Open Access Research Journal of
Chemistry and Pharmacy
Journals home page: https://oarjpublication/journals/oarjcp/
ISSN: 2783-0276 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(RESEARCH ARTICLE)

Check for updates

Selected Metal and Polycyclic Aromatic Hydrocarbon Profiles in *Eichhornia Crassipes* from Omuechi in Ikwerre Local Government Area, Nigeria

Jack Gbenenee Tetam [1, *], Gift Kiisi Nkin [2] and Reward Mee-eeBari Kpaanadee [3]

[1] *Department of Biochemistry, Faculty of Science, Rivers State University, P.M.B 5080 Nkpolu-Oroworukwo Port Harcourt, Rivers State, Nigeria.*
[2] *Department of Chemistry, Faculty of Science, Rivers State University, P.M.B 5080 Nkpolu-Oroworukwo Port Harcourt, Rivers State, Nigeria.*
[3] *Department of Biochemistry, Faculty of Sciences, University of Port Harcourt, East/West Road, PMB 5323 Choba, Rivers State, Nigeria.*

Open Access Research Journal of Chemistry and Pharmacy, 2025, 07(02), 027-036

Publication history: Received on 04 November 2025; revised on 10 December 2025; accepted on 12 December 2025

Article DOI: https://doi.org/10.53022/oarjcp.2025.7.2.0019

Abstract

Environmental pollution remains a significant global concern, and aquatic plants have been recognized as effective phytoremediators due to their capacity to bioaccumulate contaminants. This study assessed the concentrations of selected metals and polycyclic aromatic hydrocarbons (PAHs) in *Eichhornia crassipes* (water hyacinth) collected from the Omuechi River in Omuechi Community, Ikwerre Local Government Area, Rivers State. Fresh samples were collected, sun-dried, and pulverized prior to laboratory analysis. Results revealed the presence of 16 PAHs in E. crassipes, including carcinogenic compounds such as benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[b]fluoranthene, and benzo[k]fluoranthene. Anthracene and benzo[ghi]perylene recorded the lowest concentrations (0.04 ± 0.00 ppm), while benzo[b]pyrene showed the highest concentration (0.34 ± 0.00 ppm). All detected PAH levels exceeded the WHO permissible limits. Similarly, concentrations of metals were recorded: Copper (66.95 ± 0.00 mg/L), Iron (70.15 ± 0.01 mg/L), Lead (131.50 ± 0.01 mg/L), Chromium (50.80 ± 0.01 mg/L), Nickel (35.70 ± 0.00 mg/L), Manganese (339.45 ± 0.01 mg/L), and Zinc (191.29 ± 0.01 mg/L), all were within WHO recommended limits. These findings indicate significant pollution of the Omuechi River and demonstrate the high bioaccumulation potential of *Eichhornia crassipes,* underscoring its suitability for phytoremediation applications.

Keywords: *Eichhornia crassipes;* Heavy metals; Polycyclic aromatic hydrocarbons; Bioaccumulation; Aquatic macrophytes; Environmental pollution; Omuechi Ikwerre L.G.A

1. Introduction

The release of contaminants into the environment through both human and natural activities remains one of the most critical global challenges. Rapid industrial and economic development, coupled with the increasing production and consumption of diverse chemicals and compounds, has led to the generation of numerous unwanted pollutants, many of which pose significant risks to both ecosystems and human health [1]. Heavy metals, in particular, have become a major public health concern as exposure has escalated due to industrialization and various anthropogenic processes. The pollution of water and air by toxic metals increasingly threatens millions of people worldwide [2].

Heavy metals are generally described as metallic elements with densities higher than that of water. Their toxicity is often linked to both their heaviness and their ability to induce harmful effects even at low exposure levels. This category also includes metalloids such as arsenic, which is known for its pronounced toxicity [3]. Common examples of heavy metals include mercury, cadmium, arsenic, chromium, thallium, cobalt, and zinc[5]. Although these elements naturally occur in the earth's crust, most cases of environmental contamination and human exposure arise from anthropogenic activities such as mining, smelting, industrial production, and the domestic and agricultural use of metal-containing

* Corresponding author: Jack Gbenenee Tetam

compounds [3]. Heavy metal toxicity remains a serious threat to human well-being. These metals have no biological benefit, yet they may mimic essential elements or interfere with normal metabolic functions. While some metals, like aluminium, can be eliminated from the body, others accumulate within tissues or along the food chain, leading to chronic toxicity [4]. Heavy metals are especially ubiquitous because they are non-biodegradable and persistent. They accumulate in food items either through uptake, surface adsorption, or contamination during processing [5, 6, 17]. Their concentrations in water and aquatic organisms are of particular importance, as these metals may be toxic or essential depending on their levels. Essential metals play important physiological roles, for instance, iron is crucial for oxygen binding, transport, and release in higher organisms [6]. Nevertheless, metals such as Cd, Pb, Cr, Cu, Zn, As, and Ni remain among the most hazardous contaminants within the environment.

