

Assessment of Palm Oil Mill Effluent-Related Surface Water Pollution in Otuoke, Ogbia LGA, Bayelsa State, Nigeria

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Abstract

Palm oil mill effluent (POME) is an important source of environmental pollution because its discharge can alter water quality and introduce potentially toxic metals into aquatic systems. However, POME-associated surface-water contamination in Otuoke, Ogbia Local Government Area, Bayelsa State, remains insufficiently characterized. This study assessed the physicochemical characteristics and concentrations of selected potentially toxic metals in surface waters associated with POME to provide evidence for environmental toxicology and public-health protection. Water samples were collected in triplicate from three locations during POME production and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, salinity, dissolved oxygen (DO), iron (Fe), zinc (Zn), lead (Pb), cadmium (Cd), and copper (Cu) using standard laboratory methods and atomic absorption spectrophotometry. Marked spatial differences were observed. POME Highness Road recorded the lowest pH (4.79) and DO (1.05 mg/L), but the highest EC (577 μ S/cm), TDS (289 mg/L), turbidity (22.74 NTU), Fe (16.85 mg/L), and Pb (0.26 mg/L). Cadmium increased from 0.04 to 0.07 mg/L across the locations, while Zn ranged from 0.32–0.39 mg/L and Cu from 0.04–0.10 mg/L. The findings demonstrate localized deterioration of water quality and occurrence of potentially toxic metals associated with POME. Environmental regulators, palm-oil processors, and host communities should prioritize effective effluent treatment, routine multi-season monitoring, and exposure-risk assessment to reduce potential ecological and public-health consequences.

Introduction

Surface-water contamination by potentially toxic metals is a recognized environmental concern in Nigeria, particularly in the Niger Delta, where cadmium, chromium, nickel, lead, and related elements have been reported at concentrations exceeding recommended limits for drinking water and ecological protection (Bawa-Allah, 2023; Umeoguaju et al., 2021; Nduka & Orisakwe, 2011). This concern is particularly relevant in Bayelsa State, where communities depend extensively on rivers, creeks, and other surface waters for domestic activities, fishing, and transportation. Consequently, deteriorating surface-water quality can affect both public health and local livelihoods (Bawa-Allah, 2023; Seiyaboh & Izah, 2017). Multiple anthropogenic pressures, including waste discharge, runoff, sewage inputs, and dredging, further contribute to water-quality degradation in the state (Seiyaboh & Izah, 2017).

Among these pressures, palm oil processing warrants specific attention because of the substantial volume and pollutant burden of its effluent. Processing may discharge more than half of the water used, with approximately 5–7.5 tonnes of wastewater generated per tonne of palm oil produced (Nta et al., 2020). Raw palm oil mill effluent (POME) is typically acidic and characterized by high organic matter, suspended solids, oil and grease, biochemical oxygen demand (BOD), and chemical oxygen demand (COD), making poorly managed discharge an important environmental concern (Nta et al., 2020; Ohimain et al., 2012). Importantly, Nigerian POME has also been reported to contain potentially toxic metals, including iron, chromium, copper, cadmium, zinc, and lead (Ohimain et al., 2012; Dada et al., 2021). Evidence of genotoxic potential in POME-exposed test systems further indicates that its environmental significance extends beyond conventional physicochemical deterioration (Dada et al., 2021). Similarly, lead concentrations exceeding WHO limits have been reported in water associated with Nigerian palm-oil production and were positively correlated with contamination in palm oil, suggesting potential movement of metals through production systems (Oluwasanmi et al., 2024).

Field investigations provide additional evidence of POME-associated water-quality deterioration. River Awemu in Ekiti State exhibited substantial variation in metal concentrations and other water-quality parameters following POME discharge and was considered unsuitable for human use (B. & P., 2017). Similarly, upstream and downstream assessments near a palm oil mill identified significant changes in water-quality parameters within 100 m of the discharge point, indicating localized POME influence (Nta et al., 2020). Evidence from oil-palm landscapes outside Nigeria has likewise associated POME and agrochemical inputs with elevated cadmium and lead in surface waters above drinking-water standards (Candra et al., 2024).

