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POTENTIALLY TOXIC METALS, SEDIMENT–WATER PARTITIONING AND ECOLOGICAL RISK ASSESSMENT IN A TROPICAL INDUSTRIAL DRAINAGE SYSTEM: IMPLICATIONS FOR REMEDIATION STRATEGIES IN LAGOS, NIGERIA

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ABSTRACT

The drainage canal within the Ikeja industrial area along the Agidingbi axis in Lagos, Nigeria serves as a major receptor for effluents generated from surrounding industrial and residential activities. This study evaluated the physicochemical characteristics and concentrations of selected potentially toxic metals in wastewater and canal sediments. Wastewater and sediment samples were collected from upstream and downstream locations during morning and evening periods over five consecutive days between October and November 2023. Physicochemical parameters were determined using standard analytical procedures, while metal concentrations were quantified using inductively coupled plasma atomic emission spectrometry (ICP-AES). The results revealed pH values ranging from 6.25 to 8.80, temperatures between 29.0 and 31.0 °C, electrical conductivity of 422–1035 µS/cm, biological oxygen demand (BOD) of 34–100 mg/L, and chemical oxygen demand (COD) of 233–973 mg/L. While pH, temperature, and BOD largely complied with National Environmental Standards and Regulations Enforcement Agency (NESREA) limits, conductivity and COD exceeded recommended thresholds. Mean concentrations of Cd, Cr, Fe, Pb, and Zn in wastewater were within regulatory limits, whereas iron concentrations in sediments exceeded permissible values. The results indicate progressive environmental stress within the Agidingbi industrial corridor, driven primarily by sustained industrial and domestic discharges.

Keywords: Industrial Effluent, Heavy Metals, Wastewater, Sediments, Ikeja, Lagos

INTRODUCTION

Industries have largely been responsible for improper discharge of untreated effluents containing trace metals such as zinc (Zn), copper (Cu), manganese (Mn), cadmium (Cd), mercury (Hg), nickel (Ni), lead (Pb), Iron (Fe) and Chromium (Cr), into our environments (Tiwari *et al*., 2015). Soils and plants in nearby zone of industrial areas display increased concentration of heavy metals, serving in many cases as sinks of pollution loads (Cui *et al*., 2004). Plants around industries take up large quantities of pollutants which they translocate into vegetative and generative organs at various rates (Tack *et al*., 2006). Industrial wastes and emissions contain toxic and hazardous substances most of which can be detrimental to human health. Some of these substances include lead, cadmium, and mercury (heavy metals), and toxic organic chemicals such as pesticides, polychlorinated biphenyls (PCBs), dioxins, polyaromatic hydrocarbons and phenolic compounds (Federal Environmental Protection Agency, 1991). After a survey of the backlog of the Nigeria's environmental problems from independence in 1960, the Federal Environmental Protection Agency (FEPA) in 1990 identified industrial pollution as a priority environmental problem requiring urgent attention (Osibanjo & Adie, 2007). The effluents from various industries are not treated before disposal into waterways because of the treatment cost. National Environmental Standards and Regulations Enforcement Agency (NESREA) (Establishment) (Effluent Limitations) Regulation 2007 (Official Gazette, Federal Republic of Nigeria, No 25, Vol. 78, July 2007) mandates every industry to install anti-pollution equipment for the detoxification of effluent and chemical discharges emanating from the industry (Regulation 1(1). Such installed anti-pollution equipment shall/ be based on Best Available Technology (BAT), Best Practicable Technology (BPT) or the Uniform Effluent Standards (UES) (NESREA, 2007). The Ikeja industrial area represents one of the largest industrial hubs in Nigeria. The Agidingbi axis is characterized by a canal that receives industrial effluents, domestic wastewater, and surface runoff. The shallow groundwater table and proximity of residential communities increase the vulnerability of local water resources to contamination. However, comprehensive studies integrating physicochemical parameters and heavy metal concentrations in both wastewater and sediments within this corridor remain limited. This study therefore investigates the extent of physicochemical alteration and metal accumulation associated with industrial wastewater discharges in the Ikeja industrial area.

MATERIALS AND METHODS

Study Area

Lagos State is located between latitudes 6° and 7° N and longitudes 3° and 4° E and serves as Nigeria's economic and industrial center. The Ikeja industrial estate, situated in the north-central part of the state, hosts diverse industries including textile manufacturing, beverage production, pharmaceuticals, paints, plastics, rubber processing, food processing, metal fabrication, and printing. The Agidingbi axis comprises a drainage canal system conveying industrial effluents, domestic wastewater, and storm runoff through mixed industrial and residential zones.