Concerns regarding polycyclic aromatic hydrocarbons (PAHs) emerged strongly in the 1960s and 1970s when two groups of food toxicants, including PAHs and N-nitroso compounds, were identified for their tumor-inducing potential [7]. PAHs consist of chemical compounds with two or more fused aromatic rings. They are typically colorless to pale-yellow solids, widely distributed in air, water, and soil, and recognized as environmentally harmful pollutants [8]. Structurally, PAHs encompass a vast group of organic substances, approximately 10,000 compounds, composed solely of carbon and hydrogen [9]. Their physicochemical properties vary, ranging from semi-volatile compounds to those with high boiling points, allowing them to exist in both gas and particulate phases of ambient air. They are non-polar, lipophilic, semi-volatile, and persistent [10]. The health effects of PAHs depend on the intensity, duration, and route of exposure, as well as the toxicity of individual PAH compounds. Factors such as age and pre-existing health conditions may further influence their impacts [11]. Occupational exposure to high PAH concentrations has been associated with eye irritation, nausea, vomiting, diarrhea, and confusion. PAH mixtures can also cause skin irritation and inflammation. Compounds such as anthracene, benzo(a)pyrene, and naphthalene are known skin irritants, while anthracene and benzo(a)pyrene may induce allergic skin reactions [11].

The presence of metals and PAHs in aquatic environments can be mitigated through bioaccumulation by certain plant species. One such plant with notable remediation potential is *Eichhornia crassipes* (water hyacinth). Commonly known as water hyacinth, *E. crassipes* is a globally recognized invasive aquatic plant that, despite its ecological challenges, possesses a rich phytochemical and nutritional profile. Its biomass contains significant levels of secondary metabolites, including alkaloids, flavonoids, phenolic acids, tannins, saponins, and terpenoids, which contribute to its medicinal and antioxidant properties [12, 13]. The leaves and petioles have particularly high concentrations of total phenolics and flavonoids, compounds noted for their strong free-radical scavenging capacities [14]. Nutritionally, the plant is also rich in macro- and micronutrients, making it a potential resource for livestock feed and even human consumption after proper processing [15]. Its crude protein content is often comparable to that of conventional forage crops[16]. and it contains substantial carbohydrates, crude fiber, and minerals such as potassium, calcium, magnesium, and iron [13]. Given the rising levels of environmental pollution and the established role of plants as phytoremediators, it is important to investigate the potential of *Eichhornia crassipes* to bioaccumulate pollutants such as heavy metals and PAHs. This is particularly relevant because the plant is widely distributed across major waterways, where it may serve as an efficient natural bioaccumulator.

2. Materials and methods

2.1. Study Area

2.1.1. Geographic Description of Omuechi

Omuechi is a riverine community located in Ikwerre Local Government Area of Rivers State, Nigeria [18]. The community lies within the Niger Delta region, characterized by low-lying floodplains and networks of natural waterways [19]. The Omuechi River flows across the community and serves as an important ecological and socio-economic resource. The terrain is predominantly flat with patches of freshwater swamps and riparian vegetation. The area forms part of the humid tropical zone of southern Nigeria and is accessible through local footpaths and interconnecting rural roads [20].

2.1.2. Climatic and Hydrological Features

Omuechi experiences a humid tropical climate marked by two major seasons: a rainy season (April–October) and a dry season (November–March) [21]. Annual rainfall ranges between 2,000 and 2,500 mm, with relative humidity often exceeding 75% [22]. Temperatures are generally high year-round, averaging 26-30°C. Hydrologically, the Omuechi River is a slow-flowing freshwater body fed by surface runoff, rainfall, and adjoining streams [23]. Water levels fluctuate seasonally, rising significantly during peak rainfall periods. The river's hydrology supports diverse aquatic flora and fauna, including *Eichhornia crassipes*, which proliferates along its banks [24]. However, seasonal flooding, siltation, and the accumulation of organic matter influence water quality and flow dynamics [25].

2.1.3. Anthropogenic Activities

A range of human activities influence the ecological condition of the Omuechi River. These include small-scale agriculture, artisanal sand mining, domestic waste disposal, washing and bathing activities, and the discharge of untreated runoff from residential areas [26]. In addition, the proximity of the community to expanding peri-urban settlements contributes to increased environmental pressure, including the release of chemical contaminants and organic pollutants into the river system [27]. These anthropogenic influences collectively impact water quality and create conditions that promote the accumulation of pollutants in aquatic plants such as *Eichhornia crassipes* (water hyacinth) [28]. Increased nutrient loading from runoff further enhances plant proliferation and pollutant uptake [29]. The cumulative effects of these activities contribute to ecological degradation and altered riverine dynamics [30].