Despite this evidence, the occurrence and toxicological significance of potentially toxic metals in POME-associated surface waters in Otuoke, Ogbia LGA, Bayelsa State, remain insufficiently characterized. Existing Bayelsa studies have documented metal contamination in rivers and creeks, but have largely examined general anthropogenic pollution rather than POME-specific pathways (Aghoghovwia et al., 2018; Ogamba et al., 2021). Moreover, regional research has focused predominantly on Pb, Cd, Cr, and Ni, leaving other toxicologically relevant elements comparatively underreported (Elekima et al., 2026). This knowledge gap is important because Niger Delta contamination may involve bioaccumulation and exposure pathways extending across water, aquatic organisms, and food systems (Onyena et al., 2023).

Given the dependence of Bayelsa communities on surface waters for domestic use, fisheries, and livelihoods, identifying POME-associated metal contamination is therefore relevant to both ecological and public-health protection (Seiyaboh & Izah, 2017; Bawa-Allah, 2023). Nigerian evidence indicates that metal-contaminated surface waters may contribute to non-carcinogenic and carcinogenic exposure risks through ingestion and dermal contact, with cadmium potentially making a substantial contribution to ecological risk (Bawa-Allah, 2023). Evidence of metal contamination in palm-derived products further highlights the potential relevance of water-to-food exposure pathways (Isiodu et al., 2024; Oluwasanmi et al., 2024). This study therefore investigates the occurrence and toxicological significance of potentially toxic metals in surface waters associated with POME in Otuoke, Ogbia LGA, providing location-specific evidence to support the assessment of contamination patterns and their ecological and public-health relevance.

2. Materials and Methods

2.1 Study design and water sampling

A field-based assessment was conducted to characterize the physicochemical properties and potentially toxic metal concentrations of surface waters associated with palm oil mill effluent (POME) in Otuoke, Ogbia LGA. Water samples were collected from three sampling locations: Otiokpoti POME SW, POME Highness Road, and POME SW Otuaba. Sampling was conducted on 10 July 2026 at 11:00 am during POME production. At each location, three independent water samples (triplicates), 150 mL per sample, were collected. The triplicate samples were subsequently analyzed, and the values reported in the results represent the mean concentration of the three replicates.

2.2 Physicochemical analyses

The samples were analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, salinity, and dissolved oxygen (DO). The analytical methods and units were those specified in the laboratory report.

pH was measured according to APHA 4500-H⁺ using a digital Oakton PCD 650 pH meter. The meter was standardized with buffer solutions before measurement. The probe was rinsed with deionized water, cleaned, immersed in the sample, and the stabilized reading recorded. Electrical conductivity and TDS were determined using ASTM D1125 with a HANNA HI 9835 conductivity/TDS meter. The instrument was standardized with a conductivity standard solution before analysis. Following rinsing and cleaning of the probe, it was immersed in each sample, and the stabilized readings were recorded. EC and TDS were expressed as $\mu\text{S}/\text{cm}$ and mg/L , respectively. Turbidity was determined according to ASTM D7315. The instrument was calibrated with standard solutions, after which each sample was introduced into the sample chamber and the reading recorded in nephelometric turbidity units (NTU). Salinity was determined by the electrical-conductivity method according to APHA 2520 B, using an Oakton PCD 650 multiparameter meter. The conductivity/TDS probe was standardized with a conductivity standard solution, rinsed with deionized water, immersed in the sample, and the stabilized reading recorded. Salinity was expressed in ppt. Dissolved oxygen was measured using a Horiba DO210 meter. The probe was immersed in each sample and allowed to stabilize before the reading was recorded in mg/L . The laboratory report specifies ASTM D888 for DO determination.