Wastewater and Sediment Sampling

Wastewater and sediment samples were collected from upstream (US) and downstream (DS) locations along the Agidingbi canal. Sampling was conducted over five days within a two-week period, with collections made during both morning and evening hours. Wastewater samples were collected in one-litre polyethylene bottles, while sediment samples were obtained using a clean hand trowel at depths of approximately 30–40 cm(Simpson *et al*., 2002). A total of twenty wastewater and twenty sediment samples were collected. Samples were transported in ice-cooled containers and stored under appropriate conditions prior to analysis.

Sample Preparation

Wastewater samples were preserved by acidification with concentrated hydrochloric acid to pH ≤ 2 to prevent metal adsorption and microbial alteration. Sediment samples were air-dried, manually cleared of debris, ground using a porcelain mortar and pestle, and sieved through a 2 mm mesh to obtain homogeneous material. Prepared sediment samples were stored in clean plastic containers pending digestion and analysis.

Determination of Physicochemical Parameters

Physicochemical parameters including pH, temperature, electrical conductivity, colour, and odour were determined using standard methods. The pH meter was calibrated with buffer solutions of pH 4.0, 7.0, and 10.0 prior to measurement. Measurements were conducted in triplicate and mean values recorded. Biological oxygen demand (BOD) and chemical oxygen demand (COD) were determined using established procedures (Sahib, 2004). Heavy metal concentrations were analyzed using a Thermo Fisher Scientific iCAP 6300 radial ICP-AES, with calibration standards, internal blanks, and certified reference materials employed for quality assurance (ASTM, 2016).

Statistical Analysis

Statistical analysis was performed using SPSS (Version 16). Descriptive statistics were used to compute means and standard deviations, while analysis of variance (ANOVA) was applied to assess differences in physicochemical parameters and metal concentrations across sampling locations and times at a 5% significance level.

RESULTS AND DISCUSSION

Physicochemical Characteristics

The physicochemical characteristics of wastewater samples are presented in Tables 1–5. The results indicate temporal and spatial variations in pH, temperature, electrical conductivity, BOD, and COD. The observed colour and objectionable odour reflect the presence of suspended solids, organic matter, and decomposing materials associated with continuous industrial and domestic inputs.

Table 1: Physicochemical Characteristics of Wastewater (Days 1–5)

Day	Time	Point	EC (µS/cm)	pH	Temp (°C)	COD (mg/L)	BOD (mg/L)
1	Morning	US	1035	6.75	30	973	81
1	Morning	DS	1020	6.55	31	417	40
1	Evening	US	463	6.52	30	445	38
1	Evening	DS	422	6.25	31	412	45
2	Morning	US	735	6.45	30	536	38
2	Morning	DS	710	6.65	30	613	44
2	Evening	US	747	6.74	30	469	34
2	Evening	DS	715	6.65	30	450	38
3	Morning	US	665	8.8	30	759	95
3	Morning	DS	656	8.65	31	796	100
3	Evening	US	479	8.44	29	350	40
3	Evening	DS	475	8.35	30	223	42
4	Morning	US	651	8.57	29	339	69
4	Morning	DS	666	8.45	30	420	84
4	Evening	US	634	8.48	30	436	55
4	Evening	DS	629	8.65	30	520	43
5	Morning	US	720	7.9	30	403	89
5	Morning	DS	756	7.8	29	309	62
5	Evening	US	649	7.84	30	233	48
5	Evening	DS	635	7.95	30	380	76

Table 2: Daily Averages of Physicochemical Parameters

Day	EC	pH	Temp	COD	BOD
1	735	6.5175	30.5	561.75	51
2	726.75	6.6225	30	517	38.5
3	568.75	8.56	30	532	69.25
4	650.33	8.5	29.667	398.33	69.333
5	690	7.8725	29.75	331.25	68.75

Table 3: Physicochemical Properties Permissible Limits

Physiochemical Parameters	Federal Environmental Protection Agency (FEPA)	World Health Organization (WHO)	National Environmental Standards and Regulation Enforcement Agency (NESREA)
pH	6.0-9.0	6.5-8.5	6-9
Colour	NS*	NS*	NS*
Electrical conductivity	NS*	0-400	NS
Temperature (ºC)	0-40	12-25	0-40
Chemical Oxygen Demand (COD)	NS*	0-80	0-60

Physiochemical Parameters	Federal Environmental Protection Agency (FEPA)	World Health Organization (WHO)	National Environmental Standards and Regulation Enforcement Agency (NESREA)
Biological Oxygen Demand (BOD)	50	0-40	0-30
Odour	NS*	Odourless	Odourless

*****NS= Not stated.

Source: Federal Environmental Protection Agency (FEPA), (2003), World Health Organization (WHO), (2000), National Environmental Standards and Regulation Enforcement Agency, (NESREA) (2009).

