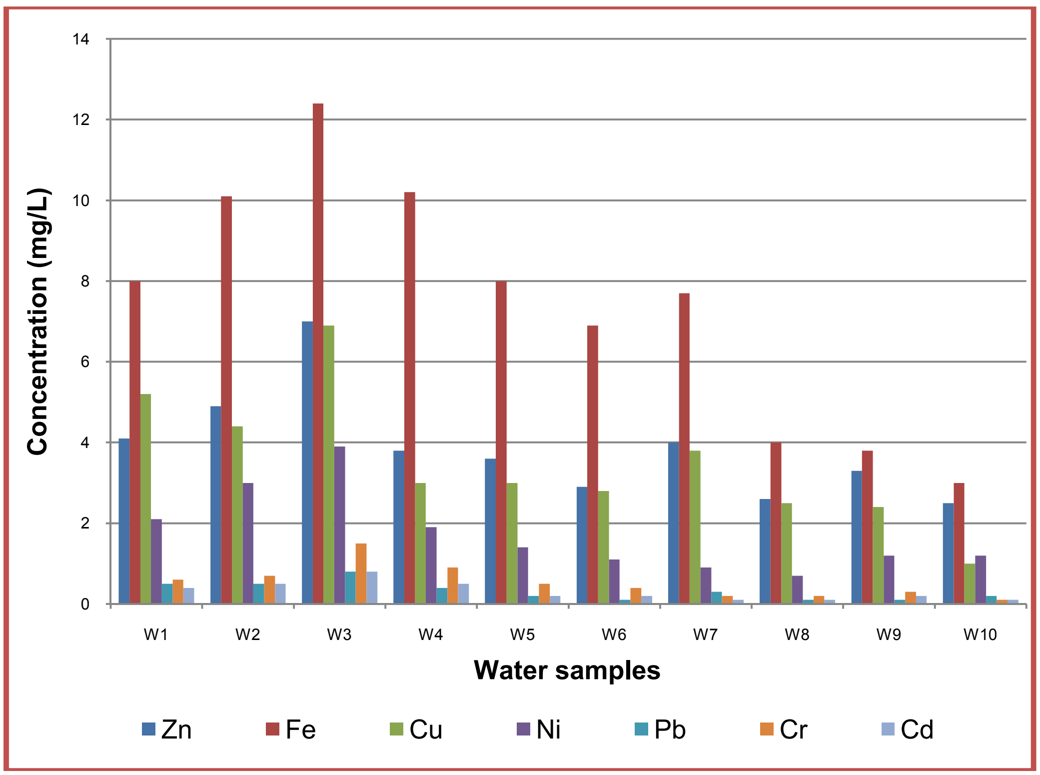

Fig. 5. Heavy metal distribution in water samples

Table 5. Some statistical data for heavy metals in water samples (mg/l)

Parameters	Zn	Fe	Cu	Ni	Pb	Cr	Cd
Average	3.87	7.41	3.5	1.74	0.32	0.54	0.31
Minimum	2.5	3.0	1.0	0.7	0.1	0.1	0.1
Maximum	7.0	12.4	6.9	3.9	0.8	1.5	0.8