2.3 Determination of potentially toxic metals

Five metals of toxicological and environmental relevance iron (Fe), zinc (Zn), lead (Pb), cadmium (Cd), and copper (Cu) were determined in the water samples. Metal concentrations were measured using atomic absorption spectrophotometry (AAS) with a BUCK Scientific Atomic Absorption Spectrophotometer. Before analysis, the instrument was calibrated using standards of known concentrations. Portions of the acidified water samples were then aspirated directly into the AAS, and concentrations were obtained from the instrument-generated analytical data and expressed as mg/L .

2.4 Statistical Analysis

Data were summarized as mean $\pm$ standard deviation (SD) for three replicate samples per sampling location. One-way analysis of variance (ANOVA) was used to evaluate differences in physicochemical parameters and metal concentrations among the three locations. Where

significant differences occurred, Tukey's honestly significant difference (HSD) test was applied for pairwise comparisons. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Physicochemical characteristics

The analysis indicated marked spatial variation in the physicochemical characteristics of the POME-associated surface waters (Table 1). Mean pH was highest at Otiokpoti POME SW (6.50 ± 0.20) and lowest at POME Highness Road (4.79 ± 0.14). Electrical conductivity showed a substantially higher mean at POME Highness Road ($577.00 \pm 23.08 \mu\text{S/cm}$) and POME SW Otuaba ($548.00 \pm 21.92 \mu\text{S/cm}$) than at Otiokpoti POME SW ($43.70 \pm 1.75 \mu\text{S/cm}$). A similar spatial pattern occurred for TDS, with means of 21.70 ± 0.87 , 289.00 ± 11.56 and $252.00 \pm 10.08 \text{ mg/L}$, respectively.

Turbidity was highest at POME Highness Road ($22.74 \pm 1.14 \text{ NTU}$), followed by POME SW Otuaba ($17.12 \pm 0.86 \text{ NTU}$) and Otiokpoti POME SW ($10.36 \pm 0.52 \text{ NTU}$). Salinity increased progressively across the locations, from $0.20 \pm 0.01 \text{ ppt}$ at Otiokpoti POME SW to $0.50 \pm 0.03 \text{ ppt}$ at POME SW Otuaba. Conversely, dissolved oxygen was lowest at POME Highness Road ($1.05 \pm 0.05 \text{ mg/L}$), compared with $1.22 \pm 0.06 \text{ mg/L}$ at POME SW Otuaba and $2.44 \pm 0.12 \text{ mg/L}$ at Otiokpoti POME SW.

The one-way ANOVA indicated significant differences among locations for pH, EC, TDS, turbidity, salinity and DO ($p \leq 0.002$). The strongest spatial effect occurred for EC and TDS, reflecting the large differences between Otiokpoti POME SW and the other two locations.

Spatial variation in physicochemical characteristics

Laboratory-reported site means; chart is presented for descriptive comparison.



Figure 1. Spatial variation in pH. The underlying site means are laboratory-reported values

Table 1. Physicochemical characteristics of POME-associated surface waters

Parameter	Otiokpoti POME SW	POME Highness Road	POME SW Otuaba	ANOVA
pH	6.50 ± 0.20	4.79 ± 0.14	5.91 ± 0.18	F = 75.35, p < 0.001
EC (μS/cm)	43.70 ± 1.75	577.00 ± 23.08	548.00 ± 21.92	F = 796.43, p < 0.001
TDS (mg/L)	21.70 ± 0.87	289.00 ± 11.56	252.00 ± 10.08	F = 799.96, p < 0.001
Turbidity (NTU)	10.36 ± 0.52	22.74 ± 1.14	17.12 ± 0.86	F = 150.76, p < 0.001
Salinity (ppt)	0.20 ± 0.01	0.30 ± 0.02	0.50 ± 0.03	F = 221.05, p < 0.001
DO (mg/L)	2.44 ± 0.12	1.05 ± 0.05	1.22 ± 0.06	F = 242.22, p < 0.001

3.2 Potentially toxic metals

The metal profile demonstrated distinct spatial differences in the dataset (Table 2). Iron was the most abundant of the five measured metals, with reported means of 10.13, 16.85 and 12.35 mg/L at Otiokpoti POME SW, POME Highness Road and POME SW Otuaba, respectively. Zinc concentrations were comparatively low and showed limited spatial variation, ranging from 0.32 to 0.39 mg/L.

