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Toxicological Assessment of Aluminium Extrusion Effluent on the Water Quality of Okatankwo River in Akabo Ikeduru, Imo State, Nigeria

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ABSTRACT: The objective of this paper is to evaluate the physicochemical characteristics and heavy metals content of water from Okatankwo River in Ikeduru Local Government Area, Imo State, Nigeria using appropriate standard methods. Ni and Cu had an average value of 3.21mg/l and 13.53mg/l, Ca had an average value of 316.6mg/l, TDS 1741.4 mg/l and TSS 949.33mg/l. Data obtained show that concentrations of some of these heavy metals were much higher than the maximum permissible limits. From the effluent sample, Ni and Cu were found to be at highly elevated levels, also Ca, TDS and TSS exceeded the permissible limits. Other heavy metals and physicochemical parameters were within the WHO and SON standard guidelines. Possible sources of these metals could be the aluminium processing industry which is located along the Okatankwo River. It could be recommended that industrial effluent be properly treated before discharge into the Okatankwo River to prevent further pollution and contamination of the water.

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Aluminium Extrusion Effluent can significantly degrade water quality in rivers, impacting aquatic life, ecosystem health, and potentially human well-being. Effective management strategies and regulatory measures are essential to mitigate these impacts and ensure the sustainability of freshwater resources (Anunihu and Odoemenam, 2023). The impact of aluminium industrial effluent on the water quality of a river can be significant and multifaceted. Aluminium effluents can alter the pH levels of the river water, making it more acidic. This can disrupt the aquatic ecosystem by affecting the solubility of other minerals and metals present in the water. Elevated levels of aluminium in water can be toxic to aquatic organisms such as fish, invertebrates, and plants (Adams and Maher, 1999). It interferes with their respiratory systems, impairs their ability to take up oxygen, and damages their gills and other tissues. Aluminium can accumulate in the tissues of aquatic organisms over time, leading to potential health impacts as it moves up the food chain. Predatory species may accumulate higher concentrations of aluminium, posing risks to both wildlife and humans who consume affected fish or other aquatic organisms (Atuanya et al., 2016).

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Depending on the industrial process, aluminium effluent may contain acidic or basic components used for chemical reactions or pH adjustment (Bobmanuel et al., 2006). This can lead to alterations in the pH of receiving waters if not properly neutralized or treated. Untreated or allegedly treated industrial effluents often contains variable amounts of heavy metals such as arsenic, lead, nickel, cadmium, copper, mercury, zinc and chromium (Singare and Sharma, 2010). Industrial processes may introduce organic chemicals into effluents, including solvents, lubricants, or other substances used in manufacturing processes (Ekweozor et al., 2010). These can have varying degrees of toxicity and persistence in aquatic environments. Aluminium effluent can contain suspended solids, which may include fine particles of aluminium hydroxide, clay, or other materials used or generated during processing. These solids can affect water clarity and sedimentation processes in rivers. Depending on the industrial process, effluents may be discharged at elevated temperatures, which can alter water temperature regimes and affect aquatic organism's sensitive to temperature changes (European Public Health Alliance, 2009). In some cases, aluminium effluent may contain nutrients such as nitrogen or phosphorus, which can lead to eutrophication if discharged in excessive amounts, promoting algal blooms and subsequent oxygen depletion in water bodies (Johansson, 1977).

Aluminium ions can also cause sedimentation issues in rivers, affecting light penetration and hindering photosynthesis in aquatic plants. This alters habitat structures for various organisms and disrupts the ecological balance of the river ecosystem (Kennicutt, 1994). While direct exposure to aluminium through drinking water from rivers is less common due to treatment processes, contamination can occur through consumption of aquatic organisms. Long-term exposure to elevated levels of aluminium has been associated with neurological disorders and other health issues in humans (Mosley et al., 2004). Governments often regulate the discharge of aluminium and other pollutants into water bodies through environmental laws and permits. Efforts to control and reduce aluminium effluents typically involve improved industrial processes, wastewater treatment technologies, and monitoring programs to safeguard water quality (Onyenechere et al., 2011). The composition of aluminium industrial effluent can vary depending on the specific industrial processes involved. The specific composition and concentrations of these components in aluminium industrial effluent can vary widely depending on the industry, the production methods, and the effectiveness of wastewater treatment measures in place (Patil, 2009). Monitoring and regulation are critical to ensuring that effluents do not adversely impact water quality, aquatic ecosystems, or human health downstream. However, typical components found in aluminium industrial effluent that can impact water quality include: aluminium sulfate, and aluminium chloride which used in industrial processes (Salomons, 1984). These can be highly soluble in water and contribute to increased aluminium concentrations in effluent. Hence, the objective of this paper is to evaluate the physicochemical characteristics and heavy metals content of water from Okatankwo River in Ikeduru Local Government Area, Imo State, Nigeria.