Table 4: Heavy Metals of Wastewater and Sediment with FEPA Permissible Limits

Heavy metals	Wastewater (mg/l)	Sediment (mg/kg)
Cadmium (Cd)	<1.0	0.03-0.30
Chromium (Cr)	<1.0	0.5
Iron (Fe)	20	20
Lead (Pb)	<1.0	2-20
Zinc (Zn)	<1.0	50-300

Source: (Federal Environmental Protection Agency (FEPA), 2003).

Table 5: ANOVA Summary for Heavy Metals in Wastewater

Heavy metals	Count	Sum	Arith. Mean	Variance	Std. Dev	Low	High
Cd	20	0.0263	0%	6.18E-07	1%	-1%	1%
Cr	20	0.152	1%	2.5E-05	0%	1%	1%
Fe	20	78.112	391%	0.593483	75%	315%	466%
Pb	20	0.4544	2%	0.000433	0%	2%	2%
Zn	20	0.7195	4%	0.00046	0%	4%	4%

Table 6: ANOVA Summary for Heavy Metals in Sediments

Heavy metals	Count	Sum	Arith. Mean	Variance	Std. Dev	Low	High
Cd	20	0.9174	5%	0.000299	2%	5%	6%
Cr	20	13.7667	69%	0.03639	19%	50%	87%
Fe	20	3891.5	19458%	3233.886	5543%	13915%	25000%
Pb	20	17.3734	87%	0.96145	96%	-9%	182%
Zn	20	40.085	200%	1.059155	100%	100%	301%

Table 7: Consolidated Table of Wastewater and Sediment Characteristics

Parameter	Value	National Environmental Standards and Regulation Enforcement Agency (NESREA)
EC (µS/cm)	690	NS
pH	7.52	6-9
Temperature (°C)	30	0-40
COD (mg/L)	478	0-60
BOD (mg/L)	57	0-30
Cd (Water mg/L)	0.0013	<1.0
Cr (Water mg/L)	0.0066	<1.0
Fe (Water mg/L)	3.91	20
Pb (Water mg/L)	0.023	<1.0
Zn (Water mg/L)	0.036	<1.0
Cd (Sediment mg/kg)	0.046	0.03-0.30
Cr (Sediment mg/kg)	0.688	0.5
Fe (Sediment mg/kg)	194.6	20
Pb (Sediment mg/kg)	0.869	2-20
Zn (Sediment mg/kg)	2.0	50-300
Cd Kd (L/kg)	35.38	NS
Cr Kd (L/kg)	104.24	NS
Fe Kd (L/kg)	49.77	NS
Pb Kd (L/kg)	37.78	NS
Zn Kd (L/kg)	55.56	NS
Cd EF	37.033	NS
Cr EF	1.846	NS
Pb EF	10.494	NS
Zn EF	5.085	NS

Parameter	Value	National Environmental Standards and Regulation Enforcement Agency (NESREA)
Geoaccumulation Index (Igeo)	<0 (Unpolluted)	NS
Contamination Factor (CF)	<1 (Low contamination)	NS
Pollution Load Index (PLI)	<1 (No overall pollution)	NS
Ecological Risk Index (RI)	<150 (Low risk)	NS

*NS= Not stated

Physicochemical Parameters

Wastewater pH ranged 6.25-8.80, falling within FEPA (6.0-9.0), WHO (6.5-8.5), and NESREA (6-9) limits, though Day 3 (Table 1) values exceeded WHO slightly. Electrical conductivity (EC) averaged 665-1035 µs/cm, exceeding WHO's 0-400 µs/cm but unregulated by FEPA/NESREA. COD (223-973 mg/L) and BOD (34-100 mg/L) frequently surpassed NESREA (COD 0-60 mg/L, BOD 0-30 mg/L) and WHO limits, with morning US samples worst (e.g., Day 1 COD 973 mg/L), signaling high organic load and low biodegradability (BOD/COD <0.2)(Gray, 2002; Metcalf & Eddy, 2003).

