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PHYSICOCHEMICAL QUALITY, POTENTIALLY TOXIC ELEMENTS CHARACTERIZATION AND TOXICOLOGICAL RISK ASSESSMENT OF INDUSTRIAL EFFLUENTS IN IJU RIVER, OGUN STATE, NIGERIA

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ABSTRACT

The study aimed to determine the physicochemical quality, concentration of potentially toxic elements (PTEs) and potential health risks of exposure to industrial effluents in the Iju River. Composite water samples were collected from six stations (effluent before treatment, point of treatment, effluent after treatment, point of discharge, 50 m and 100 m downstream), of the river. Temperature and pH were tested in situ, then the sample was transported to the laboratory for analysis. The physicochemical quality of the samples was carried out using standard methods. PTE levels were estimated using an Atomic Absorption Spectrometer (AAS). The study showed a high concentration of pH (6.45 and 8.89) and turbidity (1.00 - 11.0 NTU) in the effluent before treatment, at the point of treatment and 50 m downstream. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were high in all sampling stations (7.54, 89.4, 95.2, 95.1, 85.2, 60.5 mg/L and 95.4, 111, 125, 121, 106, 85.5 mg/L) while dissolved oxygen (DO) was low (2.22, 2.54, 3.25, 4.52, 4.98, 7.56 mg/L) across stations compared to the WHO standards (20.0mg/L, 50.0 mg/L and 13.0-14.0 mg/L) for BOD, COD and DO respectively. The obvious similarity between BOD, COD and DO might be due to the presence of a high level of organic or inorganic matter which is oxygen-demanding. Interestingly, this could be linked to anthropogenic activities. Fe concentration in the stations (except 100 m downstream), and the concentration of Cd at the point of treatment and 50 m downstream were higher (0.004 and 0.005 mg/L) than the WHO standard (0.003 mg/L). Health risk assessment showed that all studied PTEs at the time of investigation have a non-significant hazard effect on exposure. Therefore, the effluent is polluted with organic, inorganic materials, and Cd, and Fe at some of the stations.

Keywords: Iju river, Industrial effluent, physicochemical, potential toxic element, Ogun State

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INTRODUCTION

Advancements in technology and industrialization have brought with them the problem of waste management. Industrial waste in particular is now recognized as one of the greatest contaminants of the water body (Khalid *et al.*, 2018). Water is essential for human life, but it is also a limited and vulnerable resource. Therefore, safeguarding the availability of a sufficient amount of water with acceptable quality is an important

technical and societal challenge to be addressed (Khalid *et al.*, 2018).

The growing water stress globally is alarming and it is worth noticing that the agro–sector itself consumes approximately 70% of the entire water resource (Winpenny *et al.*, 2010). The continuously rapid industrialization, urbanization, economic growth, population expansion and the generation of wastewater have also increased drastically (Alobaidy *et al.*, 2010). Due to the excessive use of water, around 60% of the world's population faces water shortages (Khalid *et al.*, 2018). The huge amount of wastewater may have an impact on water availability, general economic conditions, life quality, and cultural and religious values in human civilization without effective management (Kalavrouziotis, 2015).

River pollution is an intense environmental problem in third-world countries, with developed nations adopting stringent water quality requirements to control river pollution (Winpenny *et al.*, 2010). Generally, water resources are under a great threat of pollution in recent times due to the rapid increase in population which has coincided with the establishment of human settlements and industries which lack appropriate waste disposal infrastructure (Varol and Sen, 2018). Effective management of effluent treatment plants remains a critical concern of many government regulators in towns and cities (Varol and Sen, 2018). The indiscriminate disposal of poorly treated effluents into surface water bodies remains a more challenging problem.

Literature has documented potentially toxic elements (PTEs) contamination in Nigerian rivers, including various toxicological risk assessments (Alabi *et al.*, 2013: Isa *et al.*, 2013: Adebanjo and Adedeji, 2019; Edori *et al.*, 2019; Elemile *et al.*, 2019). However, there is still a need to ensure good water quality at every level, with a major concern in low and medium–income countries which are known to practice a lot of indiscriminate disposal of waste (World Bank, 2016). River pollution results in the reduction of water quality which in turn poses a human health risk (Varol and Sen, 2018), a reconnaissance visit to River Iju (also known as River Atuwara) has revealed a lot of anthropogenic activities taking place in the area; such as discharge of domestic wastes from households and washing of automobiles, block industry on the banks, effluent discharged from industries among others.

Communities and individuals in developing countries in Africa such as Nigeria often consume or use PTE contamination in water above the WHO standard (WHO, 2011). PTEs such as chromium, lead, cadmium, arsenic and mercury are known to be highly toxic to aquatic life and humans, causing liver and kidney problems including cancer in humans (Nguyen *et al.*, 2018). The study of physicochemical quality and PTE concentration in the industrial effluents associated with the river is required to assess the quality of the river water for domestic and health usage. Consequently, such is the investigation's goal.

MATERIALS AND METHODS

Study Area

This study was carried out in Iju River also known as Atuwara River (Latitude 6.58333° or 6° 35' N, Longitude 3.15° or 3° 9' E) located in Ogun State, Southwestern Nigeria and about 18 Kilometres from Lagos State, a major commercial hub in west Africa. The town is inhabited mostly by Owu and Egba natives whose ancestors settled there between 1842 and 1845. The map of the Iju River as presented by Omole and Alonge (2012) is shown in Fig. 1.