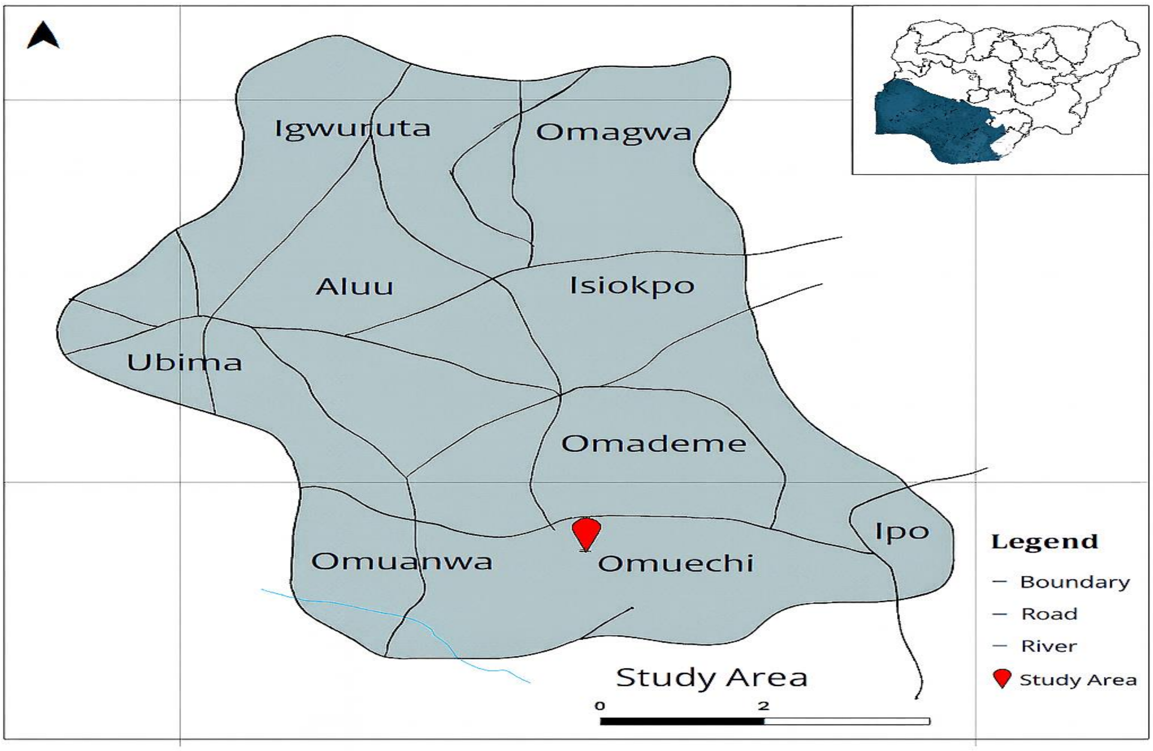

Figure 1 Map of the study area showing nearby communities and sampling point.

2.2. Sample Collection

Fresh samples of *Eichhornia crassipes* (water hyacinth) were collected from the Omuechi River in Omuechi Community, Ikwerre Local Government Area, Rivers State. Sampling was conducted at multiple points along the river to obtain a representative composite sample of the aquatic vegetation. Plants were carefully uprooted by hand from the water column and riverbanks to avoid contamination from external materials. Collected samples were placed in clean polyethylene bags, appropriately labelled, and transported to the laboratory on the same day to prevent degradation or loss of analytes. All handling procedures followed standard environmental sampling protocols to ensure sample integrity prior to processing.

2.3. Sample Preparation

In the laboratory, the fresh *Eichhornia crassipes* (water hyacinth) samples were thoroughly rinsed with clean distilled water to remove adhering sediments and impurities. The samples were then sun-dried for seven days until a constant weight was achieved, ensuring adequate moisture removal for accurate analytical measurements. The dried plant material was subsequently ground into a fine powder using a clean mechanical grinder, with the grinder surfaces wiped between batches to avoid cross-contamination. The powdered samples were sieved to obtain uniform particle size and stored in airtight, labelled containers under dry conditions until required for laboratory analysis. All preparatory procedures adhered to established quality assurance and quality control (QA/QC) guidelines.