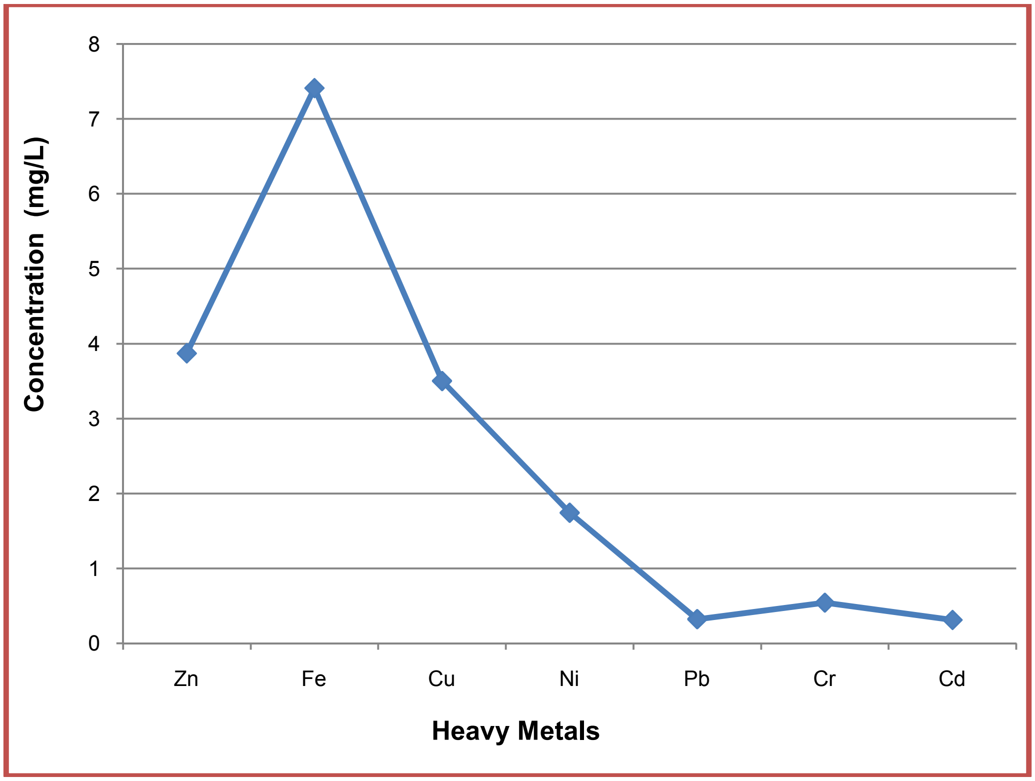

Fig. 6. Average concentration of heavy metals in water sample

Table 6 and Fig. 7 show the results of the physico-chemical analysis of 10 water samples and a linear regression plot of EC and TDS respectively.

Table 6. Physico-chemical parameters of water samples

Sample	EC (µmhos/cm)	TDS (mg/l)	Temp. (°C)	pH
W1	1002.8	850.7	18	6.9
W2	1200.8	999.2	19	6.8
W3	2032.2	1879.1	20	6.6
W4	797.5	567.7	15	6.9
W5	500.1	480.3	17	5.5
W6	480.9	459.9	15	7.1
W7	540.8	490.6	14	6.8
W8	450.1	430.7	17	6.9
W9	420.6	403.3	16	7.2
W10	416.8	400.9	15	7.1

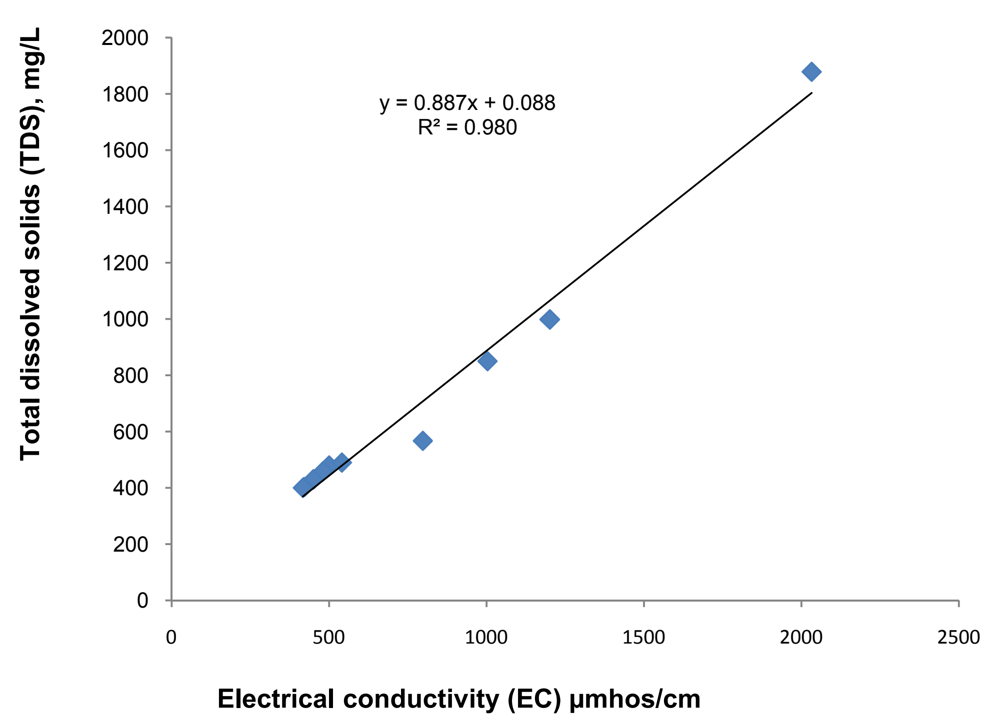

Fig. 7. Linear regression of EC and TDS of water samples

4. DISCUSSION

The average concentration of heavy metals in order of abundance in effluent samples is given as Fe>Zn>Cu>Cr>Ni>Pb>Cd while the trend in water samples is given as Fe>Zn>Cu>Ni>Cr>Pb>Cd respectively. The concentration of Fe is higher in both the effluent and water samples compared to other metals which show an enrichment of Fe while Cd has the lowest value. There appears to be a corresponding hydrochemical trend between effluent and water samples for Fe, Zn, Cu, Pb and Cd with respect to average concentration. Chromium and Nickel indicate a substitution phenomenon in the analysed samples.