MATERIALS AND METHODS

Area of Study: Ikeduru L.G.A. is one of the 27 L.G.As of Imo State, Nigeria with a population of 199,316 according to the 2006 National Population Census; with an annual growth rate of 9%. It is located on longitude 7°04-E and 7°14-E and latitude 5°29-N and 5°39-N. (Figure 1).

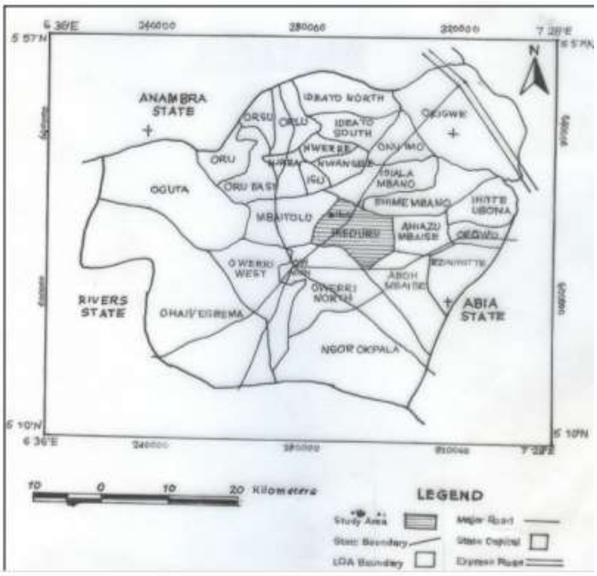

Fig. 1. Map of Imo State showing the study area

It is drained by series of rivers and streams namely Okatankwo, Oramiriukwa and Mbaa. The rivers are characterized by dry valleys which are usually covered by flood waters in periods of high rainfall. The aquifers are recharged by means of flood water infiltration during the rainy season. In this study, the Okatankwo river transverses Akabo, Atta, Inyishi communities in Ikeduru LGA of Imo State; with Inyishi hosting an aluminium extrusion plant. There is no reported incidence or evidence of improper waste disposal practices such as waste discharge into the surrounding water bodies; however, there is a high probability of some environmental impact resulting from industrial production activities within the host communities. Other sources of potential water contamination may result from erosion water run-off, fishing activities, farming activities such as washing of some farm produce in the rivers (example bread-fruit, cassava) and washing of motor vehicles along the river banks (Singare and Sharma, 2010).

Climatic Conditions: The study area is in the humid tropics with over 2,000 mm of rainfall per annum and a mean annual temperature of about 27ºC. The rainy season commences in March/April and ends in October/November.

Study design: Effluents were collected from the nearby aluminium extrusion industry and water samples were collected at 5 selected points along the receiving river.

Sampling: Samples of the effluent were collected directly from the industry each month for a period of three months (April- June, 2016) as well as the water samples which were collected at five distinct points in the river during the morning, afternoon and evening period using 50cl bottles. (number of samples collected each month, n =16). The bottles were thoroughly washed with distilled water twice, at the point of collection; the bottles were rinsed with the water samples before sample collection, corked tightly and labelled. All the samples were taken to the Soil science laboratory of National Root Crops Research Institute, Umudike where the test was carried out.

*Determination of heavy metals***:** by the Atomic Absorption Spectrophotometer (American Chemistry Society. Washington DC 1968). 100ml of the sample was measured into a beaker and placed on a hot plate to evaporate to dampness, 10ml of conc. HNO_3 added and further heated to reduce the volume, 5ml of per chloric acid was added to the sample and heated to complete the digestion, until a profuse per chloric fumes emerged. The sample was transferred into a 50ml volumetric flask and made up to the mark using distilled water. The digest was used for the determinations of the heavy metals using the atomic absorption spectrophotometer. PG 500 Instruments. Water analysis by atomic absorption and flame emission spectroscopy. Trace inorganic elements in water (Udochukwu et al., 2017; Anyanwu et al., 2023).