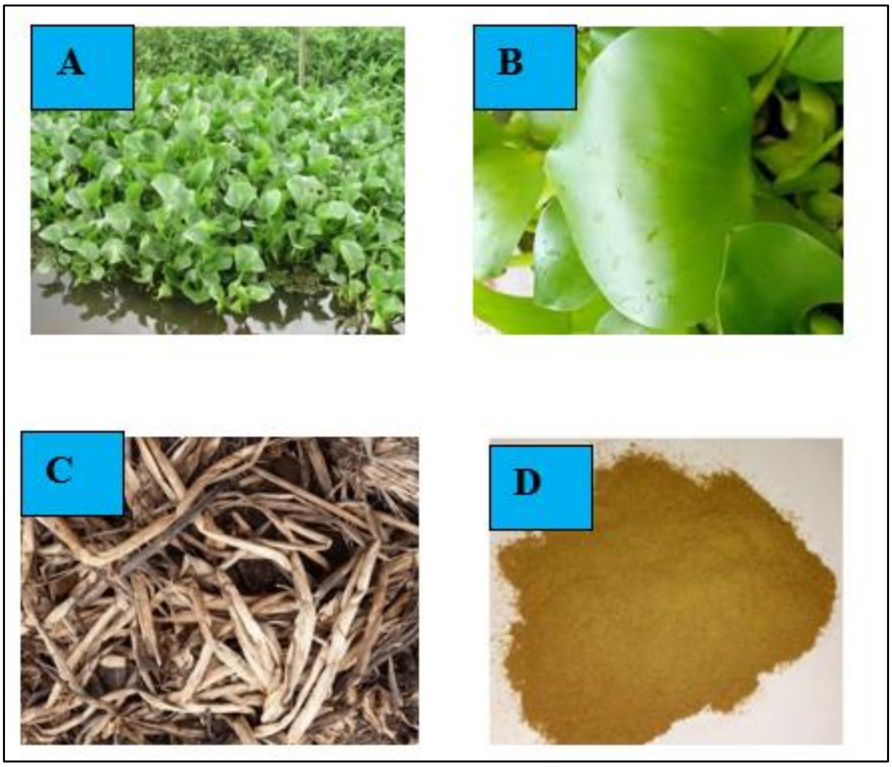

Figure 2 ***(A)*** Fresh Eichhornia crassipes (water hyacinth) plants at the sampling site; ***(B)*** collected leaves prepared for laboratory processing; ***(C)*** sun-dried sample leaves; and ***(D)*** homogenized sample material after blending

2.4. Heavy metal analysis

2.4.1. Wet Digestion Method

The concentrations of selected heavy metals in *Eichhornia crassipes* were determined using the wet digestion method. A mixed acid solution was prepared by combining 100 mL of analytical-grade H_2SO_4, HNO_3, and $HClO_4$ in a ratio of 40% : 40% : 20%**,** respectively. This acid mixture served as the digestion reagent for solubilizing the metal content of the plant samples. Exactly 10 g of the homogenized plant sample was measured and transferred into a clean, dry conical flask. Subsequently, 2 mL of the prepared acid mixture was added to the sample. The flask was placed on a hot plate inside a well-ventilated fume cupboard to ensure safe handling of fumes generated during digestion. Heating continued until the production of dense whitefumes**,** indicating complete breakdown of organic matter and adequate digestion of the sample matrix. Following digestion, the sample was allowed to cool at room temperature. The digest was then filtered using Whatman No. 1 filter paper into a 100 mL volumetric flask to remove particulate residues. The filtrate was made up to the 100 mL mark using distilled water. The final solution was transferred into clean, labelled sample bottles and stored for instrumental analysis. All glassware used in digestion was pre-washed with detergent, rinsed with distilled water, and acid-washed to minimize contamination.

2.4.2. Instrumentation: Atomic Absorption Spectrophotometry (AAS)

Heavy metal concentrations were quantified using an Atomic Absorption Spectrophotometer (AAS)**.** The instrument was calibrated prior to analysis using a series of certified standard solutions covering the expected concentration range for each metal. Calibration curves with correlation coefficients ($R^2 \geq 0.995$) were generated to ensure analytical precision. Each metal was analyzed at its specific resonance wavelength under optimized operating conditions, including appropriate lamp current, slit width, and burner height. The hollow cathode lamps specific to each target element (Cu, Fe, Pb, Cr, Ni, Mn, Zn) were installed and allowed to stabilize before measurements commenced.

2.4.3. Operation or Procedure

The atomic absorption spectrophotometer (AAS) was prepared for analysis by installing the appropriate hollow cathode lamp for the target metal. The wavelength dial was set according to the specifications provided by the analytical methodology, and the slit width was adjusted as required. The instrument was then turned on and allowed to warm up until all energy sources stabilized, which typically required 10 to 20 minutes. Following the warm-up period, the lamp current was readjusted, and the wavelength was fine-tuned to achieve optimal energy output. The lamp alignment was verified, and the burner head was installed and positioned appropriately. Air flow was initiated and adjusted in accordance with the manufacturer's instructions to ensure maximum sensitivity for the metal being analyzed. Acetylene flow was then turned on, adjusted, and the flame was ignited and allowed to stabilize for several minutes. A blank solution was first aspirated, and the instrument was zeroed to establish the baseline measurement. A standard solution, with a concentration near the middle of the linear range, was subsequently aspirated, and the nebulizer aspiration rate was adjusted to achieve maximum sensitivity. Both the vertical and horizontal positions of the burner were fine-tuned to optimize the response signal. The blank was aspirated once more to re-zero the instrument, ensuring accuracy and precision. Finally, the sample solution was aspirated, and the absorbance was recorded for analysis.

2.4.4. Calculations

The analyte concentration was quantified either by interpolation from the calibration curve or directly from the instrument response, expressed in milligrams or micrograms per liter in accordance with the established calibration protocol. The resulting concentration values were subsequently adjusted by the relevant dilution factor to yield the final analyte concentration.

