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Plant Composition and Edaphic Assessment of Heavy Metals in a Waste Effluent Receiving Wetlands in Uyo, Nigeria

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Abstract

Heavy metals, once released into the environment, are problematic pollutants due to their harmful effects on living organisms. This study assessed the heavy metal composition in plants and soil in a wetland receiving waste effluents. Vegetation was sampled using a 5 m x 5 m quadrat through systematic sampling at regular intervals to determine density and frequency. Soil samples were taken at two depths (0 - 15 cm and 15 - 30 cm) using a soil auger, and their physicochemical properties were analyzed using standard methods. Shoots of dominant plant species were also collected for heavy metal analysis. The results showed that *Alchornea cordifolia* had the highest density (2800 ± 100.32 st/ha), while *Caladium bicolor* had the lowest (33.00 ± 1.20 st/ha). The mean heavy metal concentrations (mg/kg) in the soil were Fe (571 ± 48.36), Zn (78.24 ± 8.52), Cu (10.74 ± 0.30), Ni (8.42 ±0.98), Pb (4.95±0.70), and Cd (2.21±0.19), while the plant's shoot was Fe (15.26±1.85), Zn (11.30±1.36), Ni (8.50±0.61), Cu (6.82±0.85), Pb (5.81±0.50), and Cd (2.51±0.11). The translocation factor threshold of heavy metals in the wetland exceeded 1 for Cd, Ni, and Pb, while Fe, Zn, and Cu had values < 1. The soil of this wetland was moderately contaminated with Cd, Ni, Fe, and Cu and was very highly contaminated with Pb and Zn. The degree of contamination obtained in this wetland was 42.25. This study has demonstrated that the ecosystem was polluted by heavy metals to varying degrees, thus, necessitating urgent management and protection measures to ensure its future sustainability.

Keywords: Wetland, Toxicity, Biomagnification, Bioaccumulation, Physicochemcial

Introduction

Heavy metals, once released into the environment, are problematic pollutants due to their harmful effects on living organisms. These metals and metalloids, with an atomic density greater than 5.0 g/cm^2, are toxic even at low concentrations (Duffus, 2002; Lenntech, 2004) [11, 14]. They contaminate soil, water, and air, leading to bioaccumulation and biomagnification and posing significant health risks, including mutagenic, teratogenic, neurotoxic, and carcinogenic effects (Ngole and Ekosse, 2012; Ngole, 2015) [17, 16]. Cadmium and lead are particularly harmful, with cadmium linked to kidney disease, lung damage, and fragile bones, and lead causing nervous disorders (ATSDR, 2015) [5]. Heavy metals are present in various products due to their chemical and physical properties, but their environmental accumulation has increased due to indiscriminate waste disposal, especially in wetlands (Ramsar, 2011) [19]. Wetlands, which include areas of marsh, fen, peatland, or water, are often misused as dumping grounds for industrial and domestic waste, posing severe environmental and ecological threats (Ramsar, 2011) [19]. Soil contamination by heavy metals is a growing concern due to critical role of soil in providing nutrients and supporting livelihoods (Abdullah *et al*., 2009; Asongwe *et al*., 2014) [1, 4]. Contaminated soils compromise ecological stability as heavy metals persist and bioaccumulate, eventually entering the food chain through plants and animals (Dosumu *et al*., 2003) [10]. Plants grown on contaminated soils absorb these metals, posing significant health risks to humans.

Fertilizers, pesticides, and mulch, essential for agricultural production, have led to soil contamination when applied excessively (Zhang and Zhang, 2007) [24]. Many pesticides contain heavy metals like Hg, As, Cu, and Zn (Arao *et al*., 2010) [3]. Phosphoric fertilizers are significant sources of heavy metals, generally having a higher metal content compared to compound, potash, and nitrogen fertilizers (Boyd, 2010) [6]. Cadmium, commonly found in phosphoric fertilizers, increases soil and plant uptake with

extensive use. In addition, mulch production often involves heat stabilizers containing Cd and Pb, further contaminating soils (Satarug *et al*., 2003) [20]. The cumulative impact of these agricultural inputs and waste disposal practices underscores the urgent need for better management to prevent heavy metal pollution and protect environmental and human health. This study assessed the plant compositions and heavy metal content in a wetland contaminated by waste effluents.

