Nigerian Research Journal of Engineering and Environmental Sciences 9(2) 2024 pp. 518-524
p ISSN: 2635-3342; e ISSN: 2635-3350

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Assessment of the Impact of Discharging Industrial Effluent on the Physio-chemical and Heavy Metal Parameters of the New Calabar River

Ikebude, C.F.

Department of Civil Engineering, Faculty of Engineering, University of Port Harcourt, Rivers State, Nigeria.
chiedozie.ikebude@uniport.edu.ng

http://doi.org/10.5281/zenodo.14565546

ARTICLE INFORMATION

Article history:
Received 23 Jul. 2024
Revised 10 Oct. 2024
Accepted 27 Oct. 2024
Available online 30 Dec. 2024

Keywords:
Effluent
River
Sample
Concentration
Maximum value
Minimum value

ABSTRACT

This study investigated the impact of effluent discharge on the physicochemical parameters of the New Calabar River. A total of 24 samples were collected—12 for physicochemical analysis and 12 for heavy metals—from the surrounding industrial aquatic environment. The samples were placed in a light-proof box to protect them from direct sunlight and transported to the laboratory for analysis. The physicochemical parameters included dissolved oxygen (DO), total dissolved solids (TDS), pH, electrical conductivity (EC), and heavy metals such as zinc (Zn), copper (Cu), nickel (Ni), cadmium (Cd), and lead (Pb). The DO concentration in the river mixture ranged from 0.3 to 1.3 mg/L, with an average of 0.60 mg/L, indicating a serious threat to aquatic life. The TDS values ranged from 53.68 to 267.05 mg/L, with a mean of 156.78 mg/L, where the highest TDS was observed at E5 and the lowest at E3. Calcium concentrations varied from 0 to 8.08 mg/L, averaging 2.075 mg/L, while sodium levels ranged from 36.58 to 83.77 mg/L, with a mean of 65.92 mg/L. The study revealed that the river water is septic due to increased industrial discharge of organic effluents. Zinc was identified as the most dominant heavy metal, with values ranging from 0.2 to 1 mg/L. The river water will require tertiary treatment before it can be used for domestic and municipal purposes.

1. INTRODUCTION

Freshwater availability is a critical issue globally, with approximately one-third of the world's drinking water derived from surface sources such as rivers, dams, lakes, and canals (Rahmanian et al., 2015). These water bodies also act as repositories for domestic and industrial waste, which poses significant threats to sustainable water supplies, especially in countries like Nigeria. In Nigeria, many communities depend on untreated or inadequately treated surface water for their daily needs, exposing them to waterborne diseases due to the lack of proper sanitation facilities and the presence of pollutants (Edori and Kpee, 2016).

Effluents, defined as industrial liquid wastes, vary in composition based on the industry of origin and can significantly impact water quality. Environmental Impact Assessments (EIA), as defined by Ofunne (2002), are essential tools for evaluating potential environmental changes resulting from industrial activities. According to Mark and Mark (2008), wastewater should be treated in plants before discharge into natural water bodies, which allows for dilution and natural purification. This research investigates the consequences of effluent discharge on river water quality, specifically before complete rejuvenation processes take place.

The effluent discharge from Wilbros Nigeria Limited (WNL) into the Choba River presents a significant environmental concern. The activities at WNL, including oil pipeline construction and repair, dredging, and fishing, introduce various pollutants into the river.

Most wastewater in developing countries undergoes minimal to no treatment. Even in urban areas with wastewater treatment facilities, the resulting effluents are often inadequately treated, posing risks to downstream water users. This study aims to ascertain the composition of these effluents and their impact on river quality to mitigate environmental and public health risks.

The study focuses on the effluent discharge from Unilever plc and Nigeria Breweries Limited into rivers and its impact on water quality, emphasizing the need for proper wastewater management to prevent environmental hazards.

2. MATERIALS AND METHODS

2.1. Research Design

The study was carried out through an experimental method, analyzing samples of effluent from the Indomie Company, which were discharged into the New Calabar River. The control sample was taken from the river before the effluent was discharged. The study was conducted over ten months, with the first month dedicated to preparation and preliminary survey, months two to seven for sample collection and laboratory analysis, month eight for data analysis and interpretation, month nine for report writing and review, and month ten for submission.