Statistical analysis: Values of the various parameters were subjected to statistical analysis using statistics package for social science (SPSS). Completely randomize Design (CRD) with three replicates for each site in each parameter analyzed was used for the Analysis of variance (ANOVA) thereafter Duncan Multiple Range Test (DTMRT) was used for mean differentiation. Data were then represented with mean ± standard error (Udochukwu et al., 2014; 2024).

RESULT AND DISCUSSION

The results from this study shows the heavy metal content of Okatankwo river in the first month shows that Ni values were slightly within the SON standard although the effluent value of 3.45 mg/l was above it. Site 2 and 3 values of 0.32 mg/l and 0.38 mg/l were above the standard of 0.1 mg/l and 0.2 mg/l for WHO and SON respectively. There was a significant different ($P \leq 0.05$) between site 4 and the other sites for Zn. This result is collaborated with (Anunihu, and Odoemenam, 2023) who observed similar trend in their research on Inyishi river.

The effluent value of 0.74 mg/l and a mean range of 0.05 ± 0.01mg/l to 0.63 ± 0.42 mg/l along the sites were above the WHO standard of 0.01 mg/l (Table 1). The mean values for Al and Cr showed no significant difference ($P \geq 0.05$) among the means of the various sites. In the second month, the mean values of Pb and Fe showed no significant different also ($P \geq 0.05$) among the sites although the Pb value exceeded the WHO standard of 0.05 mg/l. All the sites had values of Zn that were below the 5.0mg/l WHO standard.

There was a significant different ($P \leq 0.05$) between site 4 and site 5 for Al. From site 2 Cr had all the values below WHO and SON permissible limit of 0.05 mg/l except for site 3 which was slightly above it at 0.06 ± 0.01 (Table 3).

The heavy metal content of Okatankwo River in the 3rd month show no significant difference ($P \geq 0.05$) for Pb at the different sites. The 8.10 mg/l effluent value for Zn was above WHO permissible limit and also slightly above the values of the sites which ranged from 2.29 ± 0.15 mg/l to 4.04 ± 0.98 mg/l. Site 1,2,4,3 differed significantly ($P < 0.05$) in Cd. However, values of Cd concentrations for the sites were slightly above the WHO Standard (Table 5). The presence of these heavy metals increased the acidity and altered the physicochemical parameters of the river which as a result of the continuous release of heavy metal contaminated effluent from the Aluminum factory at Inyishi which now flow down to the Akabo section of the Okantankwo River (Yadav et al., 2007; Weston, 2002).

Physicochemical parameters from the 1st month shows that temperature had no significant difference among the sites and all the sites were above WHO standard of 23ºC. COD, TSS and TDS were all below the permissive limits for WHO and SON for the effluent and all the sites. Salinity ranged from 0.02 ± 0.003

mg/L to 0.08 ± 0.003 mg/l for the sites and 6.117 mg/l for the effluent. Site 5 which is the control site had the highest value in ammonia at 23.60 ± 2.27 mg/l and the lowest being site 1 at 12.13 ± 0.47 mg/l, they were all above SON permissible limit at 4.0 mg/l. Magnesium recorded the highest value of 63.55 ± 3.74 mg/l at site 3 and the rest of the sites ranged from 29.98 ± 3.542 mg/l to 38. 08 ± 2.91 mg/l. Phosphate had a mean range of 15.50 ± 3.90 mg/l to 23.67 ± 1.66 mg/l and the effluent was at 187.00 mg/l all were above the SON permissible limit of 5.0 mg/l. Also, Potassium and Sodium were significantly below the WHO standard

Table 1: Mean ± SE for parameters measured at selected sampling sites for heavy metals of the 1st month. (mg/l)