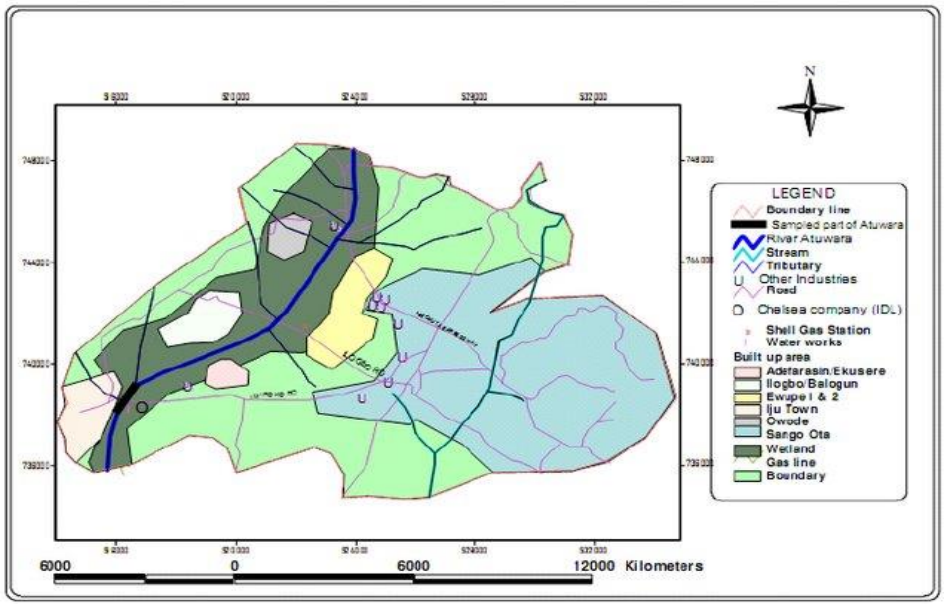

Fig. 1: The map of Ado-Odo Ota LGA showing the Iju River (River Atuwara) in blue

Sample Collection and Preservation

The collection of water samples was done with 2000 cm^3 sterile plastic containers (previously soaked in 5% HNO_3 overnight) to make a composite at six different stations (viz effluent before treatment, point of treatment, effluent after treatment, point of discharge, 50 m and 100 m downstream) of the river. When sampling, all necessary precautions were taken to prevent contamination. The temperature and pH of the sample were determined *in situ*, labelled appropriately and transported to the chemistry laboratory for analysis in an iced – cooler and was kept at a temperature of about 4°C before analyses. Water samples were promptly collected into dark DO bottles for DO and BOD measurements, and 1 cm^3 of the Winkler no. 1 & 2 solution was added to fix dissolved oxygen. They were kept at room temperature after collection.

Quality Assurance of the Reagents

All chemicals used were of AnalaR grade (BDH, England), and reagent blanks were made following the specifications to evaluate the reagents' purity. To ensure the highest level of instrument accuracy, all field meters and equipment were checked and calibrated according to the manufacturer's specifications and instructions (Ma *et al.*, 2020).

Physicochemical Analysis

The physicochemical quality of the water samples namely: pH, Temperature, Total dissolved solids, Electrical conductivity, Turbidity, Total Hardness, Chloride, Dissolved Oxygen, Biochemical Oxygen demand and Chemical Oxygen Demand was carried out using standard methods (APHA-AWWA-WEF, 2006; AOAC, 2019). The pH of the samples was determined using a pH meter (electrometric method). Temperature and pH were measured in situ. After standardizing the apparatus with known buffer solutions of pH 4, pH 7, and pH 10, the pH measurements of the water samples were immediately taken. Total dissolved solids and Electrical conductivity were determined using a digital water quality meter (Model: EZ-9909SP**)**, Turbidity was determined using a Turbid meter. The total Hardness of water was carried out using an EDTA titrimetric method with Eriochrome BlackT as an indicator. Chloride (mercuric nitrate colourimetric method). The water sample (100 cm^3) was measured in the conical flask using Potassium Chromate as the indicator. The solution was then titrated against a dilute Silver nitrate. A brick red colouration indicates the endpoint.

Determination of Sulphate

Sulphate was carried out gravimetrically using barium chloride as a precipitator. A sample volume of 50 cm^3 was measured into a 250 cm^3 beaker and diluted with distilled water to a volume of 150 cm^3. Four drops of the methyl orange indicator and 1 cm^3 of concentrated HCl were added. Barium chloride (10 cm^3 of a 10% solution) was then added to it, and the mixture was heated for five minutes. The solution was

kept overnight and then filtered with Whatman filter paper. Distilled water was used to rinse the filter paper to remove the chloride ions. The filter paper was heated to 800°C in a muffle furnace for 60 minutes, ignited at 80°C in an oven using a silica crucible, cooled in a desiccator, and then weighed. After repeating the steps of ignition, cooling, and weighing to produce a constant figure, the sulphate content was measured.