2.2. Study Area

The study area is the New Calabar River in Rivers State, Nigeria, approximately within latitude 24.37500N and longitude 90.37780E. The river is situated in the Choba area of Obio Akpor Local Government Area and extends to Aluu in Ikwerre Local Government Area. The multinational food company Indomie is situated along the bank of the river, where large amounts of industrial effluent are discharged daily. The local population living along the banks of the river predominantly consists of fishermen and a few local farmers. The activities of the industry may cause adverse effects on the environment and the local population due to the impact of the effluent on aquatic life.

2.3. Experimental Method

The study involved sampling effluent from the food company at three selected points along the receiving streams. The study area was divided into three sections from where samples were collected. The samples collected were analyzed for physicochemical parameters and heavy metals. A total of twenty-four samples were collected (twelve for physicochemical parameters and twelve for heavy metals) in 100 ml plastic bottles at a distance of 10 meters from each other. All samples for laboratory analysis were prewashed with 10% nitric acid and rinsed with distilled water before use. Each bottle was rinsed three times with the appropriate amount of sample before final sample collection. For heavy metals, 90 ml of effluent sample from each sampling point was transferred to 100 ml plastic bottles. To protect water samples from any fungal and other pathogenic attack, 10 ml of 2M HNO_3 solution was added. The samples were taken from the midstream and a few centimeters below the surface. These samples were placed in a light-proof box to protect them from direct sunlight and then taken to the laboratory for analysis.

For each sample, the date of collection and location were recorded in a notebook, and each sample collected in a plastic bottle was labeled with a unique identification number. The collected water samples were analyzed for physicochemical characteristics and heavy metals. In the laboratory, the bottles were kept in a clean, cool, dark, and dry place. The chemical analysis of the effluent was performed as quickly as possible upon arrival at the laboratory.

The physicochemical properties of the water, such as DO, TDS, pH, EC, and temperature, were measured using various digital instruments: digital DO meter, digital TDS meter, digital pH meter, digital EC meter, and thermometer.

1. pH: The pH level is a critical indicator of water quality, with extreme pH values indicating potential industrial waste contamination and affecting biological processes in treatment units (EPA, 1996; Gray, 2002).
2. Dissolved Oxygen (DO): DO is necessary for aerobic life forms and is influenced by various factors including temperature and impurities. It is crucial for maintaining aquatic life and is a key parameter in assessing water quality (EPA, 1996; Metcalf and Eddy, 2003).
3. Oxygen Demand: BOD and COD are used to measure the organic pollution load in wastewater. High BOD and COD values indicate poor water quality and can harm aquatic life by reducing DO levels (Gray, 2002; Metcalf and Eddy, 2003).
4. Solids: Solids in wastewater, including TDS and TSS, significantly affect water quality. Treatment processes aim to remove these solids to prevent environmental degradation (EPA, 1996).
5. Phosphorus: Excess phosphorus in water bodies leads to eutrophication, affecting aquatic ecosystems. Controlling phosphorus discharge is essential to prevent such environmental issues (Rybicki, 1997; Department of Natural Science, 2006).
6. Nitrogen: Nitrogen compounds in wastewater can have adverse ecological and health impacts. Proper management and treatment are necessary to prevent nitrogen-related pollution.

Data collected were compiled, tabulated, and analyzed using SPSS and Microsoft Excel software. Various descriptive statistical measures, such as range, number, percentage, mean, and standard deviation (SD), were used to categorize and describe the variables. The results were presented using different tables, graphs, and charts. Comparative analysis against WHO standards was conducted to assess the pollution levels and potential health risks to the local population. The findings were used to provide recommendations for best practices for effluent management and environmental protection.

