

## Comparative Assessment of Selected Wastewater-Tolerant Plants for Phytoremediation

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### ABSTRACT

Industrial effluents discharged into aquatic and riparian ecosystems often contain toxic heavy metals that compromise wetland biodiversity, water quality, and human health. Phytoremediation using wastewater-tolerant plant species offers a low-cost and eco-friendly alternative for heavy metal removal. This study assessed and compared the phytoremediation potential of three dominant wastewater-tolerant plants *Typha domingensis*, *Cynodon dactylon*, and *Nymphaea lotus*, along an effluent channel in Kano metropolis, Nigeria. Plant samples were collected from the effluent channel, taxonomically identified, and analyzed for heavy metal concentrations (Pb, Cd, Cu, Ni, Zn, Cr, Fe) using standard laboratory procedures. Data were subjected to descriptive statistics, one-way ANOVA, and calculation of bioconcentration factors (BCF) to determine species-specific accumulation efficiency. All species accumulated heavy metals at varying concentrations. Mean levels (mg/kg) ranged from 3.46–4.65 for Pb, 9.24–14.77 for Cd, 13.22–22.17 for Cu, 13.44–14.09 for Ni, 11.8–26.15 for Zn, 4.96–7.38 for Cr, and 10.41–15.82 for Fe. Although interspecies differences were not statistically significant ( $p > 0.05$ ), BCF values revealed distinct uptake trends: *Cynodon dactylon* was most efficient for Cu and Zn, *Nymphaea lotus* showed higher accumulation of Pb and Fe, while *Typha domingensis* demonstrated relatively balanced uptake across metals. The three wastewater-tolerant plant species demonstrated substantial phytoremediation potential, with complementary uptake capacities that can be harnessed for integrated effluent management. Their deployment in constructed wetlands and natural drainage systems could provide a sustainable strategy for mitigating heavy metal pollution and restoring ecological balance in contaminated wetlands.

**Keywords:** Phytoremediation, Wastewater-tolerant plants, Bioconcentration factor, Heavy metals.

### INTRODUCTION

Land and water are critical natural resources that sustain life on Earth. However, their quality and availability are under increasing threat due to human activities. Rapid industrial growth, coupled with unsustainable exploitation, has led to severe degradation of land and aquatic ecosystems worldwide (Ekhaie and Anayasi, 2005; Singh and Singh, 2016). Industrial effluents, in particular, are a major source of pollutants that often contain heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), cobalt (Co) (Mukhtar *et al.*, 2017), and their complexes, which are toxic, non-biodegradable, and pose long-term risks to both ecosystems and human health (Pescod, 1992; Fu and Wang, 2011).

In Nigeria, and specifically in Kano metropolis, industrial wastewater discharge remains a pressing environmental challenge. Although the Kano State Ministry of Environment has provided guidelines for the proper management of hazardous waste, enforcement is weak, and compliance by industries is often poor. As a result, untreated wastewater accumulates in ditches, canals, and tributaries, with limited reuse for peri-urban vegetable irrigation but

without sustainable treatment or recycling (Yusuf *et al.*, 2006).

Phytoremediation, the use of plants to absorb, sequester, and metabolise contaminants, has emerged as a cost-effective and eco-friendly approach for wastewater management (Ali *et al.*, 2013; Rezanian *et al.*, 2016). Several macrophytes, such as *Typha* spp., *Phragmites* spp., and *Eichhornia crassipes*, have demonstrated high tolerance and accumulation capacity for heavy metals (Chandra and Yadav, 2011; Dordio *et al.*, 2011; Sukumaran, 2013). Previous studies have demonstrated the potential of *Typha* species in the uptake of Cd, Cr, Cu, and Zn from polluted water and sediments (Klink *et al.*, 2013; Chayapan *et al.*, 2016).

Although many studies have examined the phytoremediation potential of *Typha* species (LuCasey, 2010; Chandra and Yadav, 2011; Dordio *et al.*, 2011), limited work has compared multiple macrophyte species simultaneously under the same effluent conditions in Nigeria. Therefore, this study aimed to evaluate the capacity of three dominant macrophyte species—*Typha domingensis*, *Cynodon dactylon*, and *Nymphaea lotus*—to accumulate and

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sequester heavy metals from industrial wastewater in Kano metropolis. By comparing their uptake patterns and bioconcentration factors, the study provides insight into their relative suitability for phytoremediation and wastewater management.