	Site 1	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
Ni	0.23±0.12^{a}	0.32±0.11^{a}	0.38±0.15^{a}	0.29±0.03^{a}	0.18±0.04^{a}	3.445	<0.10	0.20
Cu	0.85±0.11^{a}	0.36±0.15^{a}	0.27±0.08^{a}	0.31±0.03^{a}	0.29±0.11^{a}	14.45	<0.05	1.00
Pb	0.61±0.11^{a}	0.51±0.13^{a}	0.52±0.09^{a}	0.57±0.08^{a}	0.61±0.11^{a}	2.88	0.05	0.01
Fe	11.99±1.77^{a}	13.77±2.29^{a}	14.26±2.56^{a}	15.17±4.97^{a}	15.67±1.62^{a}	24.18		
Zn	3.30±0.98^{a}	2.89±0.95^{a}	3.06±0.58^{a}	1.94±0.27^{a}	2.25±0.68^{a}	5.00	5.00	3.00
Cd	0.05±0.01^{a}	0.07±0.03^{a}	0.09±0.04^{a}	0.36±0.01^{a}	0.63±0.42^{a}	0.740	<0.01	0.03
Al	4.61±0.49^{a}	7.52±1.95^{a}	6.09±1.21^{a}	5.00±0.71^{a}	4.29±0.41^{a}	38.40	0.20	0.20
Cr	0.04±0.01^{a}	0.05±0.01^{a}	0.06±0.01^{a}	0.05±0.01^{a}	.03±0.01^{a}	0.44	<0.05	0.05

Means with the same alphabet are not significantly different
SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

Table 2: Mean ± SE for parameters measured at selected sampling sites for physicochemical parameters of the 1st month.

	Site 1	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
pH	5.47±0.24^{a}	5.10±0.12^{a}	5.57±0.41^{a}	5.20±0.40^{a}	5.05±0.20^{a}	8.80	8.50	6.50-8.50
TEMP(^{0}C)	28.43±1.15^{a}	29.17±1.43^{a}	28.77±0.34^{a}	28.53±0.54^{a}	28.47±1.22^{a}	28.00	23.50	
COLOUR (EBC)	0.03±0.004^{a}	0.13±0.06^{b}	0.02±0.002^{a}	0.05±0.03^{a}	0.02±0.005^{a}	0.224		
TURBIDITY(NTU)	0.03±0.00^{b}	0.02±0.002^{a}	0.02±0.003^{a}	0.02±0.003^{a}	0.01±0.002^{a}	0.116	5.00	-
EC (µS/cm)	8.97±2.00^{ab}	5.01±1.01^{a}	5.38±0.62^{a}	7.01±1.94^{ab}	11.33±1.39^{b}	108.20	400.00	1000.00
DO (mg/l)	4.36 ± 0.31^{b}	3.73 ± 0.12^{ab}	4.07 ± 0.02^{ab}	3.70 ± 0.25^{ab}	3.57 ± 0.27^{a}		5.00	
BOD (mg/l)	1.22 ± 0.03^{ab}	0.87 ± 0.03^{a}	1.80 ± 0.56^{b}	1.50 ± 0.06^{ab}	1.50 ± 0.06^{ab}	2.60	3.00	-
COD (mg/l)	16.83 ± 0.52^{a}	12.00 ± 4.17^{a}	11.19 ± 0.32^{a}	10.59 ± 0.87^{a}	11.04 ± 0.50^{a}	208.10		200.00
TDS (mg/l)	29.90±4.38^{a}	32.57±6.85^{a}	26.73±10.28^{a}	18.38±5.59^{a}	23.10±5.06^{a}	3944.0	500.00	500.00
TSS (mg/l)	13.70±0.60^{a}	13.47±2.34^{a}	13.23±1.76^{a}	16.90±3.61^{a}	18.73±3.15^{a}	1143.00		1500.00
SALINITY (mg/l)	0.02±0.003^{a}	0.06±0.02^{a}	0.04±0.01^{a}	0.02±0.005	0.08±0.03^{a}	6.117	200.00	
NH_4^+ (mg/l)	12.13±0.47^{a}	16.13±1.21^{a}	15.27±0.70^{a}	15.10±1.99^{a}	23.60±2.27^{b}	137.2		4.00
NO_3^- (mg/l)	7.00±0.81^{a}	7.48±1.68^{ab}	8.40±1.62^{ab}	5.43±1.32^{a}	11.67± 0.93^{b}	36.40	50.00	50.00
Cl^- (mg/l)	119.52±1.88^{a}	114.78±7.76^{a}	100.58±2.37^{a}	115.97±12.35^{a}	126.62±12.35^{a}	265.88	250.00	250.00
Ca^{2+} (mg/l)	93.51±14.13^{b}	44.07±10.59^{a}	77.13±14.45^{ab}	91.22±17.42^{b}	92.18±12.87^{b}	248.50	150.00	150.00
Mg^{2+} (mg/l)	32.42±7.98^{a}	33.78±5.40^{a}	63.55±3.74^{b}	38.08±2.91^{b}	29.98±3.542^{a}	53.50	150.00	
PO_4^{3-} (mg/l)	17.20±2.21^{a}	17.97±5.34^{a}	15.50±3.90^{a}	23.67±1.66^{a}	23.67±1.66^{a}	187.00		5.00
K^+ (mg/l)	0.41±0.04^{a}	0.56±0.12^{a}	0.58±0.05^{a}	0.54±0.06^{a}	0.54±0.02^{a}	5.50	200.00	
Na^+ (mg/l)	1.18±0.32^{a}	0.84±0.02^{a}	0.87±0.03^{a}	0.83±0.02^{a}	0.83±0.02^{a}	25.10	200.00	