Determination of Dissolved Oxygen (DO)

Dissolved oxygen was carried out using Winkler's method. 200cm^3 of the water sample was cautiously transferred into a 300 cm^3 BOD bottle. 1cm^3 of Winkler's method reagent was added, followed by 1 cm^3 concentrated sulphuric acid. The resulting mixture was titrated against 0.025 N sodium thiosulphate to the end point where there was a colour change using starch as an indicator. The titre value was recorded (Biswas, 2015). Biochemical oxygen demand is carried out using Winkler's method. BOD bottle was prepared and incubated at 20° C for 5 days in the cupboard. After five days, the method used for the DO estimate was carried out. BOD was then calculated as $DO_1 - DO_5$.

Determination of Chemical Oxygen Demand (COD)

Reflux conventional procedures were used to determine COD. A reflux flask was filled with 50 cm^3 of the water sample, 10 cm^3 of a potassium dichromate solution and 1 g of mercuric sulphate added. Antibumping beads were added to the solution to prevent it from boiling over. Swirling was used to carefully add 10 cm^3 of concentrated sulfuric acid containing silver sulphate via the condenser's open end. After running the reflux equipment for about an hour, it was let to cool. The flask was taken out, and the mixture within was diluted with distilled water to make 150cm^3. Three drops of the ferroin indicator were added to the resultant solution. This sample was titrated with regular ferrous ammonium sulphate until the colour of the sample abruptly changed from blue-green to reddish-brown. The blank samples were then computed.

Acid Digestion and Potentially Toxic Elements Estimation

The water sample (10 cm^3) was measured using a measuring cylinder. The sample was poured into a 250cm^3 of sterilized conical flask and treated with 20cm^3 of concentrated Nitric acid (NHO_3). The mixture was placed on a hot plate at 90 ^{o}C in a fume cupboard until a clear solution was achieved. The flask was allowed to cool to ambient temperature, then the digest was then filtered with Whatman No. 42 filter paper and diluted up to mark with deionized water in a 250 cm^3 standard volumetric flask (AOAC, 2019), then PTEs were estimated using Atomic Absorption Spectroscopy.

Human Health Risk Assessment

The river assessed in this study is a potential source for drinking and domestic use (e.g., washing, bathing, drinking and cooking as an alternative during water scarcity) by the surrounding local communities, therefore water ingestion and dermal contact are assumed to be the main pathways for risk assessment (Hadzi *et al.,* 2018**)**. Therefore, the human health risks of exposure were evaluated via the ingestion and skin contact route according to the United States Environmental Protection Agency (USEPA) equation (RAGS, 2018). The average daily intake (ADI) for PTEs in the sample was calculated using Equations 1 and 2.

$$ADI_{ing} = C \times \frac{IngR \times EF \times ED}{BW \times AT} \times 10^{-6} \quad \ldots\ldots (1)$$

$$ADI_{derm} = (C \times SA \times PC \times EF \times ED \times CF | BW \times AT) \ldots . (2)$$

Where:

ADI_{ing} - average daily intake through ingestion per Kilogram of body weight (Hadzi *et al.,* 2018).

C - concentration of PTEs in a water sample (mg/L),

IngR - ingestion rate per unit time (L/day)

ED - exposure duration (years), which is equal to the life expectancy,

EF - exposure frequency (days/ year),

BW - body weight (kg), and

AT - averaging time (ED x EF).

For the conversion factor from years to days, 365 days were used.

ADI_{derm} - average daily intake via dermal exposure,

SA - total skin surface area (cm3),

CF - volumetric conversion factor for water (1000 cm^3), and

PC - chemical-specific dermal permeability constant (cm/h).

The non–cancer risk expressed as the target hazard quotient (THQ) was calculated by dividing the ADI value for PTEs on each

exposure pathway (ingestion & dermal) with their respective reference doses (RfDs) using Equation 3.

$$THQ = \frac{ADI}{RfD} \quad \ldots\ldots (3)$$

Since some PTEs may interact synergistically (Famuyiwa *et al.*, 2022), it is assumed that the risk of all PTEs is additive. Therefore, this assumption served as the basis for calculating the aggregate of non–cancer risks known as the hazard index (HI) and the sum of cancer risk (CR) respectively. Non–cancer risk is computed using equation 4.

$$HI = \Sigma HQ_i \quad \ldots\ldots (4)$$

According to the HI's interpretation, a value of HI = or < 1 suggests that there will be no adverse health Implication, while a value of HI > 1 indicates that there is a chance that there will be such an implication. The level of concern therefore increases when HI is > 1 (US EPA, 2002). Cancer risk due to prolonged exposure to potential carcinogens was computed by multiplying the individual ADI for each pathway with the slope factor (SF) using Equation 5.

$$CR_i = ADI_i \times SF_i \ldots\ldots (5)$$

Where:

CR_i - cancer risk due to exposure pathways (ingestion and dermal) and

ADI - average daily intake via dermal exposure,

SF - cancer slope factor (mg/kg/ day).

Generally, an excess carcinogenic risk of 10^{-6}, shows a probability of a one in a million chance of a population of equally exposed individuals to be at the risk of developing cancer, which is considered the target cancer risk. The values are considered to be negligible and acceptable while cancer risk above 10^{-4} is considered significant and unacceptable (US EPA, 2013)

Data Analysis

Microsoft Excel 2013 version was used for data analysis, graphical presentation and also for computing health risk assessment.