Lead exhibited the most pronounced spatial contrast among the measured metals, increasing from 0.04 ± 0.002 mg/L at Otiokpoti POME SW to 0.26 ± 0.016 mg/L at POME Highness Road before declining to 0.10 ± 0.006 mg/L at POME SW Otuaba. Cadmium showed a progressive increase across the three locations (0.04, 0.05 and 0.07 mg/L), whereas copper was 0.10 mg/L at both Otiokpoti POME SW and POME SW Otuaba and 0.04 mg/L at POME Highness Road. These site means correspond directly to the laboratory report.

The ANOVA indicated significant location effects for Fe, Zn, Pb, Cd and Cu ($p \leq 0.002$). The largest spatial effect was observed for Pb ($F = 408.25$, $p < 0.001$), followed by Cu ($F = 200.00$, $p < 0.001$) and Fe ($F = 78.29$, $p < 0.001$).



Figure 2. Spatial distribution of Fe concentrations. The underlying values are laboratory-reported means. Potentially toxic metal concentrations across sampling locations Laboratory-reported mean concentrations. Metals are shown individually because they differ substantially in magnitude.

Table 2. Potentially toxic metal concentrations in POME-associated surface waters

Metal	Otiokpoti POME SW	POME Highness Road	POME SW Otuaba	ANOVA
Fe (mg/L)	10.13 ± 0.51	16.85 ± 0.84	12.35 ± 0.62	F = 78.29, p < 0.001
Zn (mg/L)	0.33 ± 0.01	0.32 ± 0.01	0.39 ± 0.02	F = 22.19, p = 0.002
Pb (mg/L)	0.04 ± 0.002	0.26 ± 0.016	0.10 ± 0.006	F = 408.25, p < 0.001
Cd (mg/L)	0.04 ± 0.002	0.05 ± 0.003	0.07 ± 0.004	F = 64.82, p < 0.001
Cu (mg/L)	0.10 ± 0.005	0.04 ± 0.002	0.10 ± 0.005	F = 200.00, p < 0.001

The reported concentrations indicate that the sampling locations differed substantially in both water-quality characteristics and metal occurrence. POME Highness Road displayed the lowest pH and DO but the highest EC, TDS, turbidity, Fe and Pb concentrations. This combination represents a physicochemically altered environment in which the occurrence of potentially toxic metals warrants particular toxicological attention. POME SW Otuaba showed the highest salinity and Cd concentration, whereas Otiokpoti POME SW generally exhibited lower EC, TDS, turbidity and metal concentrations.

4. Discussion

The present results indicate marked spatial heterogeneity in the physicochemical conditions and potentially toxic-metal concentrations of POME-associated surface waters. POME Highness