2.5. Polycyclic Aromatic Hydrocarbon (PAH) Extraction and Analysis

The extraction, clean-up, and analysis of polycyclic aromatic hydrocarbons (PAHs) from fly ash were conducted following the USEPA Method 3550C. An ultrasonic extraction technique was employed in this study. Briefly, 10 g of fly ash samples were accurately weighed into clean, pre-labelled beakers. A total of 30 mL of a 1:1 (v/v) mixture of dichloromethane (DCM) and acetone was added to each sample. The mixtures were subjected to ultrasonic agitation using a Bransonic Ultrasonic Cleaner 2200 for 15 minutes per cycle over a duration of 1 hour, followed by a 10-minute settling period. Each sample underwent two successive extraction cycles to ensure exhaustive recovery of PAHs. The resulting extracts were decanted into clean, pre-labelled beakers and combined. An internal standard solution of o-terphenyl was then added to the combined extracts. Subsequently, the extracts were concentrated to a final volume of 1 mL under a gentle stream of nitrogen within a fume hood to prevent analyte loss and solvent evaporation.

2.5.1. Clean-up Procedure

Solid-phase extraction (SPE) cartridges were employed for the purification of the concentrated extracts. Prior to sample application, the cartridges were pre-conditioned by packing with glass wool, 10 g of activated silica gel, and 5 g of anhydrous sodium sulfate (Na_2SO_4) to eliminate residual moisture. A slurry of the DCM extract was prepared to facilitate loading onto the cartridges. The 1 mL concentrated extract was applied to each pre-conditioned cartridge, and PAHs were eluted using DCM. The eluates were subsequently concentrated under ambient conditions in a fume hood to a final volume of 1 mL. Anhydrous Na_2SO_4 was added to each sample to remove any remaining traces of water before transferring the purified extracts into vials. The vials were then stored at 4 °C until further analysis.

2.5.2. Gas Chromatography (GC-FID) Analysis of PAHs

Gas chromatography coupled with a flame ionization detector (GC-FID) was employed for the quantitative determination of polycyclic aromatic hydrocarbons (PAHs) in the extracted samples. GC-FID is widely regarded as a robust and sensitive analytical technique for volatile and semi-volatile organic compounds, providing high resolution, reproducibility, and linear response over a broad concentration range. In this study, 1 µL of the cleaned and concentrated extract was injected into the GC system equipped with a capillary column specifically designed for PAH separation. The column temperature program was optimized to achieve baseline resolution of all target PAH compounds, typically starting from a low initial temperature to separate lighter PAHs and gradually ramped to higher temperatures for heavier, high-molecular-weight PAHs. Helium was employed as the carrier gas at a constant flow rate to ensure efficient separation and minimal peak broadening. The flame ionization detector (FID) operated by combusting the effluent from the column in a hydrogen-air flame, producing ions proportional to the number of carbon atoms present. The resulting electrical signal was recorded and integrated, allowing for precise quantification of individual PAHs. Calibration curves prepared from authentic PAH standards were used to determine the concentrations in the samples, with internal standards added to correct for any variability in injection or detector response. GC-FID provides rapid, reproducible, and sensitive detection of PAHs and remains a preferred method for environmental monitoring of organic pollutants, offering the capability to distinguish multiple PAH congeners even in complex environmental matrices.

2.5.3. Quality Assurance / Quality Control

To ensure the reliability and accuracy of the analytical results, strict quality assurance and quality control (QA/QC) measures were implemented throughout the study. Blank determinations were routinely performed to assess potential contamination from reagents, glassware, and instruments, thereby ensuring that any background signals did not interfere with sample analysis. Recovery studies were conducted by spiking known concentrations of metals and polycyclic aromatic hydrocarbons (PAHs) into Eichhornia crassipes samples, allowing for the evaluation of the extraction and analytical procedures. The percentage recoveries obtained were used to assess method accuracy and validate the efficiency of the extraction and detection techniques. Calibration curves were constructed for each target analyte using standard solutions over a range of concentrations relevant to the study. These curves provided a basis for quantifying the analytes in the samples and ensured linearity and sensitivity of the analytical methods. Furthermore, replicate analyses were performed on selected samples to evaluate the precision and reproducibility of the measurements. The combined application of blank determinations, recovery studies, calibration curves, and replicate analyses ensured that the data generated were both accurate and reproducible, thereby enhancing the credibility of the study findings.

2.6. Statistical Analysis

All quantitative results were expressed as the mean ± standard deviation of triplicate determinations. Statistical comparisons were performed using one-way analysis of variance (ANOVA) in SPSS software version 25.0, with significance assessed at the 95% confidence level.

3. Result

Table 1 Polycyclic Aromatic Hydrocarbons content of *Eichhornia Crassipes obtained from Omuechi River.*

S/N	Compounds (ppm)	Concentration	WHO permissible limits (2023)
1	Naphthalene	0.08±0.00	<0.01
2	Acenathylene	0.05±0.01	<0.01
3	Acenaphthene	0.14±0.00	<0.01
4	Fluorene	0.07±0.00	<0.01
5	Phenanthrene	0.05±0.02	<0.01
6	Anthracene	0.04±0.00	<0.01
7	Fluoranthene	0.05±0.04	<0.01
8	Pyrene	0.06±0.00	<0.01
9	Benz[a]anthracene	0.05±0.00	<0.01
10	Chrysene	0.06±0.00	0.012
11	Benzo[b]fluoranthene	0.16±0.01	0.012
12	Benzo[k]fluoranthene	0.32±0.00	<0.01
13	Benzo[b]pyrene	0.34±0.00	0.005
14	Indeno[1,2,3cd]pyrene	0.07±0.06	<0.01
15	Dibenz[a,h]anthracene	0.08±0.01	<0.01
16	Benzo[ghi]perylene	0.04±0.00	<0.01

Values are expressed as mean ± standard deviation

Table 2 Selected metal concentrations present in *EichhorniaCrassipes*Obtained from Omuechi River.