## MATERIALS AND METHODS

### Study Area

The study was carried out along the Kano-Zaria highway in Kano metropolis, Nigeria (11.99°N, 8.51°E, elevation 479 m above sea level). The drainage canal, approximately 1.66 km long, originates at an industrial effluent discharge point (N11°53'30.1", E008°32'29.8") and drains into the Tatswarki tributary (N11°53'39.2", E008°31'37.5").

### Sample Collection

Wastewater samples were collected bimonthly over three months from four sampling points along the canal. Macrophyte species flourishing in the drainage channel were collected, identified using Akobundu and Agyakwa (1998) and Jepson Herbarium Guide (2013), and confirmed at the Bayero University Kano Herbarium. Plant samples were air-dried, ground, and sieved for analysis.

### Heavy Metal Analysis

Wastewater digestion followed Eaton *et al.* (2005), while plant digestion followed Benton and Vernon (1990). Heavy metal concentrations (Pb, Cd, Cr, Cu, Ni, Zn, Fe) were determined using an Atomic Absorption Spectrophotometer (AAS-VGP 210).

### Determination of Bioconcentration Factor

Bioconcentration factor (BCF) was calculated as the ratio of the concentration element in the plant to that of the wastewater as defined below (Sadiq 1992).

$$BCF = \frac{CB}{CW}$$

CB= Chemical concentration in organism

CW= Chemical concentration in the environment

### Statistical Analysis

One-way Analysis of variance (ANOVA) was used to compare heavy metal concentrations in plant samples using Microsoft Excel. Differences between means were considered significant if  $p < 0.05$ .

## RESULTS AND DISCUSSION

### Plant Species Identified in the Effluent Channel

Three macrophyte species were identified along the industrial effluent channel in Kano: *Typha domingensis* (cattail/reed), *Cynodon dactylon* (Bahama grass), and *Nymphaea lotus* (water lily) (Table 1). These species reflect a typical composition of aquatic and semi-aquatic vegetation found in

disturbed freshwater ecosystems across Nigeria and West Africa (Akobundu and Agyakwa, 1998; Akinyemi *et al.*, 2019).

*Typha domingensis* was the most widespread and dominant macrophyte in the effluent channel, especially near the industrial discharge point. Its dominance is consistent with observations that *Typha* species thrive in polluted or nutrient-enriched waters due to their high tolerance to stress, rapid clonal growth, and capacity to accumulate pollutants (Rezania *et al.*, 2016; Ojo *et al.*, 2019). In many African wetlands, *Typha* spp. often outcompete other vegetation under nutrient loading or wastewater inflow, making them both an ecological challenge and a potential resource for phytoremediation (Akinyemi *et al.*, 2019).

*Cynodon dactylon* was found in numerous patches, mainly along canal banks. This species is a hardy perennial grass known for its tolerance to heavy metals and its extensive root system, which aids in metal uptake and stabilisation of contaminated soils (Singh *et al.*, 2010; Abbas *et al.*, 2018). Its presence in abundance along the effluent channel suggests it plays a role in bank stabilisation while also contributing to metal uptake.

*Nymphaea lotus*, although sparsely distributed, occupied deeper aquatic sections of the canal. Aquatic lilies are less frequently reported in phytoremediation studies, but their rhizomes and floating leaves can absorb metals directly from the water column and sediments (Rai, 2008). Its lower abundance compared to *Typha* and *Cynodon* may reflect sensitivity to high pollutant loads or competition from more aggressive colonisers like *Typha*.

The co-occurrence of emergent (*Typha*), terrestrial/semiaquatic (*Cynodon*), and floating-leaved (*Nymphaea*) species provides a natural gradient of plant niches that collectively interact with contaminants in the water, sediment, and rhizosphere, highlighting their potential complementary role in wastewater management systems (Ali *et al.*, 2013; Verma and Suthar, 2015).

### Heavy Metal Accumulation in Macrophyte Species

The mean concentrations of heavy metals in the three macrophyte species are presented in Table 2. All three plants accumulated significant levels of Pb, Cd, Cu, Ni, Zn, Cr, and Fe, though with varying patterns. Importantly, except for Zn and Fe, the concentrations of most metals exceeded the WHO (1996) permissible limits for plants, indicating high levels of

contamination in the effluent channel and substantial uptake by the plants.

Lead concentrations were highest in *N. lotus* (4.65 mg/kg), followed by *C. dactylon* (4.17 mg/kg) and *T. domingensis* (3.46 mg/kg). Although Pb is poorly translocated in many plants due to its low solubility and tendency to bind with cell walls (Sharma and Dubey, 2005), aquatic macrophytes often show higher Pb uptake from sediments and water. The greater accumulation in *N. lotus* suggests that floating and submerged organs may facilitate the absorption of dissolved Pb ions. Similar findings were reported by Mishra *et al.* (2008), where aquatic lilies showed higher Pb uptake compared to emergent species.