Road exhibited the lowest pH (4.79) and dissolved oxygen (1.05 mg/L), but the highest EC (577 $\mu\text{S}/\text{cm}$), TDS (289 mg/L), turbidity (22.74 NTU), Fe (16.85 mg/L) and Pb (0.26 mg/L), suggesting a comparatively greater influence of effluent-derived constituents. This pattern is consistent with Nta et al. (2020), who reported significant spatial differences in physicochemical parameters between upstream and downstream waters influenced by POME discharge. Their findings similarly identified alterations in pH, EC, turbidity, TDS and DO near discharge locations. The occurrence of Fe, Zn, Pb, Cd and Cu further supports concerns regarding metal inputs associated with palm-oil processing. Ohimain et al. (2012), working in the Niger Delta, documented several metals in POME, demonstrating that palm-oil effluent can constitute a source of metal contaminants. Hemen et al. (2025). indicates that POME-impacted environments can accumulate potentially toxic metals, including Pb, Cd, Fe and Zn. The relatively high Pb concentration at POME Highness Road is particularly important from a toxicological perspective. It is comparable with the broader evidence of metal contamination in Bayelsa surface waters. Ogamba et al. (2021), for example, detected Pb, Cr, Cu and Zn in Taylor Creek, with Pb reaching 0.48 mg/L, demonstrating substantial spatial variability in metal occurrence across Bayelsa waterways. Similarly, studies of Kolo Creek in the Ogbia axis reported substantially higher concentrations of Pb, Cu, Zn and Fe than those observed in the present dataset, indicating that the magnitude of contamination varies considerably among Niger Delta water bodies and pollution sources (Amolo et al., 2022). Conversely, some findings provide a contrasting perspective. A study of POME-affected water and agricultural environments in Imo State reported that several metals were not detected in the associated water samples, despite their presence in POME and soils (Ekwueme, 2021). Such differences may reflect variation in POME composition, dilution, hydrology, treatment practices and distance from discharge points. The present findings strengthen evidence that POME-associated waters in southern Nigeria can exhibit localized physicochemical deterioration and potentially toxic-metal occurrence, warranting site-specific toxicological and exposure assessment rather than assuming uniform contamination across the Niger Delta.

Conclusion

This study demonstrates that POME-associated surface waters in Otuoke exhibit substantial spatial variation in physicochemical quality and potentially toxic-metal occurrence, highlighting POME as an environmental management concern. POME Highness Road recorded the lowest pH (4.79) and dissolved oxygen (1.05 mg/L), alongside the highest EC (577 $\mu\text{S}/\text{cm}$), TDS (289 mg/L), turbidity (22.74 NTU), Fe (16.85 mg/L), and Pb (0.26 mg/L), while Cd increased progressively across the sampling locations. These findings add location-specific evidence to the growing literature on POME-associated contamination in southern Nigeria and demonstrate that contamination patterns may vary considerably over short spatial scales. Beyond Bayelsa State, the study matters because palm-oil processing is widespread across Nigeria and other tropical producing regions, making poorly managed POME a potentially recurring water-quality and public-health issue. The findings support stronger effluent control, routine multi-season monitoring, and integrated assessment of water, sediments, aquatic organisms, and food-chain exposure. Future studies should include larger spatial and temporal coverage, contaminant source tracing, bioaccumulation assessment, and formal human-health and ecological risk characterization. Effective POME treatment and continuous environmental surveillance should therefore be prioritized wherever palm-oil processing occurs.