RESULTS

Physical Quality

The Physical quality of the stations is shown in Table 1. The pH of the sample ranged between 6.45 and 8.89. The highest pH was recorded in the effluent before treatment while the lowest pH was found in 100 m downstream. pH in three of the sampling stations (effluent before treatment, point of treatment and 50m downstream) is higher than the WHO's standard (6.5 – 8.5). Electrical conductivities (EC) are physical characteristics that are used to measure the ability of water to conduct an electrical current due to the presence of inorganic dissolved solids. The EC in samples from the study ranged from 175 µs/cm^3 to 278 µs/cm, with the effluent after treatment having the highest conductivity and the point of discharge sample having the lowest. The turbidity across the sample ranged from 1.00 – 11.0 NTU. Effluent before treatment had the highest turbidity while the water sample 50 m downstream had the lowest turbidity. The turbidity in 33.3% of the sampling stations (effluent before treatment and point of treatment) was higher than the WHO standard (5.0 NTU). The total dissolved solids (TDS) from the study ranged between 96 – 153 mg/L with the highest value coming from the effluent after treatment while the lowest was recorded at the point of discharge. All sampling stations had a TDS within the WHO standard (500 mg/L).

Table 1*:* Physical quality of samples across the sampling Stations

Physical Parameters	Sampling Points						WHO (2011)
	Effluent Before Treat.	Point of Treat.	Effluent After Treat.	Point of Discharge	50m DS	100m DS	
pH	**8.89**	**8.85**	7.65	7.52	**8.56**	6.45	6.5 – 8.5
Temp. (^{O}C)	25.0	25.0	25.0	25.0	25.0	25.0	25 – 29
Conductivity (µs/cm)	185	274	278	175	225	189	1000
Turbidity (NTU)	**11.0**	**9.00**	3.00	4.00	1.00	4.00	5.0
TDS (mg/L)	102	151	153	96	124	104	500

Key: Treat=Treatment, DS: Downstream Values in bold are higher than the WHO guideline value

Chemical Quality

The chemical quality of the sampled stations is shown in Table 2, The BOD and COD in the stations ranged from 60.5 – 95.2 mg/L and 85.5 – 125 mg/L respectively. The highest value for both BOD and COD across the stations was recorded in the effluent after treatment while the lowest was recorded 100 m downstream. The BOD and COD across the sampling stations were above the WHO standard (20.0 mg/L) and (50.0 mg/L) respectively. The DO concentration from the study ranged from 2.22 – 7.56 mg/L. The highest DO was recorded from 100 m downstream while the lowest was recorded in effluent before treatment. DO in the stations where lower than the WHO standard (13 – 14 mg/L). Chloride ion (Cl^-) levels recorded across the stations ranged from 24.2 – 52.5 mg/L. The highest Cl^- concentration was recorded at the point of treatment while the lowest concentration was recorded in the effluent before treatment. The concentration of Cl^- recorded from the study was within the WHO standard (250 mg/L). The concentration of sulphate (SO_4^{2-}) in the effluent sample ranged from 10.5 - 38.2 mg/L. The sulphate concentration was highest in the effluent before treatment while the lowest was recorded in 100 m downstream. The SO_4^{2-} concentration across the stations was within the WHO standard (250 mg/L).

Table 2*:* Chemical parameters of samples across the sampling stations

Chemical Parameter	Sampling Points						WHO (2011)
	Effluent Before Treat.	Point of Treat	Effluent After Treat.	Point of Discharge	50 m DS	100 m DS	
BOD (mg/L)	75.4	89.4	95.2	95.1	85.2	60.5	20.0
COD (mg/L)	95.4	111	125	121	106	85.5	50.0
DO (mg/L)	2.22	2.54	3.25	4.52	4.98	7.56	13 – 14
Chloride ion (mg/L)	24.2	52.5	51.5	37.5	25.6.	45.2	250
Sulphate ion (mg/L)	38.2	37.5	12.5	22.5	32.5	10.5	250

Values in bold are not in line with the WHO Standard

Potentially Toxic Element Concentration

The PTE concentration in sampling stations is shown in Table 3. Cadmium in 66.7% of the sampling stations was absent or below the detectable level. However, the detected Cd concentration ranged from 0.004 – 0.005 mg/L. A higher Cd level was recorded at the 50 m downstream (0.005 mg/L) while the lower was recorded at the point of treatment (0.004 mg/L). The stations with the detected Cd had a concentration higher than the WHO standard (0.003 mg/L). Copper (Cu) concentration from the study ranged from 0.011 – 0.054 mg/L. The highest Cu concentration was recorded in the effluent after treatment while the lowest was recorded at the point of discharge. Cu concentration across the stations was within the WHO standard (2.00 mg/L). Iron (Fe) concentration across the stations ranged from 0.022 to 0.123 mg/L. The highest concentration

of Fe was recorded in 50 m downstream while the lowest was recorded in 100 m downstream. Fe concentration in 83.3% of the stations was higher than the WHO standard (1.00 mg/L). Lead (Pb) concentration in 66.7% of the sampling stations was absent or below the detectable level. However, the detected Pb concentration ranged from 0.00 - 0.009 mg/L. A higher Pb concentration was recorded at the point of treatment while the lower concentration was recorded the 50m downstream. The detected Pb concentration falls within the WHO standard (0.01 mg/L). Zinc (Zn) concentrations across the stations ranged from 0.011 – 0.040 mg/L. Zn was recorded in all samples, with the highest concentration recorded at the point of treatment while the lowest was recorded in the effluent before treatment. Zn concentrations across the stations were within the WHO standard (3.00 mg/L).