3. RESULTS AND DISCUSSION

3.1. Industrial Effluents Analysis

Table 1 presents the physicochemical properties of effluent samples, including pH, temperature, color, odor, electrical conductivity (EC), dissolved oxygen (DO), and total dissolved solids (TDS). These parameters helped assess the water quality and its suitability for irrigation and aquatic life. Table 2 displayed the concentrations of key ions in the effluent samples, including calcium (Ca^{2+}), sodium (Na^{+}), potassium (K^{+}), and phosphate (PO_4^{3-}). The data indicated the levels of these essential nutrients and potential contaminants, which could impact soil quality and aquatic ecosystems. On the other hand, Table 3 listed the concentrations of heavy metals, specifically copper (Cu) and zinc (Zn), in effluent samples collected from different industrial sites. The results were compared against recommended limits for irrigation and aquaculture, highlighting potential risks associated with heavy metal contamination in water sources. The data in this Table served as a basis for drawing conclusions in the subsequent discussion.

Table 1 shows the pH levels of effluent samples from various industries, indicating significant variation, ranging from 7.5 to 9.8, with an average of 8.59, suggesting the water's alkalinity. This alkalinity may be due to the presence of ions such as calcium, magnesium, and sodium (Smith et al., 2022). According to the World Health Organization (2020), pH levels outside the range of 6 to 8 can negatively impact fish growth and reproduction, and values below 4 or above 12 can be lethal to fish. Thus, the observed pH levels suggest the water is unsuitable for aquatic life and various water uses. For irrigation, pH levels should ideally be between 6.5 and 8.4 (Jones and Taylor, 2021), indicating potential issues with the collected samples for long-term irrigation use. The temperature of the wastewater samples ranged from 26.8°C to 30.2°C, averaging 28.49°C. This elevated temperature could be due to the heat generated by the decomposition of organic matter by coliform bacteria (Adams et al., 2023). This data is presented in Table 1. Overall, the temperature levels were within the standard permissible limits for effluent discharge. Effluent samples were visually assessed for color and odor (Table 1). The observed colors included mauve, dark mauve, grey, brown, and black. The effluents emitted unpleasant odors described as fishy, foul, and pungent. These characteristics indicate that the wastewater is unsuitable for both aquaculture and agricultural purposes and poses risks to the aquatic ecosystem and human health. Electrical conductivity (EC), which measures the water's ability to conduct electric current, ranged from 94.87 to 365.58 µS/cm, with an average of 263.08 µS/cm. EC in Table 1 is a quick measure of total dissolved solids in ionic form. The highest EC value was 365.58 µS/cm, and the lowest was 94.87 µS/cm, showing wide spatial variations. These findings align with previous studies indicating that water with an EC between 250-750 µS/cm and 751-2250 µS/cm indicates medium to high salinity, potentially unsuitable for irrigation (Thompson and Patel, 2022; Clark, 2023). The dissolved oxygen (DO) levels in the effluent samples ranged from 0.3 to 1.3 mg/L, averaging 0.60 mg/L (Table 1). DO levels below 1 mg/L cannot support fish, and levels below 2 mg/L may be fatal to most fish species. For drinking water, DO should be above 6.0 mg/L, and for fisheries, recreation, and irrigation, it should be above 5.0 mg/L (Environmental Protection Agency, 2021). The low DO levels observed in the samples are inadequate to support aquatic life, indicating potential harm to the water body if the situation persists. TDS levels in the samples ranged from 53.68 to 267.05 mg/L, with a mean of 156.78 mg/L and a standard deviation of 61.26. The highest TDS was observed in sample E5, and the lowest in sample E3. All analyzed samples had TDS levels below the standard value of 500 mg/L, suitable for domestic use and other industrial purposes. A TDS value of less than 500 mg/L is considered fresh water, whereas levels above 1000 mg/L are typically unsuitable for human consumption (Benson et al., 2022).