Materials and Methods

Study Area

The study was conducted in a wetland in the Uyo Local Government Area of Akwa Ibom State. The wetland is situated between longitudes 7º 9266' and 8º 00 E' and between latitudes 5º 0342' and 7º N and shares a boundary with Ibesikpo-Asutan local Government.

Fig 1: The Wetland

Vegetation and Soil Sampling

Systematic vegetation and soil sampling was conducted using 5 m x 5 m quadrats in the wetland in Uyo, Akwa Ibom State. Plants were identified to species level, with unknowns confirmed via the departmental herbarium. Dominant species' mature shoots were harvested, cleaned, and taken to the laboratory for heavy metal assays. Soil samples were collected at depths of 0 -15 cm and 15 - 30 cm, combined into composite samples, and stored in labeled Ziploc bags for physicochemical analysis in the laboratory.

The frequency of each species occurrence was calculated as follows:

$$\text{Frequency} = \frac{\text{Number of occupied quadrat for a species}}{\text{Total number of quadrats thrown}} \times 100$$

Plant density was estimated by counting individuals in 100 m², averaging counts across 10 transects, and calculating density per m². This density was then scaled to per hectare by multiplying by 10,000 m².

Plant Sample Preparation

Plant samples were air-dried, oven-dried at 105 ºC until constant weight, and pulverized into fine powder, stored in labeled polythene bags in a desiccator. Each 3.0 g sample was ashed at 450-500 ºC, cooled, dissolved in 20% hydrochloric acid, and transferred to a 100 mL volumetric flask. Heavy metal concentrations in the solutions were determined using Atomic Absorption Spectrophotometry (AAS).

Soil Sample Analysis and Digestion

Soil samples were air-dried, crushed, sieved through 2 mm, and stored in Ziploc bags for chemical and physical analysis at the University of Uyo Soil Science Department. Each 2 g sample was ground, mixed, and digested with 15 mL of concentrated nitric and perchloric acids (1:1 ratio) for 135 min until colourless. The filtered mixture was washed with deionized water, and the resulting filtrate was diluted to 100 mL. Analysis for six heavy metals (lead, iron, zinc, cadmium, and nickel) was conducted using AAS.

Physical Analysis

Fifty grams of air-dried, sieved soil was treated with 100 mL of 5% Sodium hexametaphosphate and settled for 30 min. After overnight shaking, the suspension was transferred to a one-litre glass cylinder and mixed with distilled water. Hydrometer readings at 40 sec and 3 hr were taken to determine silt and clay content, temperature-corrected to 20 °C and adjusted for the dispersing agent, providing insights into soil texture and particle distribution. The percentage of sand, silt and clay were calculated as follows:

$$\% \text{ Sand} = 100 - [H_1 + 0.36(T_1 - 20) - 2.0]\ 2$$

$$\% \text{ Clay} = [H_2 + 0.36(T_2 - 20) - 2.0]\ 2$$

$$\% \text{ Silt} = 100 - (\% \text{ sand} + \% \text{ clay})$$

Where: H_1: First hydrometer reading at 40 sec; T_1: First temperature reading at 40 sec; H_2 = second hydrometer reading at 3 hr; T_2: Second temperature reading at 3 hr; 0.36 (T – 20): Temperature correction to be added to hydrometer reading, where T: Degree Celsius. 2.0: Salt correction subtracted from hydrometer reading. The textural classification was obtained using the USDA textural triangle.

Determination of Soil pH

Twenty grams of air-dried soil, sieved to 2 mm, were mixed with 20 mL of 0.01 M $CaCl_2$ in 50 mL beakers, stirred for 30 min, and pH was measured using a pH meter in the settled suspension.