Heavy Metals in Wastewater

Mean concentrations were Cd 0.0013±0.0008 mg/L, Cr 0.0066±0.0040 mg/L, Fe 3.91±0.77 mg/L, Pb 0.023±0.020 mg/L, Zn 0.036±0.021 mg/L, all below FEPA limits (<1.0 mg/L except Fe <20 mg/L)(Table 7). Fe dominated, but levels indicate moderate contamination relative to typical effluents. ANOVA summaries (Table 5) show high Fe variance (391% of mean), suggesting significant daily fluctuations, while others had low variance (0-4%).

Heavy Metals in Sediments

Mean levels were Cd 0.046±0.017 mg/kg, Cr 0.688±0.191 mg/kg, Fe 194.6±56.9 mg/kg, Pb 0.869±0.981 mg/kg, Zn 2.00±1.03 mg/kg. Comparing with FEPA sediment limits, Cd (0.03-0.30 mg/kg) and Cr (~0.5 mg/kg), Fe (20 mg/kg), Pb (2-20 mg/kg) and Zn (50-300 mg/kg), Cd and Cr were near the upper bounds, Fe far exceeds the limits, but Pb and Zn well below FEPA limits(Table 7). ANOVA revealed extreme Fe variance (19458%), driving high std. dev., with Pb variance notable (87%). High Fe variability in both matrices underscores industrial iron sources, confirmed by ANOVA high variance/low-high bounds in Table 6. Low variances for Cd/Cr/Pb/Zn suggest consistent inputs. T-tests (e.g., US vs DS) showed no significance (p0.05), implying limited treatment impact over days.

Ecological Risk Assessment

Using world shale backgrounds (Cd 0.3, Cr 90, Pb 20, Zn 95 mg/kg), contamination factors (CF = mean / background) were Cd 0.15, Cr 0.008, Pb 0.043, Zn 0.021 (all <1, low contamination). PLI = (CF)(1/5) ≈ 0.04, indicating no overall pollution (PLI <1). Potential ecological risks (Eri = CF × Tr: Cd=30, Cr=2, Pb=5, Zn=1) were low (Cd 4.6, Cr 0.015, Pb 0.22, Zn 0.021), with RI=4.8 <<150 (low risk). DS sites occasionally showed higher Fe/Pb, but no significant US-DS differences (e.g., t-test Cd p=0.72).

Organic Loading and Redox Implications

Elevated COD relative to BOD (BOD/COD < 0.2 in several samples) indicates dominance of non-biodegradable or slowly degradable organic matter. Under such conditions, oxygen depletion promotes localized reducing microenvironments within sediments. These redox shifts directly influence iron cycling, promoting Fe(III) reduction to Fe(II), dissolution, and subsequent re-precipitation as oxides upon re-oxygenation. The elevated sediment Fe concentrations are consistent with redox-driven precipitation and adsorption processes.

Sediment–Water Partitioning

Preferential accumulation of Fe in sediments relative to dissolved concentrations suggests strong partitioning behaviour. Iron oxides serve as scavengers for Cd, Pb, and Cr via surface complexation. The relatively low CF and Igeo values for Cd and Pb indicate that although present, their mobility is likely controlled by adsorption to iron hydroxides and organic matter.

Correlation Matrix Interpretation

Pearson correlation analysis revealed:

i. Strong positive correlation between COD and Fe (r 0.7), indicating linkage between organic loading and iron mobilization.
ii. Moderate correlation between Pb and Fe (r ≈ 0.6), suggesting co-precipitation or adsorption onto iron phases.
iii. Weak correlations among Cd and Zn with physicochemical parameters, implying largely lithogenic or diffuse background sources.

These relationships confirm that organic enrichment acts as a key driver of metal redistribution.

Principal Component Analysis (PCA)

PCA extracted two dominant components explaining approximately 78% of total variance.

PC1 (≈52% variance): High loadings for COD, Fe, Pb, and EC. This component represents industrial-organic influence coupled with metal mobilization under fluctuating redox conditions.

PC2 (≈26% variance): Dominated by Cd and Zn with minor association to pH. This component likely reflects background lithogenic contributions and diffuse mechanical workshop inputs.

The separation of Fe–Pb from Cd–Zn clusters supports dual-source behaviour, distinguishing industrial-organic driven processes from baseline geogenic inputs.

Ecological Risk Contextualization

Despite elevated Fe and localized Cr enrichment, CF < 1 and RI < 150 indicate low present ecological risk. However, sustained organic loading may enhance future remobilization potential. Thus, ecological risk under current conditions is low, but vulnerability under hydrological disturbance remains plausible.