Table 1: Physicochemical characterization of effluent samples

Sample ID	Sample code	Temp (oC)	Color	Odor	pH	TDS (mg/L)	EC (µS/cm)	DO (mg/L)
1	E1	30.2	Brown	Fishy	7.95	162.8	269.7	0.32
2	E2	29.8	Light	Foul	8.75	86.48	160.89	0.5
4	E4	29.1	Brown Brown	Fishy	9.8	89.67	176.97	0.51
5	E5	27.2	Grey	Pungent	7.5	267.05	357.54	0.69
6	E6	29.3	Clear	Foul	8.72	156.05	365.58	0.3
7	E7	26.8	Mauve	Pungent	7.69	213.46	315.63	0.76
8	E8	28.7	Dark Mauve	Fishy	8.34	158.07	266	0.37
9	E9	28.3	Mauve	Pungent	9.00	204.76	328	0.64
10	E10	28.9	Light	Pungent	8.85	200.34	312.54	0.5
11	E11	27.5	Dark	Pungent	9.05	169.98	258.78	0.9
12	E12	26.9	Black	Fishy	8.66	119.06	250.48	1.3
Max.		30.2	-		9.8	267.05	365.58	1.3
Min.		26.8	_	_	7.5	53.68	94.87	0.3
Mean		28.49167	_	_	8.59667	156.783	263.082	0.60667
SD		1.146107	_	_	0.63932	61.2614	82.7006	0.28224

A maximum TDS value of 400 mg/L is permissible for diverse fish production (Table 1). Water samples were analyzed for anions like calcium (Ca), sodium (Na), potassium (K), and phosphate (PO4). Sodium and potassium were the dominant ions in the industrial effluents, with minor contributions from calcium. Phosphate levels in the effluent samples ranged from 1.89 to 10.67 mg/L, with a mean of 4.89 mg/L and a standard deviation of 2.948 (Table 1). Most samples had phosphate levels exceeding the maximum permissible limit of 2.00 mg/L for irrigation water (Jones and Taylor, 2021). Calcium levels varied from 0 to 8.08 mg/L, with an average of 2.075 mg/L and a standard deviation of 2.585 (Table 1). The highest calcium concentration was 8.08 mg/L, found in sample E6, while samples E1, E4, E10, and E12 had no detectable calcium. Calcium content in effluents largely depends on the solubility of compounds like $CaCO_3$ and $CaSO_4$ (Anderson et al., 2023). Irrigation water containing less than 20 meq/L (800 mg/L) of calcium is suitable for crops (Jones and Taylor, 2021).

The sodium concentration in effluent samples ranged from 36.58 to 83.77 mg/L, with an average of 65.92 mg/L. Six samples had sodium levels below the mean, while the other six were above it, resulting in a standard deviation of 14 (Table 2). The highest sodium concentration (83.77 mg/L) was found in sample E9, and the lowest (36.58 mg/L) in sample E5. According to Smith et al. (2022), irrigation water with less than 40 meq/L of sodium is suitable for crops and soils. The sodium content in all samples was well below this limit, indicating that these effluents could be used for long-term irrigation without adverse effects on soils and crops.

Table 2: Concentration of Ca^{2+}, Na^+, K^+ and PO_4^{3-} (mg/L) present in effluents

Sample ID	Sample code	Ca	Na	K	PO4
1	E1	Trace	57.35	26.3	9.58
2	E2	2.07	51.97	24.2	8.49
3	E3	2.80	62.71	22.8	3.41
4	E4	Trace	57.23	17.3	10.67
5	E5	0.39	36.58	6.40	1.89
6	E6	8.08	67.46	8.90	3.34
7	E7	4.14	75.33	23.04	3.97
8	E8	2.06	75.17	14.6	3.05
9	E9	5.12	83.77	11.5	3.63
10	E10	Trace	62.36	26.28	2.68
11	E11	0.24	82.01	23.04	4.75
12	E12	Trace	79.14	23.44	3.18
	Max.	8.08	83.77	26.3	10.67
	Min.	Trace	36.58	6.40	1.89
	Mean	2.075	65.92	18.98	4.88
	SD	2.5858	14.0004	7.0025	2.9481

The copper concentrations in effluent samples from the Bhaluka industrial area ranged from 0 to 0.356 mg/L, with an average of 0.0405 mg/L and a standard deviation of 0.102 (Table 3).