Electrical Conductivity (EC)

Ten grams of air-dried soil was mixed with 20 mL distilled water in a 50 mL beaker and left for 30 min. Concurrently, 0.7456 g of dry KCl was dissolved to make a one-litre standard solution with a conductivity of 1.412 dS/m at 25°C. The soil sample's conductivity was measured using this calibrated meter after rinsing.

Determination of Organic Carbon

One gram of air-dried soil, passed through a 1mm sieve, was mixed with $K_2Cr_2O_7$ and concentrated H_2SO_4 in an Erlenmeyer flask. After standing and dilution, H_3PO_4, NaF, and diphenylamine indicator were added. Excess dichromate was titrated with 0.5N ferrous ammonium sulphate to a green endpoint, with blank titrations for comparison. Organic carbon percentage was calculated based on the titration results. Milliequivalent of oxidizable material per gramme of soil (me ox/g) = ml of Fe $(NH_4)_2(SO_4)_2 .6H_20$ for blank – ml for sample × normality of Fe (NH_4) $(S0_4)_2.6H_20$ divided by weight of soil (g), % C = me ox/g × 12/4000 × 1/0.77 × 100 = me ox/g × 0.39.

Where 12/4000 is the milliequivalent weight of carbon in grammes; 1/0.77 is the factor of converting the carbon actually oxidized to total carbon; and 100 is the factor to

change from decimal to percent.

Determination of Total Nitrogen

Five grams of soil were digested with digestion mixture and concentrated H_2SO_4 in a 500 mL Kjeldahl flask, heated for 4 hr and further heated for 30 min. After cooling, boric acid and distilled water were added, followed by 40% NaOH and zinc for distillation. The collected distillate was titrated with standard acid to determine soil nitrogen percentage.

$$\% N = \frac{(T-B) \times N_A \times 1.4}{S}$$

Where T: Sample titration (ml); B: Blank titration (ml); N_A: normality of acid used (to 4 decimal places); S: Sample weight (g).

Determination of Phosphorous

One gram of air-dried soil was mixed with 10 mL extracting solution in a 50 mL conical flask, shaken for 5 min, and filtered. A 2-mL aliquot of filtrate was diluted with 5 mL distilled water, mixed with 2 mL ammonium molybdate solution, and treated with 1 mL dilute $SnCl_2$.H2O. After 10 min, the % transmittance at 660 nm was measured using a spectrophotometer. Soil phosphorus was determined from a standard curve prepared with phosphorus standard solutions.

Determination of Exchangeable Cations

Approximately ten grams of air-dried soil, sieved to 2 mm, was mixed with 100 mL of 1N NH_4OAc in a 250 mL conical flask. After shaking for 30 min, the suspension was filtered through Whatman filter paper and stored for analysis. Exchangeable bases (Ca, Mg, K, and Na) were determined using flame photometry for Na and K, and the EDTA method for Ca and Mg.

Determination of Exchangeable Acidity

Five grams of air-dried soil, sieved through a 2 mm sieve, was mixed with 30 mL 1N KCl in centrifuge tubes, shaken and centrifuged. The clear supernatant from three repetitions was combined and made up to volume with 1N KCl. Fifty milliliters of the extract was titrated with 0.05N NaOH for total acidity, and after neutralization with 0.05N HCl, a second titration confirmed exchangeable acidity by the disappearance of the pink colour.

The Exchangeable Acidity (Me EA)

The milliequivalent (me) of base = normality of base × volume of base

Milliequivalent exchangeable acidity per 100 g of soil (me/100g) =

$$\frac{\text{Normality of base} \times \text{Volume of base} \times 100}{\text{Weight of soil (g)}}$$

Me Exchangeable Al = me of acid = normality of acid × volume of acid

$$\text{Me Al per 100 g soil} = \frac{\text{Normality of acid} \times \text{Volume of acid} \times 100}{\text{Weight of soil (g)}}$$

Me exchangeable H per 100 g of soil = me exchangeable acidity per 100 g soil – me exchangeable acidity per 100 g soil.