Table 3*:* The concentration of PTEs in samples across the sampling stations

PTE	Sampling Points						
	Effluent Before Treat.	**Point of Treat.**	**Effluent After Treat.**	**Point of Discharge**	**50 m DS**	**100 m DS**	**WHO (2011)**
Cd	Nd	**0.004**	Nd	Nd	**0.005**	Nd	0.003
Cu	0.025	0.012	0.054	0.011	0.012	0.015	2.00
Fe	**1.38**	**2.50**	**2.53**	**3.04**	**36.3**	0.569	1.00
Pb	Nd	0.009	Nd	Nd	0.005	Nd	0.01
Zn	0.011	0.040	0.033	0.036	0.037	Nd	3.00

Values in bold are higher than the WHO guideline value, Nd=not detected

Human Health Risk Assessment

The health risk assessment of PTEs in sampling stations is shown in Table 4 – 5. The average daily intake on exposure to the effluents presented in Table 4, shows that ingestion is the exposure pathway to the human population in the study area. The non–cancer and cancer risks of the PTEs were estimated for both adult (18 – 70 years) and children/adolescent (1 – 17 years) populations through the exposure pathways presented in Table 5.

The value of the hazard index (HI) greater than 1 indicates a high probability of adverse human health effects upon exposure (US EPA, 2014). HI value in the study for the effluents in BOTH adult and children/adolescent populations shows a downtrend of Pb> Cd.>Cu> Zn. All investigated PTEs show a HI value lower than 1. (fig. 2) which indicates no significant hazard effect on the human population exposed to the effluents around the River. The value also shows that Pb and Cd are the major contributors to PTE exposures in the adult population while Cr and Cd are major contributors to PTE exposures in the children population. The cancer risk value represented in Table 5, showed that Lead (Pb) for the adult population (1.44E – 10) and the children population (3.35E – 10) respectively were less than $1x10^{-6}$ which indicates a negligible cancer risk to the local population (Wu *et al*., 2015).

Table 4: Average Daily Intake (ADI) of PTEs in sample

PTE	Human population			
	Adult		Children	
	ADI_{ing}	ADI_{derm}	ADI_{ing}	ADI_{derm}
Cd	3.17E – 08	7.32E – 10	2.96E – 07	8.28E – 10
Cu	1.47E – 07	3.38E – 09	1.37E – 06	3.83E – 09
Fe	6.33E – 05	1.46E – 06	5.91E – 04	1.65E – 06
Pb	4.93E – 08	1.14E – 09	4.60E – 07	1.29E – 09
Zn	2.57E – 07	5.94E – 09	2.40E – 06	6.72E – 09

Key: ADI_{ing}=Average daily dose for ingestion ADI_{derm}= Average daily dose for dermal

Table 5: Non–Cancer and Cancer Risk

PTE	Human population					
	Adult			Children		
	THQ_{ing}	THQ_{dermal}	$\Sigma THQ_i=HI$	THQ_{ing}	THQ_{dermal}	$\Sigma THQ_i=HI$
Cd	3.17E – 05	2.93E – 05	6.10E – 05	2.96E – 04	3.31E – 05	3.29E – 04
Cu	3.68E – 06	8.45E – 08	3.21 – 06	3.43E – 05	9.58E – 08	3.43E – 05
Pb	1.64E – 04	3.26E – 07	1.65E – 04	1.53E – 03	3.69E – 07	1.53E – 03
Zn	8.57E – 07	1.98E – 08	8.76E – 07	8.00E – 06	2.24E – 08	8.02E – 06
	CR_{ing}	CR_{dermal}	TCR	CR_{ing}	CR_{dermal}	TCR
Pb	1.44E – 10	–	**1.44E – 10**	3.35E – 10	–	**3.35E – 10**