S/N	Selected metals(mg/L)	Concentration	WHO permissible limits
1	Copper	66.95±0.00	2 – 100
2	Iron	70.15±0.01	70,000 - 550,000
3	Lead	131.50±0.01	2 – 200
4	Chromium	50.80±0.01	1 – 1000
5	Nickel	35.70±0.00	10 – 500
6	Manganese	339.45±0.01	20 -3000
7	Zinc	191.29±0.01	10 – 300

Values are expressed as mean ± standard deviation

4. Discussion

In this study, Table 1 presents the concentration of PAHs in *Eichhornia crassipes* (water hyacinth) collected from the Omuechi River. A total of sixteen PAHs were detected, including several known carcinogens such as benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[b]fluoranthene, and benzo[k]fluoranthene. Among the compounds analyzed, anthracene and benzo[ghi]perylene exhibited the lowest concentrations (0.04 ± 0.00 ppm), whereas benzo[a]pyrene was detected at the highest concentration (0.34 ± 0.00 ppm). Polycyclic aromatic hydrocarbons (PAHs) are persistent organic pollutants that pose significant threats to both environmental and human health. They are characterized by their ability to persist in soil and aquatic systems, bioaccumulate in living organisms, and exert toxic, mutagenic, and carcinogenic effects. Notably, all measured PAH concentrations exceeded the permissible limits set by the World Health Organization (WHO), indicating a considerable risk to human and ecological health, including potential neurological disorders, kidney damage, and increased cancer risk. The detection of highly toxic PAHs, particularly benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[b]fluoranthene, and benzo[k]fluoranthene, is of particular concern due to their potent carcinogenicity and their ability to bioaccumulate in aquatic organisms, potentially transferring through the food chain to humans [31]. The elevated concentrations of these compounds in *E. crassipes* suggest that the Omuechi River is subjected to continuous input of anthropogenic pollutants. Likely sources include the incomplete combustion of organic materials such as vehicular exhaust, industrial emissions, and the burning of refuse, as well as petroleum spills and urban runoff containing residues from roadways and industrial areas [32]. The results demonstrate that *Eichhornia crassipes* functions effectively as both a bioindicator and bioaccumulator of PAHs. Its floating root system and high affinity for hydrophobic organic compounds enable it to uptake and concentrate these contaminants efficiently from both the water column and sediments. The high concentration of benzo[a]pyrene (0.34 ppm) is particularly significant as this compound is widely recognized as a marker for PAH pollution and is among the most potent environmental carcinogens. The findings indicate that *E. crassipes* can reflect the level of contamination in the river and highlight the dual role of this plant: while it offers potential for phytoremediation of contaminated waters, it also participates in the transport and cycling of hazardous pollutants within the ecosystem. These observations are consistent with previous studies reporting the use of aquatic macrophytes as bioindicators for environmental monitoring and for correlating plant tissue concentrations with ambient pollutant levels.

In addition to PAHs, heavy metal contamination is a pressing environmental concern due to its persistence, bioaccumulative nature, and toxicological implications. Table 2 presents the concentrations of selected heavy metals in *E. crassipes* from the Omuechi River. The results reveal levels of copper (66.95 ± 0.00 mg/L), iron (70.15 ± 0.01 mg/L), lead (131.50 ± 0.01 mg/L), chromium (50.80 ± 0.01 mg/L), nickel (35.70 ± 0.00 mg/L), manganese (339.45 ± 0.01 mg/L), and zinc (191.29 ± 0.01 mg/L), all were within the WHO permissible limits. Among these metals, lead, chromium, and nickel are non-essential and toxic, while copper, iron, manganese, and zinc are essential elements required in trace amounts for plant metabolic processes. The metal concentrations are likely attributable to multiple anthropogenic activities, including the discharge of untreated industrial effluents, agricultural runoff containing fertilizers and pesticides, and localized geogenic inputs from the catchment area. Additional contributions may arise from artisanal and mechanical workshops, informal metalworking activities, and urban runoff. Similar to its role in PAH accumulation, *E. crassipes* is recognized globally as a hyperaccumulator of heavy metals. Its dense and fibrous root system provides a large surface area for absorption and adsorption, effectively removing metals from the water column [2]. High concentrations of essential metals, such as manganese and zinc, may partially reflect the plant's metabolic requirements, leading to “luxury uptake” and bioaccumulation beyond physiological needs. The significantly elevated levels of non-essential and toxic metals, particularly lead (131.50 mg/L), underscore severe anthropogenic contamination. Non-essential metals, including lead and chromium, lack known biological functions in plants, and their accumulation serves as a direct indicator of environmental pollution, posing ecotoxicological risks to aquatic organisms and potential for trophic transfer to higher organisms [33]. While the concentrations of all metals were within the permissible limits, the results also demonstrate the effectiveness of *E. crassipes* as a biomonitoring tool and potential agent for phytoremediation. Its ability to accumulate high metal loads, particularly toxic elements such as lead, highlights its usefulness in mitigating environmental pollution, although the associated ecological risks through food web transfer must be considered. The combined data on PAHs and heavy metals indicate that the Omuechi River is under substantial anthropogenic pressure, reflecting both chemical pollution and environmental degradation. *Eichhornia crassipes*, through its bioaccumulative properties, provides valuable insight into contaminant levels, offers a potential phytoremediation strategy, and emphasizes the need for urgent pollution management and environmental monitoring to safeguard ecosystem and public health.