Effective Cation Exchange Capacity (ECEC)

This was obtained by summing up the values of exchangeable cations (Ca, Mg, K and Na) and exchangeable acidity and expressed as me/100g.

$$\text{This was calculated as \% B.S} = \frac{TEB}{ECEC} \times 100$$

Where TEB = Total Exchangeable Bases

ECEC = Effective Cation Exchange Capacity

TEB was obtained by adding the values of Ca, Mg, K, and Na.

Determination of Micronutrients

One gram of air-dried soil, passed through a 2 mm sieve, was digested with 20 mL nitric acid and 10 mL perchloric acid on a hot plate until the solution turned white, cooled, and filtered. The filtrate was diluted to 50 mL with distilled water, and micronutrient concentrations (Pb, Cd, Ni, Zn, and Fe) were analyzed using AAS, reporting values in mg/kg.

Determination of Transfer Factor (TF)

The plant transfer factor (TF) was calculated based on dry weight using Olănescu's formula (2007). $TF = \frac{M_p}{M_s}$, Where, TF: Transfer Factor; M_p and M_s: Metal content in plant (mg/kg) and soil (mg/kg), respectively.

Determination of Contamination Factor and Degree of Contamination

The contamination factor (CF) was calculated using Hakanson's formula (1980), comparing metal concentrations in soil samples to background values.

$$CF = \frac{\text{Cmetal}}{\text{Cbackground value}}$$

Total metal concentrations (C_{metal}) in soil or plant extracts were compared to background values ($C_{background}$) from control sites: Fe = 216.3 mg/kg, Ni = 2.90 mg/kg, Pb = 0.29 mg/kg, Zn = 5.3 mg/kg, Cu = 4.25 mg/kg, Cd = 0.94 mg/kg. Contamination factors (CF) were calculated using Hakanson's classification (1980): $CF < 1$ for low contamination, $1 \leq CF \leq 3$ for moderate contamination, $3 \leq CF \leq 6$ for considerable contamination, and $CF > 6$ for very high contamination.

Statistical Analysis

Mean and standard error were calculated from triplicates of soil physico-chemical parameters using SPSS 20.0. Duncan multiple range test was conducted to determine significance at $P < 0.05$.

Results

Floristic Composition of Wetland

The floristic composition of the study area is presented in Table 1. A total of 21 plant species were recorded and Fig 2 shows some of the representative plants. *Alchornea cordifolia* was the most abundant species, with a density value of 2800 ± 100.32 stems per hectare, while *Caladium bicolor* had the lowest density value at 33.00 ± 1.20 stems per hectare. The most frequent species were *A. cordifolia* and *Pteridium aquilinum*, both with a frequency of 75%.

Physicochemical Characteristics of Soil Samples

The mean physical and chemical characteristics of the soil in the study area are presented in Table 2. The soil pH was moderately acidic, with a mean value of 5.25 ± 0.09. Electrical conductivity had a mean value of 0.10 ± 0.02 dS/m. The soil had low percentages of organic carbon and total nitrogen, with mean values of 2.45 ± 0.37% and 0.06 ± 0.01%, respectively. Phosphorus and potassium contents were also low, with mean values of 4.17 ± 1.62 mg/kg and 0.13 ± 0.02 cmol/kg, respectively. The exchangeable comprising of Ca, Mg and Na had mean values of 3.00 ± 0.34 cmol/kg, 1.32 ± 0.12 cmol/kg, and 0.07 ± 0.001 cmol/kg, respectively. Exchangeable acidity had a mean value of 2.18 ± 0.20 cmol/kg. The Effective Cation Exchange Capacity had a mean value of 6.86 ± 0.39 cmol/kg, and mean of the base saturation was 65.65 ± 2.87%. Particle size analysis revealed that the soil was predominantly sandy, with a mean value of 88.26 ± 0.86%. Silt and clay contents were 4.92 ± 0.00% and 7.15 ± 0.67%, respectively (Table 2).