Key: THQ = Target hazard Quotient, CR =Cancer Risk, TCR = Total Cancer Risk

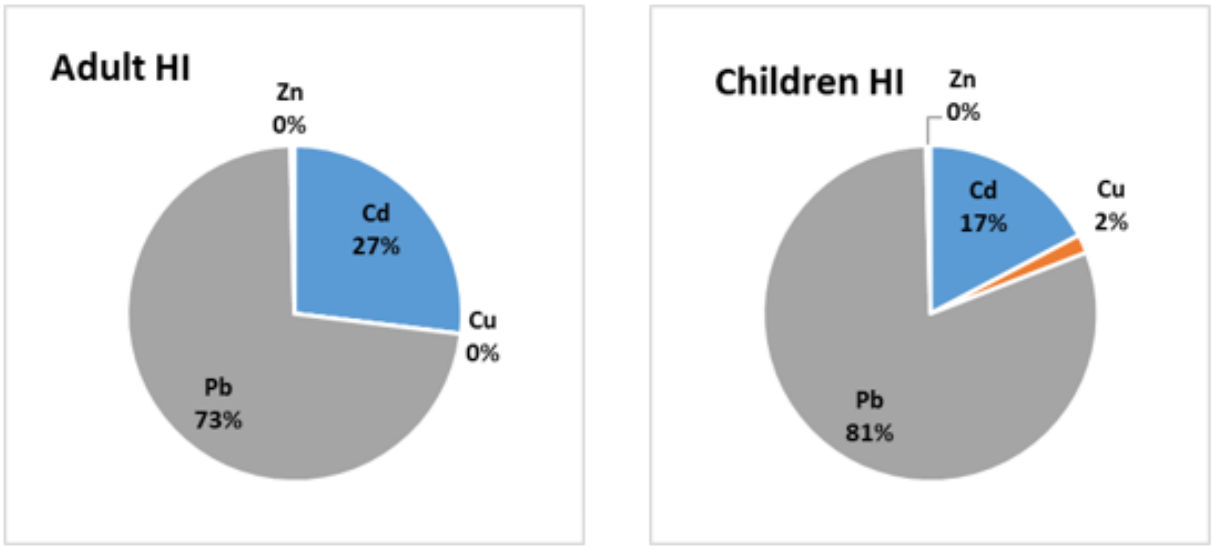

Fig. 2: Percentage Hazard Index of PTEs in Effluents around River on Adults and Children

DISCUSSION

Physicochemical Quality

Although pH has no harmful effects on human health, its impact on human physiology cannot be overstated (Isa *et al.*, 2013). The pH for 83.3% of the samples was higher than the pH reported in Surface water in Ogbomosho, Nigeria (5.7–6.7) (Adelowo *et al.*, 2012) and Iju River, Ogun State (7 – 7.5) (Alabi *et al.*, 2013). The temperature of the samples was constant (25 ^{o}C) across the sampling sections, standing within the WHO standard (25 – 29^{o}C). 83.3% of the temperature recorded in this study is higher than the temperature reported in previous studies in abattoir effluence, Omu – Aran, Nigeria (26.90 – 26.70 °C) (Elemile *et al.*, 2019) and Palm oil mill effluents, Rivers Nigeria (45–70^{o}C) (Kanu and Achi, 2011).

All of the water samples had EC levels that were lower than the WHO standard (1000 µs/ cm). The EC level reported from this study is exponentially larger than previous report from Industry effluent in Imo State, Nigeria (10460 µs/ cm) (Ogemdi and Gold, 2018), Omu – Aran, Nigeria (547 – 431.87 µs/cm) (Elemile *et al.*, 2019) and Iju River, Ogun State (436 – 1100 µs/cm) (Alabi *et al.*, 2013). An increase in turbidity of a water sample is related to an increase in pathogenic organism levels in the water (Isa *et al.*, 2013). The high turbidity recorded is traceable to the high level of organic matter in those sections. Compared to other studies, the turbidity recorded in 83.3% of the stations was higher than the report from effluent in Omu – Aran, Nigeria (2.00 NTU) (Elemile *et al.*, 2019), drastically lower than effluent in Imo State, Nigeria (847 NTU) (Ogemdi and Gold, 2018), Nkoho River, Abia State, Nigeria (119.43 NTU), (Chidozie and Nwakanma, 2017) and 40% in Asa River, Nigeria (1.5 – 189 NTU) (Adekunle and Eniola, 2008). The TDS recorded from the study is lower than the report from effluents in Nkoho River, Abia State, Nigeria (246.7 mg/l), (Chidozie and Nwakanma, 2017) and Imo State, Nigeria (485 mg/l) (Ogemdi and Gold, 2018).

The BOD from the study were higher than the values recorded in effluents in Nkoho River, Abia State, Nigeria (16.50 mg/L), (Chidozie and Nwakanma, 2017) but lower than to report from Imo State, Nigeria (485 mg/L) (Ogemdi and Gold, 2018). COD in the station is similar to the report from effluents in Nkoho River, Abia State, Nigeria (85.93 mg/L), (Chidozie and Nwakanma, 2017) but lower than that of Imo State, Nigeria (172 mg/L) (Ogemdi and Gold, 2018). The similarity between BOD and COD shows the presence of the high level of organic or inorganic matter that oxygen demands in the sampling sections traceable to anthropogenic pollution. DO concentration in the river below the acceptable level can be harmful to aquatic habitation (Puri and Kumar, 2012). The DO concentration from 50% of the stations is similar to the previous report in the same river (2.85 – 3.05 mg/L) (Alabi *et al.*, 2013) and Omu – Aran, Nigeria (5.80 – 7.23 mg/L) (Elemile *et al.*, 2019). The concentration of Cl^- in 66.7% of the stations is higher than the concentration recorded in 83.3% of the stations studied in Omu–Aran, Nigeria (Elemile *et al.*, 2019), grossly higher than that of the Imo State, Nigeria (3.5 mg/L) (Ogemdi and Gold, 2018). Concentration recorded from the study were lower than the reports from Imo State, Nigeria (80 mg/L) (Ogemdi and Gold, 2018) and Nkoho River, Abia State, Nigeria (367.9 mg/L), (Chidozie and Nwakanma, 2017).