*Typha domingensis* accumulated the highest Cd (14.77 mg/kg), followed by *N. lotus* (12.08 mg/kg), while *C. dactylon* accumulated less (9.24 mg/kg). Cd is highly mobile and readily absorbed by plants, often replacing essential cations like Zn and Ca (Das *et al.*, 1997). The high Cd uptake by *T. domingensis* is consistent with previous studies highlighting *Typha* spp. as effective Cd hyperaccumulators (Chayapan *et al.*, 2016; Sukumaran, 2013). The higher BCF observed for Cd in *Typha* underscores its suitability as a phytoremediation candidate for Cd-contaminated wastewater.

Cu and Zn concentrations were highest in *C. dactylon* (22.17 mg/kg and 26.15 mg/kg, respectively). Grasses, particularly *C. dactylon*, are known for their efficient uptake of micronutrients such as Cu and Zn, which are essential for photosynthetic and enzymatic activities but become toxic at elevated levels (Yadav, 2010). The high uptake in *C. dactylon* may reflect root-level interactions with sediments, where these metals often accumulate. Similar findings were reported by Abbas *et al.* (2018), who observed *C. dactylon* effectively removing Cu and Zn from contaminated soils.

Cr concentration was highest in *T. domingensis* (7.38 mg/kg), exceeding WHO permissible limits (3.0–5.0 mg/kg). Chromium is highly toxic, especially in its hexavalent form, and can damage plant metabolic

processes (Shanker *et al.*, 2005). The ability of *Typha* to accumulate Cr highlights its tolerance to stress and aligns with findings by Dordio *et al.* (2009), who reported Cr uptake by *Typha latifolia* in constructed wetlands.

Ni concentrations were relatively similar across the three species (13.44–14.09 mg/kg), with *N. lotus* showing the highest accumulation. Ni is an essential micronutrient at low levels but becomes toxic at higher concentrations (Kabata-Pendias, 2011). Its uniform uptake across species suggests that Ni bioavailability in the wastewater was relatively consistent.

Fe concentrations ranged from 10.41 mg/kg (*T. domingensis*) to 15.82 mg/kg (*N. lotus*). Unlike other heavy metals, Fe and Zn concentrations remained within WHO permissible limits. This could be attributed to their role as essential plant micronutrients, which are tightly regulated in plant tissues (Marschner, 2012). The higher Fe accumulation in *N. lotus* may be linked to sediment interactions in deeper water zones, where Fe solubility increases under low oxygen conditions (Reddy and DeLaune, 2008).

#### Metal Uptake and Species-Specific Patterns

The results suggest distinct accumulation patterns among the three macrophyte species: *Typha domingensis*: Strong affinity for Cd and Cr, demonstrating high tolerance and suitability for treating Cd- and Cr-polluted effluents. *Cynodon dactylon*: High uptake of Cu and Zn, reflecting its ability to stabilise soils and remove micronutrient metals. *Nymphaea lotus*: Higher Pb, Ni, and Fe uptake, possibly due to its aquatic growth habit and direct interaction with dissolved ions in water. These findings align with previous reports showing species-specific preferences in metal uptake (Ali *et al.*, 2013; Klink *et al.*, 2013). Importantly, the complementary uptake patterns suggest that integrating different macrophytes in constructed wetland systems could enhance the removal efficiency for a broader spectrum of heavy metals.