Heavy Metal Concentrations in Soil and Plant Samples

The mean heavy metal concentrations in soil and plant samples of the study area are presented in Table 3. In the soil samples, Fe had the highest concentration with a mean value of 571 ± 48.36mg/kg, while Cd had the lowest at 2.21 ± 0.19 mg/kg. The heavy metal composition (mg/kg) in the wetland soil followed this order: Fe (571±48.36) > Zn (78.24±8.52) > Cu (10.74±0.30) > (Ni) (8.42±0.98) > Pb (4.95±0.70) > Cd (2.21±0.19). The mean concentration of the heavy metals in the plant's tissues (*A. cordifolia*) revealed that Fe had the highest value (15.26 ± 1.85 mg/kg) while Cd had the least value (2.51 ± 0.11 mg/kg). The heavy metal composition (mg/kg) in the wetland followed this decreasing order: Fe (15.26±1.85) > Zn (11.30±1.36) > Ni (8.50±0.61) > Cu (6.82±0.85) > Pb (5.81±0.50) > Cd (2.51±0.11). The mean values for Cd, Pb was significantly different from the mean Ni, Fe, Zn and Cu in soil samples and plants at $P < 0.05$ (Table 3).

Translocation Factor Threshold for Heavy Metals in the Wetland

Fig 3 shows the graphical representation of the translocation factor threshold of heavy metals in the wetland. The translocation factor exceeded unity (> 1) for Cd, Ni, and Pb, indicating high mobility from soil to plant tissues, while, Fe, Zn, and Cu had translocation factor values less than one (< 1), and suggesting lower mobility.

Heavy Metal Contamination Factor and Degree of Contamination

The pollution grade of the soil according to contamination factor and degree of contamination values is shown in Table 4. The Pb recorded the highest contamination factor at 17.07, while Cd had the lowest value of 2.35. The contamination factor of the wetland followed this order: Pb (17.07) > Zn (14.76) > Ni (2.90) > Fe (2.64) > Cu (2.53) > Cd (2.35). According to the contamination intensity rating, the soil in this wetland showed a moderate contamination with Cd, Ni, Fe, and Cu, and very high contamination with Pb and Zn. The degree of contamination calculated for this wetland was 42.25, classifying the soil as exhibiting a very high degree of contamination.

Table 1: Floristic Composition of the Wetland

Plant species	Family	Density (st/ha)	Frequency (%)
Acroceras zizaniodes	Poaceae	2300.33 ± 90.62	25
Ageratum conyzoides	Asteraceae	1000 ± 80.32	50
Alchornea cordifolia	Euphorbiaceae	2800 ± 100.32	75
Anthocleista vogelli	Gentianaceae	100.00 ± 15.20	50
Aspilia africana	Compositae	666.67 ± 45.10	50
Caladium bicolor	Araceae	33.00 ± 1.20	25
Clappertonia ficiifolia	Malvaceae	166.67 ± 20.32	50
Cnestis ferruginea	Connaraceae	133.33 ± 20.14	25
Cocus nucifera	Arecaceae	66.67 ± 9.65	50
Commelina benghalensis	Commelinaceae	514.67 ± 40.00	50
Cyperus haspan	Cyperaceae	133.33 ± 20.45	50
Cyrtosperma senegalense	Araceae	66.67 ± 5.62	50
Elaeis guineensis	Arecaceae	133.33 ± 18.24	50
Icacinia trichantha	Icancinaceae	100 ± 18.62	50
Ipomoea involucrata	Convolvulaceae	200 ± 26.10	50
Lygodium sp.	Lygodiaceae	100.00 ± 15.01	25
Mitragyna ciliata	Rubiaceae	66.67 ± 15.21	50
Paspalum vaginatum	Poaceae	1333.33 ± 19.50	50
Pteridium aquilinum	Dennstaedtiacceae	2333.33 ± 83.20	75
Raphia hookeri	Arecaceae	133.33 ± 19.63	50
Sellaginela myosurus	Sellaginellaceae	1666.67 ± 40.12	25