Potentially Toxic Element Concentration

Cadmium toxicity from this sampling station can result in health issues such as respiratory and kidney dysfunctions on prolonged exposure (WHO 2011). The result from the study was lower than Cd reported in Elelenwo River, Rivers State, Nigeria (0.25 mg/L) (Edori *et al.*, 2019), and Osun stream (0.03 mg/l) (Adebanjo and Adedeji, 2019). Compared to other studies, 83.3% of the stations have a Cu concentration lower than the reports from Imo State, Nigeria (0.036 mg/L) (Ogemdi and Gold, 2018) and Omu–Aran, Nigeria (1.21- 1.08 mg/L) (Elemile *et al.*, 2019). Iron in water promotes the development of iron-reducing bacteria that help with the oxidation process that transforms iron II into iron III (WHO 2011). Compared to other studies, 83.3% of the stations have a concentration lower than 50% of the stations in surface water in Minna, Niger State, Nigeria (1.08 - 9.28 mg/L) (Idris *et al.*, 2013) and all sampled points in River Iju, Nigeria (1.03 - 2.21 mg/L) (Alabi *et al.*, 2013). The concentration of Pb from the study is lower than the reports from Minna, Niger State, Nigeria (0.01 - 0.09 mg/L) (Idris *et al.*, 2013) and Omu – Aran, Nigeria (0.06 -0.16 mg/L) (Elemile *et al.*, 2019). The concentration Zn from the study is lower than the reports from Omu–Aran, Nigeria (2.60 – 1.27 mg/L) (Elemile *et al.*, 2019) and Imo State, Nigeria (0.073 mg/L) (Ogemdi and Gold, 2018).

CONCLUSION

Based on the findings of the study, it could be ascertained that there are high organic and inorganic materials which could progressively alter the dissolved oxygen in the river water. This might eventually result in a threat to the aquatic organisms and the quality of the river water, High Fe concentration in the stations (except 100m downstream) could promote the development of iron-reducing bacteria while Cd toxicity at the point of treatment and 50 m downstream might result in health issues on prolonged exposure.

Recommendations

Due to the community's reliance on river water as a source of drinking water and domestic use. The community should be informed about the safe use of water from 100m downstream for domestic uses and proper boiling before consumption by community leaders and authorized agencies, and industries should enhance the treatment of their effluent. Additionally, more study needs to be done on the microbiological status, PTE concentrations of the soil and sediments in and around the effluents/River.

REFERENCES

Adebanjo, J. A. and Adedeji, W. O. (2019) Studies on heavy metals contents of Osun River at the pre-urban settlement and across Osogbo City, Nigeria, *Journal of Taibah University for Science,* 13:1, 318 – 323

Adekunle, A. S., and Eniola, I. T. K. (2008). Impact of industrial effluents on quality of segment of Asa river within an industrial estate in Ilorin, Nigeria. *New York Science Journal, 1*(1), 17 – 21.

Adelowo, O. O., Akinlabi, I. A. and Fagade, O. E. (2012). Environmental impact assessment of Attenda abattoir, Ogbomoso

southwestern Nigeria on the surface and groundwater quality using geoelectrical imaging and microbiological analysis. *Environmental monitoring and assessment*, *184*(7), 4565 – 4574.

Alabi, M. A., Idowu, G., Osoteku, O. A., Fasuyi, F. H., Adeyemi, Y. A., Adedokun, T. A. and Adelowo A. A. (2013). Water Quality Assessment of Iju River in Ogun State, Nigeria: Effect of Human Activities, *OSR Journal of Environmental Science, Toxicology and Food Technology*, *6*(3), Pp:64 – 68

Alobaidy, A. H. M. J., Maulood, B. K. and Kadhem, A. J. (2010). Evaluating raw and treated water quality of Tigris River within Baghdad by index analysis. *journal of water resource and protection*, *2*(7), 629.

AOAC (2019). *Official Methods of Analysis* (21st ed.). Washington, DC, USA. Association Official Analysis Chemists (assessed Mar. 2022).

APHA-AWWA-WEF (2006). Standard methods for the Examination of water and wastewater, American Public Health Association, American Water Works Association, Water Environment Federation, Washington DC (assessed Mar. 2023).

Biswas, J. (2015) Assessment of physicochemical quality of food wastewater of Raipur area. *International Journal of Engineering Research*, vol. 3, no. 1.

Chidozie, K. and Nwakanma, C. (2017) Assessment of Saclux Paint Industrial Effluents on Nkoho River in Abia State, Nigeria. *Journal of Ecosystem & Ecography* 7: 240. doi:10.4172/2157 – 7625.1000240

Edori, O. S., Iyama, W. A. and Amadi, M. C. (2019). Status of heavy metals contamination in water from the Elelenwo River, Obio – Akpor, Rivers State, Nigeria. *Direct Research Journal of Chemistry and Material Science*, *6*(3), 25 – 31.

Elemile, O. O., Raphael, D. O., Omole, D. O., Oloruntoba, E. O., Ajayi, E. O. and Ohwavborua, N. A. (2019). Assessment of the impact of abattoir effluent on the quality of groundwater in a residential area of Omu – Aran, Nigeria. *Environmental Sciences Europe*, *31*(1), 1 – 10.