5. Conclusion

The findings of this study indicate that, while the concentrations of selected heavy metals in the Omuechi River were generally within acceptable quality standards, the levels of polycyclic aromatic hydrocarbons (PAHs) present a clear concern for both environmental and public health. The detection of multiple carcinogenic and toxic PAHs above recommended limits underscores the potential ecological and human health risks associated with prolonged exposure to these contaminants. The accumulation of both PAHs and heavy metals in *Eichhornia crassipes* highlights the plant’s strong bioaccumulation capacity. Its extensive root system and affinity for hydrophobic and metallic pollutants enable it to effectively concentrate contaminants from the aquatic environment, confirming its suitability as a biomonitoring organism. This bioaccumulative property also demonstrates the potential of *E. crassipes* as a phytoremediation agent, capable of removing or reducing the load of hazardous substances from polluted water bodies. The study emphasizes the dual role of *Eichhornia crassipes*: as a valuable tool for assessing the extent of aquatic contamination and as a potential natural mitigator of environmental pollutants. However, the presence of high PAH concentrations signals the urgent need for targeted pollution control measures to reduce anthropogenic inputs into the Omuechi River and to safeguard both ecosystem integrity and human health. Continued monitoring and management strategies, combined with the application of phytoremediation approaches, could provide an effective pathway toward improving water quality in the river system.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

References

[1] Abaj, A. N. and Ogbugbuaja, V. 0.(2012). Effects of inorganic fertilizers and herbicides on levels of some heavy metals in soils and grains of rice grown in selected areas of Benue state, Nigeria.*International Journal of Applied and Resources Technology*, 1(28), 160 – 166.

[2] Adewole, M. B. and Uchegbu, L. U. (2010). Properties of soils and plants uptake within the vicinity of selected automobile workshops in Ile-Ife, south western Nigeria. *Ethiopian Journal of Environmental studies and Management,* 3(3), 23-28.

[3] Tchounwou, P.B., Clement, G.Y., Patlolla, A.K. and Dwayne, Y.S. (2012).Heavy metal toxicity and the environment.*Journal ofMolecular, Clinical and Environmental Toxicology,* 4(5), 133-164.

[4] Jaishankar, M., Mathew B.B., Shah M.S. and Gowda K.R.S. (2014).Biosorption of Few Heavy Metal Ions Using Agricultural Wastes. *Journal of Environment Pollution,* 45(2), 145-159.

[5] Tetam, J. G., Nkin, G. K., & Mee-eeBari, K. R. (2025). Assessment of selected metals and polycyclic aromatic hydrocarbons in the gills and muscles of *Oreochromis niloticus* from Oyorokoto River, Andoni, Rivers State, Nigeria. *International Journal of Chemistry and Chemical Processes, 11*(6), 56–66.

[6] Manahan, S. E. (2017). *Environmental chemistry* (10th ed.). CRC Press.

[7] Jagerstad, W. and Skog, L. (2015). Blood levels of polycyclic aromatic hydrocarbons in children and their association with oxidative stress indices: an Indian perspective. *Clinical Biochemistry*, 41(3), 152-161.

[8] Honda, L., Tamamura, S., Sato, T., Ota, Y., Wang, X., Tang, N. and Hayakawa, K. (2020).Long-range transport of polycyclic aromatic hydrocarbons (PAHs) from the eastern Asian continent to Kanazawa, Japan with Asian dust.*Atmos. Environ*. 41, 2580–2593.

[9] Danyi, H., Rengarajan, T., Rajendran, P., Nandakumar, N., Lokeshkumar, B., Rajendran, P. and Nishigaki, I. (2019).Exposure to polycyclic aromatic hydrocarbons with special focus on cancer.*Asian Pacific Journal of Tropical Biomedicine,*5(8), 182–189.

[10] Plaza-Bolańos, M. Jacob, J. and Tang, N. (2010).The significance of polycyclic aromatic hydrocarbons as environmental carcinogens. 35 years research on PAH—A retrospective. *Polycyclic Aromatic Compound*, 28(2), 242–272.

[11] Wang, K., Skupinska, K., Misiewicz, I., and Kasprzycka-Guttman, T. (2011). Polycyclic aromatic hydrocarbons: physicochemical properties, environmental appearance and impact on living organisms. *Acta Pollution Pharmacology*, 61, 233–240.