a: Acroceras zizaniodes b: Ageratum conyzoides c: Alchornea cordifolia
d: Anthocleista vogelli e: Aspilia Africana f: Cnestis ferruginea
g: Commelina benghalensis h: Ipomoea involucrate i: Paspalum vaginatum
j: Pteridium aquilinum k: Raphia hookeri l: Sellaginela myosurus

Fig 2: Some of the Plants in the Wetland

Table 2: Mean Values of Physicochemical Characteristics of Soil Samples

Soil parameters	x̄: ± S.E
pH	5.25 ± 0.09
EC (ds/m)	0.10 ± 0.02
Organic carbon (%)	2.45 ± 0.37
Total nitrogen (%)	0.06 ± 0.01
Phosphorus (mg/kg)	4.17 ± 1.62
Ca (cmol/kg)	3.00 ± 0.34
Mg (cmol/kg)	1.32 ± 0.12
Na (cmol/kg)	0.07 ± 0.001
K (cmol/kg)	0.13 ± 0.02
Exchangeable acidity (cmol/kg)	2.18 ± 0.20
ECEC (cmol/kg)	6.86 ± 0.39
Base Saturation (%)	65.65 ± 2.87
Sand (%)	88.26 ± 0.86
Silt (%)	4.92 ± 0.00
Clay (%)	7.15 ± 0.67

Keys: x̄: Mean; S.E: Standard Error.

Table 3: Heavy Metal Concentration in Plants and Soil Samples

Heavy Metal	mg/kg (x̄ ± S.E)	
	Soil Samples	Plants
Cd	2.21 ± 0.19[a]	2.51 ± 0.11[a]
Ni	8.42 ± 0.98[b]	8.50 ± 0.61[b]
Fe	571 ± 48.36[d]	15.26 ± 1.85[c]
Pb	4.95 ± 0.70[a]	5.81 ± 0.50[a]
Zn	78.24 ± 8.52[c]	11.30 ± 1.36[b]
Cu	10.74 ± 0.30[b]	6.82 ± 0.85[b]

Key: x̄: Mean; S.E: Standard Error; mean within the column followed by the different superscript letters are significant as determined by Duncan multiple range test ($P < 0.05$).

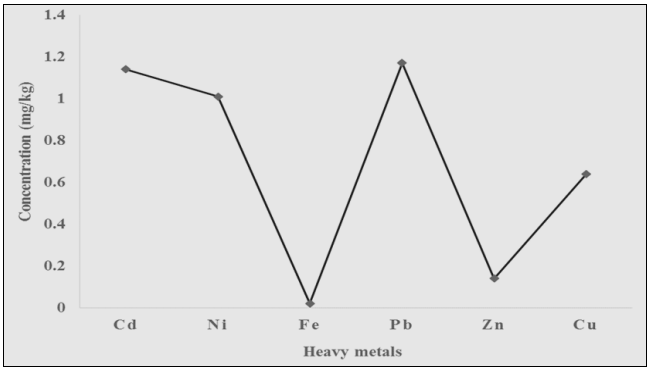

Fig 3: Translocation Factor Threshold for Heavy Metals in the Wetland

Table 4: Contamination Factor and Degree of Contamination of the Wetland

Heavy Metal (mg/kg)	Contamination Factor
Cd	2.35
Ni	2.90
Fe	2.64
Pb	17.07
Zn	14.76
Cu	2.53
Contamination degree	42.25

Discussion

A survey of the floristic composition of this wetland revealed a rich diversity of obligate and facultative hydrophytes. The observed pattern of species occurrence in our study agrees with findings of Clarke and Warwick (2001) [8] that plant species tend to grow together in similar environmental conditions. Although these species coexist, their responses to environmental factors vary, explaining the differences in density and frequency values recorded in the wetland.