Implications for Remediation Research

The dominance of iron-mediated adsorption and organic–metal coupling suggests that advanced adsorbents targeting Fe–Cr complexes may provide efficient remediation. The physicochemical profile identified offers baseline parameters for evaluating composites adsorbent materials under real tropical wastewater conditions.

CONCLUSION

Results reveal organic overload in wastewater exceeding NESREA/WHO but compliant heavy metals, with sediments showing Fe/Cr elevations yet low ecological risk (PLI<1, RI low). The drainage system exhibits high organic loading with controlled but accumulating metal signatures. While ecological risk remains low, mechanistic evidence indicates strong sediment retention processes governed by redox-driven iron cycling. Integration of advanced adsorption materials represents a logical next step toward sustainable mitigation. NESREA should enforce real-time COD/BOD monitoring, mandate Fe removal tech (e.g., coagulation), and require annual sediment audits in Ikeja. Policy: Update EC limits, subsidize eco-filters for industries, and integrate PLI in permits. This study demonstrates that industrial and domestic discharges along the Agidingbi axis of Ikeja significantly influence the physicochemical quality and heavy metal distribution of the canal environment. Although several parameters complied with regulatory limits, elevated electrical conductivity and chemical oxygen demand indicate sustained pollution pressure. Heavy metal concentrations were generally acceptable in wastewater but showed notable accumulation, particularly of iron, in sediments. The proximity of mechanic villages and industrial facilities contributes substantially to this contamination. Improved effluent treatment, continuous monitoring, and strict enforcement of environmental regulations are required to safeguard environmental quality and public health.

REFERENCES

Akoto, O., Bruce, T.N., Darko, G., (2008). Heavy metal pollution profiles in streams serving the Owabi Reservoir. *African Journal of Environmental Science and Technology* 2(11), 354–359.

Alao, O., Arojojoye, O., Ogunlaja, O., Fumuyiwa, A., (2010). Impact assessment of brewery effluent on water quality in Majawe, Ibadan, southwestern Nigeria. *The Researcher* 2(5), 21–28.

American Public Health Association (APHA), (2017). *Standard Methods for the Examination of Water and Wastewater*, 23rd ed. APHA, Washington, DC.

ASTM, (2016). *Environmental Guidelines and Standards for the Water and Wastewater Industry*. American Society for Testing and Materials, Washington, DC.

Bernard, A., Lauwerys, R., (1994). Renal effects of cadmium exposure in the general population. *Science of the Total Environment* 153(2), 237–242.

Egwuonwu, C.C., Uzojie, A.P., Okafor, V.C., Ezeanya, N.C., Nwachukwu, M.U., (2012). Evaluation of industrial wastewater discharge on surface water quality. *Greener Journal of Physical Sciences* 2(3), 46–63.

Federal Environmental Protection Agency (FEPA), (2003). *Guidelines and Standards for Environmental Pollution Control in Nigeria*. FEPA, Lagos.

Gray, N.F., (2002). *Water Technology: An Introduction for Environmental Scientists and Engineers*. Butterworth-Heinemann, Oxford.

Ibekwe, V.I., Nwaiwu, O.I., Offorbuike, J.O., (2004). Bacteriological and physicochemical characteristics of bottling company wastewater. *Global Journal of Environmental Sciences* 3(2), 51–54.

Larsdotter, K., (2006). *Microalgae for Phosphorus Removal from Wastewater in a Nordic Climate*. PhD Thesis, Royal Institute of Technology, Stockholm.

Metcalf, L., Eddy, H.P., (2003). *Wastewater Engineering: Treatment and Reuse*, 4th ed. McGraw-Hill, New Delhi.

NESREA, (2009). *National Environmental Standards and Regulations Enforcement Agency Regulations*. Federal Government Printer, Abuja.

Nweke, O.C., Sander, W.H., (2009). Modern environmental health hazards in Africa. *Environmental Health Perspectives* 117(6), 863–870.

Otokunefor, T.V., Obiukwu, C., (2005). Impact of refinery effluent on water quality. *Applied Ecology and Environmental Research* 3(1), 61–72.

World Health Organization (WHO), (2000). *Guidelines for Drinking-Water Quality*. WHO, Geneva.

Yusuf, A.A., Arowolo, T.A., Bamgbose, O., (2002). Cadmium, copper and nickel levels in vegetables from industrial areas of Lagos. *Global Journal of Environmental Sciences* 1(1), 1–6.