[12] Malik, A. (2007). Environmental challenge vis-à-vis opportunity: The case of water hyacinth. *Environment International, 33*(1), 122–138.

[13] Rezania, S., Ponraj, M., Din, M. F. M., Songip, A. R., Sairan, F. M., & Wan Abdullah, W. H. (2015). The diverse applications of water hyacinth with main focus on sustainable energy and production for new era: An overview. *Renewable and Sustainable Energy Reviews, 41*, 943–954.

[14] Bharathi, K., & Mohan, N. (2019). Phytochemical profiling and antioxidant activity of *Eichhornia crassipes* (water hyacinth). *Journal of Pharmacognosy and Phytochemistry, 8*(3), 1124–1129.

[15] El-Sayed, A. A., & Abdel-Rahim, M. M. (2018). Nutritional evaluation of water hyacinth as an unconventional feed resource for livestock. *Egyptian Journal of Nutrition and Feeds, 21*(2), 345–356.

[16] Hassan, M. S., & Edwards, P. (1992). Evaluation of water hyacinth (*Eichhornia crassipes*) as feed for ruminants. *Agricultural Wastes, 39*(1), 17–25.

[17] Tetam, J. G., Nkin, G. K., & Briggs, O. N. (2025). Bioaccumulation potential and phytochemical profiling of *Coffea arabica* and *Pueraria montana* leaves obtained from Eyaa Community in Eleme Local Government Area of Rivers State, Nigeria. *International Journal of Chemistry and Chemical Processes, 11*(6), 20–33.

[18] Nwankwo, D. I., & Akinsoji, A. (2019). Environmental characteristics of riverine communities in the Niger Delta region of Nigeria. *Journal of Environmental Geography,* 12(2), 45–53.

[19] Ekpo, B. O., & Essien, J. P. (2020). Hydrographic and ecological features of the Niger Delta floodplain ecosystems.*Nigerian Journal of Environmental Sciences,* 14(1), 22–34.

[20] Weli, V. E., & Efe, S. I. (2018). Climate and environmental dynamics of Southern Nigeria's humid tropical zone. *Journal of Climate and Hydrology, 9*(3), 101–112.

[21] Adebayo, A. A., & Udo, S. O. (2021).Seasonal climatic patterns in the humid tropics of southern Nigeria.*Nigerian Journal of Climatology,* 18(2), 33–47.

[22] Nwachukwu, C. E., & Alagoa, K. J. (2020).Rainfall distribution and humidity regimes in coastal Niger Delta communities.*Journal of Tropical Environment,* 7(1), 55–64.

[23] Okoro, B. C., & Worlu, C. E. (2019). Hydrological behavior of small river systems in the Niger Delta region of Nigeria. *Journal of Hydrology and Watershed Management,* 11(3), 112–123.

[24] Samuel, O. P., & Ezenwa, V. C. (2022). Aquatic macrophytes and ecological interactions in freshwater ecosystems of southern Nigeria.*African Journal of Aquatic Ecology,* 5(2), 77–89.

[25] Briggs, T. K., & Nduka, J. O. (2018).Flooding, siltation, and organic matter dynamics in Niger Delta freshwater bodies. *Journal of Environmental Hydrology*, 26(4), 149–160.

[26] Nwankwo, D. I., & Chukwu, L. O. (2019). Human-induced pressures on tropical freshwater systems in southern Nigeria.*Journal of Environmental Management,* 245, 112–120.

[27] Ogbonna, D. N., & Jimoh, W. L. (2020).Urban expansion and water quality deterioration in peri-urban communities of the Niger Delta.*Environmental Monitoring and Assessment*, 192(4), 215.

[28] Ekpo, B. O., & Essien, J. P. (2017).Bioaccumulation of pollutants in aquatic macrophytes of Niger Delta freshwater ecosystems.*African Journal of Aquatic Science,* 42(3), 267–276.

[29] Umesi, N., & Woke, G. N. (2021). Effects of nutrient enrichment on macrophyte growth and contaminant uptake in freshwater bodies of Rivers State.*Journal of Applied Ecology and Environmental Research,* 19(2), 1345–1358.

[30] Eke, P. E., & Ogbondeminu, F. S. (2018). Anthropogenic impacts on hydrological and ecological functions of small tropical rivers. *Journal of Water and Environment Research,* 10(3), 45–56.

[31] Abou-Arab, M., Abdel-Shafy, H. I. and Mansour, M. S. (2014). A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. *Egyptian Journal of Environmental Science*, 25(2), 107–123.

[32] Baklanov, M., Das, N. and Das, D. (2017).Strategies for remediation of polycyclic aromatic hydrocarbons from contaminated soil-an overview.*Journal of Critical Review*, 2(5), 20–25.

[33] Afzal, M.S, Ashraf, A. and Nabeel, M. (2018) Characterization of industrial effluents and groundwater of Hattari industrial estate, Haripur.*Advanced Agricultural and Environmental Science,* 1(2): 70-77.