Means with the same alphabet are not significantly different
SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

Table 3: Mean ± SE for parameters measured at selected sampling sites for heavy metal of the 2nd month

	Site 1`	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
Ni	0.21±0.10^{b}	0.34±0.11^{b}	0.67±0.15^{a}	0.35±0.04^{b}	0.19±0.06^{b}	3.940	<0.10	0.20
Cu	0.91±0.06^{a}	0.33±0.14b	0.18±0.06^{b}	0.31±0.04^{b}	0.27±0.09^{b}	15.00	<0.05	1.00
Pb	0.64±0.12^{a}	0.52±0.11^{a}	0.52±0.09^{a}	0.57±0.08^{a}	0.53±0.14^{a}	2.95	0.05	0.01
Fe	12.70±1.93^{a}	13.98±1.96^{a}	15.23±2.53^{a}	11.97±1.74^{a}	8.53±4.58^{a}	23.91		
Zn	3.58±1.00^{a}	3.13±1.03^{a}	3.44±0.67^{a}	1.8±0.14^{a}	1.94±0.13^{a}	5.42	5.00	3.00
Cd	0.06±0.02^{b}	0.26±0.21^{ab}	0.08±0.03^{b}	0.30±0.06^{ab}	0.49±0.03^{a}	1.21	<0.01	0.03
Al	4.47±0.38^{ab}	7.80±2.15^{a}	5.20±0.50^{ab}	4.23±0.28^{b}	4.63±0.47^{b}	37.00	0.20	0.20
Cr	0.04±0.01^{ab}	0.04±0.01^{ab}	0.06±0.01^{a}	0.05±0.009^{ab}	0.03±0.006^{b}	0.50	<0.05	0.05

Means with the same alphabet are not significantly different
SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

From the second month, pH values for site 1 to 5 were all below the permissive limits except for the effluent which was above WHO and SON limits. The values recorded for temperature were all above the WHO and SON limits which have been observed from previous research (Udochukwu et al., 2017). Also, TDS values for all sites were all below the permissive limits except for the effluent which was above WHO and SON limits. Electrical conductivity had no significant difference ($P \geq 0.05$) among the sites; however, they were all within the allowable limits (Udochukwu and Olanye, 2020). Calcium ion (Ca^{2+}) recorded values for site 1 to 5 which were below the limits, but the effluent value was above the WHO and SON permissible limits (Table 4). It was recorded that ammonium had values ranging from 4.90 $\pm$ 2.13 mg/l to 7.83 $\pm$ 0.43mg/l for the sites while the effluent value was 40.50mg/l, which were all above SON limits.

Nitrate on the other hand had no significant difference ($P \geq 0.05$) between sites as they were all below WHO and SON permissible limits. In phosphate there was no significant difference ($P \geq 0.05$) between the sites they were also far below the effluent value of 200 mg/l (Table 4). Industrial effluents should be properly treated before its release into the river.