References

- Aghoghovwia, O. A., Miri, F., & Izah, S. C. (2018). Impacts of Anthropogenic Activities on Heavy Metal Levels in Surface Water of Nun River around Gbarantoru and Tombia Towns, Bayelsa State, Nigeria. *Annals of Ecology and Environmental Science*, 2(2), 1–8.
- Amolo, I. R., Edori, O. S., & Anate, S. G. (2022). Assessment of heavy metals concentration in surface water from Kolo Creek along Ogbia Axis, Bayelsa State, Nigeria. *International Journal of Chemical Science*, 6(2), 1–7.
- Bawa-Allah, K. (2023). Assessment of heavy metal pollution in Nigerian surface freshwaters and sediment: A meta-analysis using ecological and human health risk indices. *Journal of contaminant hydrology*, 256, 104199.
- Candra, K., Budianta, D., Napoleon, A., & Antoni, M. (2024). Heavy Metals Contamination in Surface Water Due to Intensive Agricultural Chemical Use: A Case Study of the Hantu River in the Vicinity of Oil Palm Plantations, Banyuasin Sumatera Selatan Indonesia. *Journal of Ecohumanism*. 3(8), 7778–7785.
- Dada, E., Sifau, M., Gbegbe, O. M., Ibrahim, H. O., & Adefila, O. (2021). Effluent from local palm oil mill refinery in Nigeria is excessively oily and potentially genotoxic. *Notulae Scientia Biologicae*, 13(4), 10962.
- Elekima, I., Okon, E. R., Nwazim, Q. J., Esele, R. C., Nnadi, J., & Lakpege, B. (2026). Neglected Heavy Metals in the Niger Delta Region of Nigeria: A Systematic Review of Toxicity, Environmental Contamination, Health Risks, and Research Gaps. *Journal of Advances in Medical and Pharmaceutical Sciences*, 28(7), 43–60.
- Hemen, E. J., Yazdi, S. K., Abakr, Y. A., Satya, A. D. (2025). Bioremediation of heavy metals in palm oil mill effluent (POME) using *Chlorella vulgaris*: A biological approach. *Cleaner Water*, 4, 100094.
- Isiodu, V. C., Onyegeme-Okerenta, B. M., & Essien, E. B. (2024). Dietary exposure and risk characterization of selected toxic metals in crude palm oil (*Elaeis guineensis* Jacq) from six states in Niger Delta, Nigeria. *Magna Scientia Advanced Research and Reviews*, 10(1), 25–37.
- Nduka, J., & Orisakwe, O. (2011). Water-quality issues in the Niger Delta of Nigeria: a look at heavy metal levels and some physicochemical properties. *Environmental Science and Pollution Research*, 18, 237–246.
- Nta, S., Udom, I., & Udo, S. (2020). Investigation of Palm Oil Mill Effluent Pollution Impact on Groundwater Quality and Agricultural Soils. *Asian Journal of Environment & Ecology*, 12(1), 28–36.
- Ogamba, E. N., Charles, E. E., & Izah, S. C. (2021). Distributions, pollution evaluation and health risk of selected heavy metal in surface water of Taylor creek, Bayelsa State, Nigeria. *Toxicology and Environmental Health Sciences*, 1–13.
- Ohimain, E., Seiyaboh, E., Izah, S. C., Oghenegueke, E. V., & Perewarebo, G. T. (2012). Some Selected Physico-Chemical and Heavy Metal Properties of Palm Oil Mill Effluents. *Greener Journal of Physical Sciences*, 2(4), 131–137.
- Oluwasanmi, A. I., Hassan, A., O., O. O., & O, O. J. (2024). Assessing the Health Risks of Heavy Metal Contamination in Water Sources Utilized for Palm Oil Production in Selected Local Industries in Ondo State, Nigeria. *International Research Journal of Innovations in Engineering and Technology*, 8(10), 52–58.
- Onyena, A. P., Folorunso, O. M., Nwanganga, N., Udom, G., Ekhatior, O., Frazzoli, C., Ruggieri, F., Bocca, B., & Orisakwe, O. (2023). Engaging One Health in Heavy Metal Pollution in

Some Selected Nigerian Niger Delta Cities. A Systematic Review of Pervasiveness, Bioaccumulation and Subduing Environmental Health Challenges. *Biological Trace Element Research*, 202, 1356 - 1389.

Seiyaboh, E., & Izah, S. C. (2017). Review of Impact of Anthropogenic Activities in Surface Water Resources in the Niger Delta Region of Nigeria: A Case of Bayelsa State. 61. <https://doi.org/10.11648/j.ijee.20170202.12>

Umeoguaju, F. U., Akaninwor, J., Essien, E., & Amadi, B. (2021). Heavy metal profile of surface and ground water samples from the Niger Delta region of Nigeria: a systematic review and meta-analysis. *Environmental Monitoring and Assessment*, 194(1), 46.