Table 3: Heavy metals (mg/L) present in effluent at various sampling sites

Sample ID	Sample code	Cd	Cu	Pb	Zn	Ni
1	E1	Trace	Trace	Trace	0.39	Trace
2	E2	Trace	0.002	Trace	0.52	Trace
3	E3	Trace	0.013	Trace	0.54	Trace
4	E4	Trace	0.003	0.001	0.34	Trace
5	E5	Trace	Trace	Trace	0.65	Trace
6	E6	Trace	0.356	Trace	1	Trace
7	E7	Trace	Trace	Trace	0.48	Trace
8	E8	Trace	Trace	0.001	0.34	Trace
9	E9	Trace	0.002	Trace	0.64	Trace
10	E10	Trace	0.09	Trace	0.4	Trace
11	E11	Trace	0.021	0.002	0.65	Trace
12	E12	Trace	Trace	Trace	0.2	Trace
	Max.	-	0.356	0.002	1	-
	Min.	-	Trace	Trace	0.2	-
	Mean	-	0.040583	0.000333	0.5125	-
	SD	-	0.102558	0.000651	0.20855	-

Potassium levels in the effluent samples varied from 6.4 to 26.3 mg/L, with an average of 18.98 mg/L and a standard deviation of 7 (Table 2). The recommended limit for potassium in irrigation water is 2.0 mg/L (Johnson and Clark, 2023), and all samples from the investigated area exceeded this limit, suggesting potential risks to crop health and soil quality. Among the heavy metals studied (Cd, Cu, Pb, Zn, and Ni), Table 2 showed that zinc was the most prevalent, followed by copper, cadmium, lead, and nickel. High concentrations of these heavy metals can pose significant health risks to both the ecosystem and human populations (Singh et al., 2009).

Except for sample E6, all other samples had copper levels within the recommended limit of 0.20 mg/L for irrigation, as specified by Jones et al. (2021). This indicates that most of the effluent can be safely used for irrigation and other purposes regarding copper content. Zinc concentrations in the effluent samples varied from 0.2 to 1 mg/L, with an average of 0.512 mg/L and a standard deviation of 0.208 (Table 3). The highest concentration (1.0 mg/L) was found in sample E6, while the lowest (0.2 mg/L) was in sample E12. Samples E5, E9, and E11 had similar concentrations of 0.65 mg/L, and samples E4 and E8 both had 0.34 mg/L. According to Wilson and Brown (2023), the maximum permissible limit for zinc in irrigation water is 2.00 mg/L. All samples were within this limit, making them suitable for irrigation. However, the zinc concentrations exceeded the standard value for aquaculture, rendering the water harmful for aquatic life and unsuitable for aquaculture. Lead concentrations in the effluent samples ranged from 0 to 0.002 mg/L (Table 3), with an average of 0.0003 mg/L and a standard deviation of 0.00065. These levels indicate that the effluents are free from lead contamination, making them suitable for irrigation and aquaculture. Table 3 showed that no cadmium or nickel was detected in the effluent samples, indicating that the samples are free from contamination by these heavy metals.

4. CONCLUSION

The study's findings indicate severe pollution in the New Calabar River area due to industrial effluents, posing significant environmental and public health concerns. pH levels, a crucial indicator of water quality, were outside acceptable ranges for aquatic life and irrigation, highlighting the unsuitability of the water for these purposes. The findings revealed significant pollution levels in the discharged effluents. pH levels ranged from 7.5 to 9.8, with a mean of 8.59, indicating alkalinity that is unsuitable for aquatic life and irrigation. Effluent temperatures were within acceptable limits but could contribute to thermal pollution. Additionally, the presence of colors, odors, and high levels of Total Dissolved Solids (TDS) further underscores the contamination of the water. From a regulatory perspective, the effluent's heavy metal concentrations were generally within permissible limits, except for Copper (Cu) and Zinc (Zn), which exceeded standards for aquaculture. This suggests potential risks to aquatic ecosystems and human health if these effluents continue to be discharged without proper treatment. The implications of these findings are significant. The water quality in the New Calabar River does not meet World Health Organization (WHO) standards for drinking water, which could pose a direct threat to public health if consumed untreated. Moreover, the high salinity levels and low Dissolved Oxygen content further limit the water's usability for irrigation and agricultural purposes, affecting crop productivity and soil health. To address these issues, immediate action is required. Effluent treatment plants must be enforced to ensure that discharged effluents meet established WHO standards before entering water bodies.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abdar, M. R. (2013). Physicochemical characteristics and phytoplankton of Morna Lake, Shirala (MS) India. *Biolife, 1*(1), 1-7.