According to (Mosley et al., 2004), untreated industrial effluent will definitely affect the water quality and altered its natural biological processes (Johansson, 1977). Anunihu and Odoemenam (2023, also agree that heavy metals from industrial effluents should be within the WHO and SON allowable limits in other to monitor and control heavy metal pollution and contamination of the aquatic ecosystem.

Table 4: Mean $\pm$ SE for parameters measured at selected sampling sites for physicochemical parameters of the 2nd month.

	Site 1	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
pH	8.28 ± 0.03^{a}	8.22 ± 0.06^{a}	7.95 ± 0.06^{ab}	$7.76\pm$ 0.0.03^{bc}	7.30 ± 0.24^{c}	9.81	8.5	6.50 – 8.50
TEMP (°c)	28.10 ± 0.01^{a}	28.12 ± 0.003^{a}	28.07 ± 0.02^{a}	27.93 ± 0.02^{b}	27.81 ± 0.07^{b}	28.16	23.50	
COLOUR (EBC)	0.03 ± 0.01^{a}	0.02 ± 0.004^{a}	0.03 ± 0.01^{a}	0.04 ± 0.01^{a}	0.02 ± 0.002^{a}	0.20		
Turbidity (NTU)	0.10 ± 0.008^{a}	0.02 ± 0.003^{c}	0.02 ± 0.004^{bc}	0.04 ± 0.005^{bc}	0.03 ± 0.007^{b}	0.30	5.00	-
EC (μS/cm)	0.09 ± 0.04^{a}	0.01 ± 0.00^{a}	0.01 ± 0.001^{a}	0.01 ± 0.001^{a}	0.06 ± 0.04^{a}	0.18	400.00	1000.00
DO (mg/l)	3.38 ± 0.21^{a}	4.69 ± 0.11^{a}	4.26 ± 0.57^{b}	4.92 ± 0.30^{b}	2.80 ± 0.01^{a}		5.00	
BOD (mg/l)	1.00 ± 0.06^{b}	0.14 ± 0.03^{a}	1.60 ± 0.25^{c}	1.16 ± 0.09^{ab}	1.09 ± 0.16^{a}	92.50	3.00	-
COD (mg/l)	11.49 ± 0.37^{b}	8.65 ± 8.65^{a}	11.09 ± 0.09^{c}	12.69 ± 0.19^{a}	9.43 ± 0.23^{b}	180.40		200.00
TDS (mg/l)	28.67 ± 13.25^{a}	19.67 ± 3.71^{a}	22.67 ± 2.85^{a}	18.67 ± 3.18^{a}	41.33 ± 16.4^{a}	880.30	500.00	500.00
TSS (mg/l)	16.81 ± 1.78^{a}	22.02 ± 3.41^{a}	15.60 ± 1.56^{a}	16.00 ± 2.56^{a}	$21.53+7.19^{a}$	801.30		1500.00
SALINITY (mg/l)	0.02 ± 0.01^{b}	0.09 ± 0.03^{a}	0.02 ± 0.004^{b}	0.02 ± 0.004^{b}	0.03 ± 0.01^{b}	0.08	200.00	
NH_4^+(mg/l)	7.67 ± 2.47^{a}	7.83 ± 0.42^{a}	4.90 ± 2.15^{a}	6.37 ± 1.84^{a}	5.63 ± 1.77^{a}	40.50		4.00
NO_3^-(mg/l)	7.53 ± 2.98^{a}	7.00 ± 0.95^{a}	5.47 ± 1.58^{a}	2.40 ± 0.31^{a}	4.67 ± 1.67^{a}	30.20	50.00	50.00
Cl^- (mg/l)	44.10 ± 3.37^{a}	63.80 ± 3.00^{a}	64.45 ± 12.52^{a}	43.90 ± 4.93^{a}	56.53 ± 8.34^{a}	250.20	250.00	250.00
Ca^{2+}(mg/l)	21.68 ± 2.41^{a}	39.47 ± 11.95^{a}	26.73 ± 2.75^{a}	19.78 ± 11.13^{a}	31.77 ± 4.77^{a}	451.20	150.00	150.00
Mg^{2+}(mg/l)	18.37 ± 2.06^{a}	23.13 ± 7.33^{a}	17.00 ± 6.69^{a}	15.07 ± 7.70^{a}	22.50 ± 2.16^{a}	75.20	150.00	
K^+(mg/l)	0.33 ± 0.12^{ab}	0.45 ± 0.06^{ab}	0.62 ± 0.07^{a}	0.56 ± 0.06^{ab}	0.58 ± 0.02^{ab}	5.58	200.00	
Na^+(mg/l)	1.05 ± 0.12^{ab}	0.91 ± 0.04^{ab}	0.88 ± 0.03^{ab}	0.89 ± 0.05^{ab}	0.82 ± 0.02^{b}	25.40	200.00	
PO_4^{3-}(mg/l)	13.30 ± 0.85^{a}	14.52 ± 1.30^{a}	17.23 ± 1.64^{a}	15.60 ± 0.70^{a}	17.47 ± 1.54^{a}	115.00		5.00