The high density of *A. cordifolia* in this study is in conformity with the reports of Ita *et al*. (2017), and this suggests its strong adaptation to hydric conditions, such as anoxic environments and fluctuating water tables, along with suitable soil conditions. The presence of *A. cordifolia* and *C. senegalensis* indicates a high-water table in the ecosystem (Akobundu and Agyakwa, 1998) [2]. Low density values obtained in this study for other species corroborates the findings of Ita *et al*. (2017), and this may be due to their inability to fully adapt to hydric conditions, anthropogenic disturbances, competition for light and nutrients, and slow regeneration rates. High frequency values (75%) for *A. cordifolia* and *P. aquilinum* suggest their wide ecological amplitudes, enabling their establishment across various plots (Mbong *et al*., 2015) [15]. The presence of *E. guineensis* is consistent with the findings of Ita *et al*. (2017), reflecting human interference and the economic importance of the wetland.

In this study, the moderately acidic nature of the wetland soil was observed, and this is in agreement with Stevenson (1991) [22]. The moderately acidic nature of the wetland soil is likely due to litter decomposition, which releases organic acids (Ita *et al*., 2017). Low electrical conductivity, sodium levels, organic carbon, and total nitrogen were obtained in our study, and this may be attributed to the distance of this freshwater wetland from oceanic tidal influences. Low organic carbon and total nitrogen may be linked to poor litter decomposition and the soil's porous nature, which hinders nutrient retention (Brady and Weil, 1996) [7]. The dominance of sand particles contributes to low nutrient values for P, K, Ca, and Mg, while the low ECEC indicates a poor ability to hold cations and other exchangeable bases.

The contamination factor obtained in our results showed that this wetland soil was mostly polluted with Pb and Zn and moderately contaminated with Cd, Ni, Fe, and Cu, and this is consistent with findings by Ita and Anwana (2017) [12]. The presence of Pb and Zn is linked to numerous anthropogenic activities contributing to these metals in the wetland. The high concentration of the Pb contamination factor index (17.07) suggests its non-biodegradable nature and long persistence in both water and soil, and this agrees with Saxena *et al*. (1999) [21] that Pb could be retained in the environment for 150 - 5000 years. The low contamination factor index observed in Cd in this study agrees with the recent findings of Ita and Anwana (2017) [12], attributing its lower occurrence to reduced human activities emitting this metal and its increased uptake by plants. The degree of contamination obtained in this study was very high (42.25) compared to the values (33.71 and 39.08) reported by Ita and Anwana (2017) [12].

According to Mbong *et al.* (2015) [15], the translocation factor (TFm) is a competent technique developed to assess the level of metal in the plant as a fraction of the total soil. A transfer factor value greater than 1 indicates a serious ecosystem risk. The results from this study, as shown in metal threshold limits, raise concern. The translocation threshold factor computed for heavy metals revealed Cd, Ni, and Pb pollution as their peak values exceeded 1. These metals pose serious health risks if they bioaccumulate and biomagnify through the food chain. For instance, consumption of rice high in Cd can lead to renal tubular disease (Watanabe *et al*., 1998). Cadmium accumulates in the human body, particularly in the kidneys, causing renal dysfunction and impaired reabsorption of proteins, glucose, and amino acids (NCM, 2003) [18]. Studies on humans and animals have shown that Cd and nickel exposure can lead to cardiac failure, cancer, cerebrovascular infarction, hypercalciuria, skeletal damage, and allergic skin reactions (NCM, 2003; Das and Buchner, 2007) [18, 9].

Conclusion

Waste deposition threatens wetland ecosystems by releasing toxic metals, causing soil and water pollution. This study has revealed the high toxicity of Cd, Ni, and Pb in soil samples from the wetland and the findings has underscored the need for remediation and conservation efforts, providing essential baseline information for ecological protection and sustainable use.

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