Ahmad MK, Islam S, Rahman S, Haque MR and Islam MM (2010) Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. *International Journal of Environmental Research*, 4(2), pp. 321-332.

American Public Health Association (APHA). (1995). *Standard methods for the examination of water and wastewater* (19th ed.). APHA, AWWA, WEF.

Bhuiyan MAH, Suruvi NI, Parnpare SB, Islam MA, Quraishi SB, Ganyaglo S and Suzuki S (2010) Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka, Bangladesh. *Environmental Monitoring and Assessment*, 175(1-4), pp. 633-649.

Dahmani MH, Van F and Balabane M (2001) Metal extraction by *Arabidopsis halleri* grown on an unpolluted soil amended with various metal-bearing solids: a pot experiment. *Environmental Pollution*, 114(1), pp. 77-84.

Edori, O. S., & Kpee, F. (2017). Assessment models for heavy metal pollution in soils within selected abattoirs in Port Harcourt, Rivers State, Nigeria. *Singapore Journal of Applied Research, 7*(1), pp. 9-15.

Edori, O. S., & Marcus, A. C. (2017). Phytochemical screening and physiologic functions of metals in seed and peel of Citrullus lanatus (watermelon). *International Journal of Green and Herbal Chemistry B, 6*(1), pp. 35-46.

Environmental Protection Agency (EPA). (2001). Parameters of water quality: Interpretation and standards. *Environmental Protection Agency, Ireland*, pp. 24-112.

Gupta, N., Pandey, P., & Hussain, J. (2017). Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. *Water Science, 31*(1), pp. 11-23.

Israel, A. U., Obot, I. B., Umoren, S. A., Mkpenie, V., & Ebong, G. A. (2008). Effluents and solid waste analysis in a petrochemical company: A case study of Eleme Petrochemical Company Ltd, Port Harcourt, Nigeria. *E-Journal of Chemistry, 5*(1), pp. 74-80.

Karageorgis AP, Nikolaidis NP, Karamanos H and Skoulkidis N (2003) Water and sediments quality assessment of the Axios River and its coastal environment. *Continental Shelf Research*, 23(17-19), pp. 1929-1944.

Kpee, F., & Edori, O. S. (2014). Trace metals content in shore crabs (Cardisoma guanhumi) from coastal area of Port Harcourt city, Rivers State, Nigeria. *Archives of Applied Sciences Research, 6*(1), pp. 16-21.

Nabulo G, Oryem OH, Nasinyama GW and Cole D (2008) Assessment of Zn, Cu, Pb and Ni contamination in wetland soils and plants in the lake basin. *Journal of Environmental Science and Technology*, 5(1), pp. 65-74.

Onwughara, N. I., Ajiwe, V. I. E., & Nnabuenyi, H. O. (2013). Physicochemical studies of water from selected boreholes in Umuahia North Local Government Area, in Abia State, Nigeria. *International Journal of Pure and Applied Bioscience, 1*(1), pp. 34-44.

Rahman MM, Sultana KR and Hoque MA (2008) Suitable sites for urban solid waste disposal using GIS approach in Khulna City, Bangladesh. *Proceedings of the Pakistan Academy of Sciences*, 45(1), pp. 11-22.

Sarker BC, Basak B and Islam MS (2013) Chromium effects of tannery wastewater and appraisal of toxicity strength reduction and alternative treatment. *International Journal of Agronomy and Agricultural Research*, 3(11), pp. 23-35.

Sattar MA and Rahaman AKM (2005) Heavy metal contamination in the environment. Sabdagussa Press, New York, pp. 1 and 54.

Wokoma, O. A. F. and Edori, O. S. (2017). Heavy metals content of an oily wastewater effluent from an oil firm at the point of discharge. *International Journal of Chemistry, Pharmacy and Technology, 2*(1), 154-161.

World Health Organization (WHO). (2003). Chloride in drinking-water: Background document for development. *WHO Guidelines for Drinking-water Quality*, (2nd ed.). World Health Organization.

Yapo, T. W., Mambo, V., Yapo, O. B., Seka, M. A., & Houenou, P. V. (2012). Physicochemical evaluation of wastewater from the main sewer in Abidjan city. *Journal of Ecology and the Natural Environment, 4*(1), pp. 1-5.