Means with the same alphabet are not significantly different
SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

Table 5: Mean $\pm$ SE for parameters measured at selected sampling sites for heavy metals of the 3rd month. (Mg/l)

	Site 1	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
Ni	0.04 ± 0.01^{a}	0.31 ± 0.25^{a}	0.05 ± 0.02^{a}	0.39 ± 0.33^{a}	0.05 ± 0.01^{a}	2.23	< 0.10	0.20
Cu	0.12 ± 0.05^{b}	0.10 ± 0.02^{b}	0.18 ± 0.06^{ab}	0.24 ± 0.05^{ab}	0.38 ± 0.14^{a}	11.15	<0.05	1.00
Pb	0.48 ± 0.22^{a}	0.62 ± 0.26^{a}	0.38 ± 0.14^{a}	0.49 ± 0.24^{a}	0.69 ± 0.29^{a}	1.15	0.05	0.01
Fe	4.78 ± 0.42^{b}	4.63 ± 0.52^{b}	7.97 ± 1.50^{a}	6.89 ± 1.21^{ab}	1.04 ± 0.54^{c}	20.80		
Zn	4.04 ± 0.98^{a}	2.29 ± 0.15^{a}	2.75 ± 0.21^{a}	3.10 ± 0.64^{a}	3.87 ± 0.67^{a}	8.10	5.00	3.00
Cd	0.20 ± 0.09^{b}	0.36 ± 0.06^{b}	0.48 ± 0.08^{ab}	0.08 ± 0.02^{b}	1.44 ± 0.70^{a}	1.59	<0.01	0.03
AL	5.17 ± 0.09^{a}	4.31 ± 0.66^{a}	4.90 ± 0.96^{a}	7.43 ± 1.29^{a}	5.42 ± 1.86^{a}	44.20	0.20	0.20
Cr	0.11 ± 0.01^{a}	0.08 ± 0.01^{a}	0.45 ± 0.37^{a}	0.45 ± 0.37^{a}	0.06 ± 0.01^{a}	0.70	<0.05	0.05

Means with the same alphabet are not significantly different
SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

Table 6: Mean + SE for parameters measured at selected sampling sites for physicochemical parameters of the 3rd Month