Higher values obtained for Fe could have been due to high Fe content of chemical and biochemical additives used in the production chain by the companies in the study area. Furthermore, high Fe content could also be due to enrichment by leaching of Fe-rich Laterite soils underlying the base of the drains where the effluent samples were collected from. Iron is a common element in tropical soils. Hence, the research carried out by [11] has reported the Fe enrichment in effluents due to Fe-rich soils at the base of open drains. Iron is also common in natural fresh waters [16] and it impacts a metallic taste on drinking water at higher concentrations. Hemochromatosis is the genetic form of iron load in which patients lack a functional HFE protein involved in Fe homeostasis as a result of mutations in the HFE gene [26].

High concentration of Zn in drinking water may have deleterious effects on human health. Zinc toxicity may occur due to excessive ingestion; its symptoms are vomiting, nausea and loss of appetite [17]. Many researchers have investigated the effects of Cr and Cu on humans. Epidemiological studies have established a relationship between exposure to Cr by inhalation and lung cancer [18,19] while Cu is an essential nutrient and could also be a contaminant in drinking water. Copper compounds have been widely used in industrial processes and agriculture. Research is ongoing to establish the correlation of excessive ingestion to carriers of the gene of Wilson disease and other metabolic disorders of Cu homeostasis [18,19].

Nickel and Cadmium are toxic heavy metals. Allergic contact dermatitis is the most common effect of Ni [19]. Cadmium is carcinogenic and the kidney is the target organ for Cd toxicity and has a long biological half-life in humans of 10-35 years [20,21] while [22] emphasized the health implications of water contaminated with Pb which corroborates the findings of [16] and [21] reiterating that Pb poisoning causes abdominal pain, constipation and brain damage due to prolonged exposure [23,24,25]. Cardiovascular disease (CVD) and altered gene expression by environmental influence could be linked to heavy metal toxicity and poisoning [26] because of their cumulative deleterious effects that can cause degenerative changes.

The values of temperature and pH in effluent and water samples varied anomalously. The functional relationship between EC and TDS in effluent samples has been reported [27]. EC and TDS linear regression plots reveal that the coefficient of determination R^2= 0.9784 and R^2= 0.9809 obtained for effluent and water samples respectively reflect a good positive correlation coefficient between the two parameters. The higher the TDS values, the higher the ability of the ionic constituents in the samples to conduct electricity. Very strong positive relationships between EC and TDS in some effluent samples in some parts of Nigeria have been established [27]. Higher temperature of effluent samples might have contributed to a slight increase of temperature regime of the water samples obtained from the river and this could have affected the pH values obtained. The variation in the temperature and pH of water samples is associated with increase in the number of ions in solution due to the dissociation of molecules in response to higher temperatures.

From the foregoing, the assessment of the drinking water quality status of Isebo River depends largely on the comparison of the results obtained from laboratory analysis of water samples with the WHO guidelines values. The WHO drinking water guidelines was adopted as a benchmark in this research. It has been established that the concentration of heavy metals in water samples are generally higher than the permissible limits of the WHO.

5. CONCLUSION

A drinking water quality assessment was embarked upon in order to determine which chemical constituents are, indeed, of concern because Isebo River is a source of drinking water to the rural dwellers in the study area. The chemical analyses revealed a comparatively higher concentration of toxic heavy metals in water samples than the recommended WHO guidelines values. This could lead to potential health hazards such as brain damage, cardiovascular disease, vomiting, metabolic disorder and constipation to mention a few. If the contaminant loading persists, it may have an effect on the pollutants' carrying capacity of the ecosystem.

The higher concentrations of toxic heavy metals in effluent samples indicate indiscriminate discharge and negligence of the companies towards duty-of-care as the effluents were not pre-treated prior to disposal. Therefore, the water quality profile of Isebo River is presumably poor based on the data obtained in this research comparable with the WHO guidelines values as water quality status is one of the indices for measuring environmental performance.

6. RECOMMENDATION

The management of environmental pollution is cardinal to achieving sustainable development on a global scale. Therefore, regular and systematic monitoring of toxic heavy metals in effluents, water, animals, plants and other agricultural produce is important in order to prevent their excessive build-up in the food chain. In view of this, it is expedient that the polluting industries should endeavour to treat raw effluents before disposal using the best practice technologies (BPTs) compliant with greening the environment in order to keep the environment safe and reduce the potential health risks in the study area.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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