Famuyiwa, A.O., Umoren, O.D., Enitan, M.O. and Ande, S. (2022). Pollution and Health Risk Assessment of Potentially Toxic Elements in Indoor Dusts from Selected Offices in Adodo – Ota Local Government Area, Ogun State Nigeria. *ChemSearch Journal*, *13*(2), pp.84 – 91.

Hadzi, G. Y., Essumang, D. K., Adjei. J. K. (2018) Distribution and risk assessment of heavy metals in surface water from pristine environments and major mining areas in Ghana. *J Health Pollut* 5(9):86 – 99. https://doi. org/10.5696/2156 – 9614 – 5 – 9.86

Idris, M. A., Kolo, B. G., Garba, S. T., and Waziri, I. (2013). Pharmaceutical industrial effluent: heavy metal contamination of surface water in Minna, Niger State, Nigeria. *Bulletin of Environment, Pharmacology and Life Sciences*, *2*(3), 40-44.

Isa, A., Allamin, I. A., Ismail, H. Y. and Abubakar, S. (2013). Physicochemical and bacteriological analyses of drinking water from wash boreholes in Maiduguri Metropolis, Borno State, Nigeria. *African Journal of Food Science*, *7*(1), pp. 9–13. doi:10.5897/ajfs12.073

Kalavrouziotis, I. K., Kokkinos, P., Oron, G., Fatone, F., Bolzonella, D., Vatyliotou, M. and Varnavas, S. P. (2015). Current status in wastewater treatment, reuse and research in some Mediterranean countries. *Desalination and Water Treatment*, *53*(8), 2015 – 2030.

Kanu, I. and Achi, O. K. (2011). Industrial effluents and their impact on water quality of receiving rivers in Nigeria. *Journal of applied technology in environmental sanitation*, *1*(1), 75 – 86.

Khalid, S., Shahid, M., Bibi, I., Sarwar, T., Shah, A. H. and Niazi, N. K. (2018). A review of environmental contamination and health risk assessment of wastewater use for crop irrigation with a focus on low and high–income countries. *International Journal of environmental research and public health*, *15*(5), 895.

Ma, J., Wu, S., Shekhar, N. V., Biswas, S., & Sahu, A. K. (2020). Determination of physicochemical parameters and levels of heavy metals in food wastewater with environmental effects. *Bioinorganic Chemistry and Applications*, Article ID

8886093, 9 pages, https://doi.org/10.1155/2020/8886093

Nguyen, H. L., Leermakersk M. Osan, J., Torok, S., Baeyens, W. (2018) Heavy metals in Lake Balaton: water column, suspended matter, sediment and biota. *Science of Total Environment,* 340(1 – 3):213 – 30.

Ogemdi, I. K., and Gold, E. E. (2018). Physicochemical parameters of industrial effluents from a brewery industry in Imo state, Nigeria. *Advanced Journal of Chemistry1 (2 Section A)*, 66 – 78.

Omole, D.O and Alonge, E.O. (2012). Re-aeration Coefficient Modeling: A Case Study of River Atuwara in Nigeria. *Research Journal of Applied Sciences, Engineering and Technology* 4(10): 1237-1243,

Puri, A. and Kumar, M. (2012). A review of permissible limits of drinking water. *Indian Journal of Occupational and Environmental Medicine, 16*(1), 40. doi:10.4103/0019 – 5278.99696

Risk assessment guidance for superfund (RAGS) (2018). *Human health evaluation manual.* Vol. 1, Washington, D.C. (Accessed Feb 2023).

United States Environmental Protection Agency (2013): *Mid – Atlantic Risk Assessment*, available from http://www.epa.gov/reg3hwmd/risk/human/ concentration table/usersguide.htm (Accessed: Nov. 2022)

USEPA (U.S. Environmental Protection Agency), (2014). *USEPA Integrated Risk Information System (IRIS) online database*. Available at: http://www.epa.gov/iris (Accessed: Nov. 2022)

Varol, M. and Sen, B. (2018). Assessment of nutrient and heavy metal contamination in surface water and sediments of the upper Tigris River, Turkey. *Catena* 92(1):1 – 10. https://doi.org/10.1016/j.catena.2011.11.011

WHO (2011) *Cadmium in drinking – water. Background document for preparation of WHO Guidelines for drinking – water quality*. Geneva, World Health Organization (WHO/SDE/ WSH/03.04/80/Rev/1). (Assessed Mar. 22, 2022)

Winpenny, J., Heinz, I., Koo – Oshima, S., Salgot, M., Collado, J., Hernandez, F. and Torricelli, R. (2010). The wealth of waste: the economics of wastewater use in agriculture. *Water Reports*, (35).

World Bank, (2016) *The World Bank data: Country and Lending Groups*. Available at:http://data.worldbank.org/about/country – and – lending – groups#Low income (Accessed on: Apr 2023).

World Health Organization (WHO) (2011). *Guidelines for Drinking–water Quality, 4th edition.* http://whqlibdoc.who.int/publications/2011/9789241548151_eng.pdf?ua=1 (accessed March 11, 2023).

Wu, S., Peng, S., Zhang, X., Wu, D., Luo, W. and Zhang, T. (2015). Levels and health risk assessments of heavy metals in urban soils in Dongguan, China. *Journal Geochemical Exploration*, 148, 71 – 78.