	Site 1	Site 2	Site 3	Site 4	Site 5	Effluent	WHO	SON
pH	5.20 ± 0.15^{b}	5.53 ± 0.35^{ab}	5.77 ± 0.43^{ab}	6.43 ± 0.27^{a}	5.57 ± 0.30^{ab}	8.70	8.50	6.50 – 8.50
TEMP (^{o}C)	27.2 ± 0.56^{a}	27.27 ± 0.89^{a}	27.03 ± 1.07^{a}	$26.80\pm0.0.38^{a}$	$26.80\pm0.0.38^{a}$	29.00	23.50	
Colour (EBC)	0.08 ± 0.04^{a}	0.04 ± 0.01^{a}	0.34 ± 0.29^{a}	0.11 ± 0.004^{a}	0.08 ± 0.03^{a}	0.31		
Turbidity (NTU)	0.09 ± 0.03^{a}	0.08 ± 0.02^{a}	0.05 ± 0.02^{a}	0.08 ± 0.03^{a}	0.08 ± 0.03^{a}	0.12	5.00	-
EC (µS/cm)	3.63 ± 0.56^{a}	3.60 ± 1.39^{a}	3.02 ± 0.99^{a}	2.97 ± 0.78^{a}	4.28 ± 0.44^{a}	228.20	400.00	1000.00
DO (mg/l)	4.73 ± 0.07^{c}	4.52 ± 0.23^{bc}	4.06 ± 0.09^{b}	4.00 ± 0.19^{b}	3.32 ± 0.28^{a}		5.00	
BOD (mg/l)	0.20 ± 0.10^{a}	1.23 ± 0.28^{b}	0.23 ± 0.02^{a}	1.37 ± 0.09^{b}	1.23 ± 0.04^{b}	218.40	3.00	-
COD (mg/l)	$12.16\pm 0.09^{c\,c}$	11.34 ± 0.26^{b}	11.52 ± 0.21^{b}	11.30 ± 25^{b}	8.13 ± 0.10^{b}	221.10		200.00
TDS (mg/l)	30.90 ± 4.24^{a}	32.97 ± 6.98^{a}	44.10 ± 8.57^{a}	37.40 ± 10.66^{a}	19.53 ± 7.49^{a}	400.20	500.00	500.00
TSS (mg/l)	14.14 ± 0.52^{b}	13.24 ± 1.67^{b}	13.33 ± 2.07^{b}	13.49 ± 1.91^{b}	23.23 ± 1.96^{a}	904.00		1500.00
SALINITY (mg/l)	0.04 ± 0.02^{a}	0.06 ± 0.02^{a}	0.06 ± 0.02^{a}	$0.02\pm0.0,004^{a}$	0.09 ± 0.03^{a}	7.11	200.00	
NH_4^+(mg/l)	12.34 ± 0.68^{a}	16.77 ± 4.72^{a}	16.79 ± 0.88^{a}	21.83 ± 6.03^{a}	12.53 ± 8.74^{a}	140.40		4.00
NO_3^-(mg/l)	5.57 ± 1.48^{a}	7.90 ± 1.25^{a}	8.80 ± 1.64^{a}	8.07 ± 0.73^{a}	7.40 ± 1.80^{a}	39.00	50.00	50.00
Cl^-(mg/l)	123.51 ± 3.89^{ab}	112.82 ± 9.05^{ab}	105.51 ± 4.19^{b}	123.64 ± 9.73^{ab}	135.16 ± 7.56^{a}	282.19	250.00	250.00
Ca^{2+}(mg/l)	106.50 ± 17.90^{a}	59.90 ± 15.49^{bc}	38.03 ± 8.43^{ab}	101.01 ± 11.66^{a}	93.32 ± 13.28^{ab}	250.10	150.00	150.00
Mg^{2+}(mg/l)	37.16 ± 2.33^{ab}	29.33 ± 6.64^{b}	48.69 ± 6.71^{a}	39.02 ± 2.71^{ab}	40.99 ± 7.37^{ab}	52.99	150.00	
K^+(mg/l)	0.43 ± 0.04^{a}	$0.590.12^{a}$	0.56 ± 0.11^{a}	$0.51\pm0.0.06^{a}$	0.42 ± 0.26^{a}	3.00	200.00	
Na^+(mg/l)	0.99 ± 0.11^{a}	0.86 ± 0.30^{a}	1.67 ± 0.66^{a}	0.60 ± 0.06^{a}	0.87 ± 0.02^{a}	28.10	200.00	
PO_4^{3-}(mg/l)	15.97 ± 0.38^{b}	18.90 ± 4.10^{b}	19.73 ± 7.34^{b}	51.77 ± 13.73^{a}	14.40 ± 2.92^{b}	190.00		5.00

Means with the same alphabet are not significantly different

SE means Standard Error, < 0.01 Implies that the values were below the minimum detectable limit of 0.01

Conclusion: The results from this study have revealed the presence of heavy metals in Okatankwo River which is as a result of a continuous release of aluminium effluent from the aluminium extrusion industry in Iyinshi Village. It could be recommended that industrial effluent be properly treated before discharge into the Okatankwo River to prevent further pollution and contamination of the river.

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Data Availability Statement: Data are available upon request from the corresponding author.

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