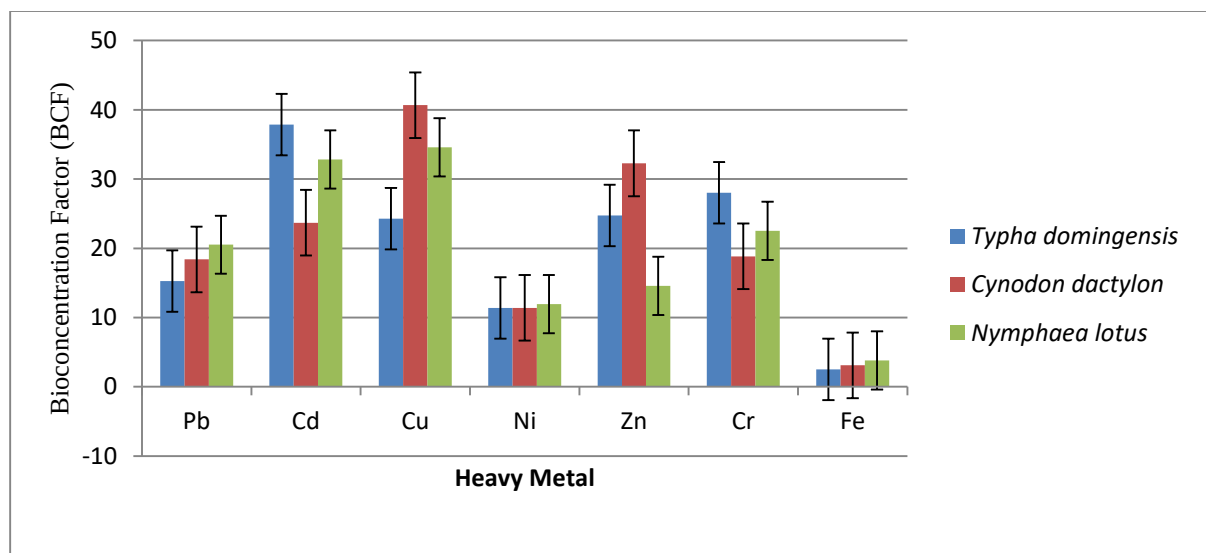
**Table 1:** Plant Species Identified along the Effluent Channel

| Plant species            | Common Name   | Local Name                  | Distribution   | Accession No. |
|--------------------------|---------------|-----------------------------|----------------|---------------|
| <i>Typha domingensis</i> | Cattails/Reed | Kachalla/<br>Geron Tsuntsu' | Widespread     | BUKHAN 251    |
| <i>Cynodon dactylon</i>  | Bahama grass  | 'Kiri-kiri'                 | Numerous       | BUKHAN 241    |
|                          | Water lily    | 'Bado'                      | Sparse aquatic | BUKHAN 250    |
| <i>Nymphaea lotus</i>    |               |                             |                |               |

**Table 2:** Mean Concentration ( $\pm$  standard error) of Heavy Metals (mg/kg) in Macrophyte Species from the Wastewater Drainage

| Heavy Metals | <i>Typha domingensis</i> | <i>Cynodon dactylon</i> | <i>Nymphaea lotus</i> | WHO (1996) | P-value |
|--------------|--------------------------|-------------------------|-----------------------|------------|---------|
| Pb           | 3.46 $\pm$ 0.893         | 4.17 $\pm$ 1.397        | 4.65 $\pm$ 0.993      | 0.01       | 0.7584  |
| Cd           | 14.77 $\pm$ 2.693        | 9.24 $\pm$ 0.872        | 12.08 $\pm$ 4.351     | 0.20       | 0.4722  |
| Cu           | 13.22 $\pm$ 7.306        | 22.17 $\pm$ 12.031      | 18.85 $\pm$ 7.577     | 0.003      | 0.7934  |
| Ni           | 13.44 $\pm$ 4.848        | 13.47 $\pm$ 4.843       | 14.09 $\pm$ 5.122     | 0.07       | 0.9945  |
| Zn           | 20.06 $\pm$ 13.470       | 26.15 $\pm$ 12.783      | 11.8 $\pm$ 5.235      | 0.01       | 0.6761  |
| Cr           | 7.38 $\pm$ 2.794         | 4.96 $\pm$ 0.637        | 5.93 $\pm$ 2.159      | 3.0-5.0    | 0.7199  |
| Fe           | 10.41 $\pm$ 4.596        | 12.89 $\pm$ 4.253       | 15.82 $\pm$ 4.697     | 0.30       | 0.7127  |

No statistical difference if  $P > 0.05$

**Figure 1:** Bioconcentration Factor (BCF) of Wastewater Tolerant Plant Species

### CONCLUSION

This study showed that *Typha domingensis*, *Cynodon dactylon*, and *Nymphaea lotus* accumulated significant levels of heavy metals from industrial wastewater in Kano metropolis. While *T. domingensis* was most effective for cadmium (Cd) and chromium (Cr), *Cynodon* accumulated higher copper (Cu) and zinc (Zn), and *Nymphaea* absorbed more lead (Pb), nickel (Ni), and iron (Fe). These species-specific uptake patterns highlight their potential for complementary use in phytoremediation systems. The high concentrations of toxic metals, particularly Cd, Cr, and Pb, exceeding WHO limits, emphasise the urgent need

for sustainable wastewater management. Incorporating these macrophytes into constructed wetlands offers a low-cost, eco-friendly strategy for pollution control and environmental restoration in Nigeria.

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