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Phytoremediation Pilot Study in a Mississippi Community Impacted by Petrochemical Refining

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Abstract

Communities in Mississippi located near petrochemical refining facilities face ongoing risks from heavy metal contamination in soils, threatening environmental quality, food safety, and public health. This pilot study evaluated the phytoremediation potential of Nerium oleander and cabbage (Brassica oleracea) in a residential fence-line community within the Cherokee Forest subdivision of East Pascagoula, Mississippi, impacted by long-term petrochemical and shipyard activities. Plants were grown directly in contaminated garden soils under natural field conditions. Soil and plant tissue concentrations of lead (Pb), cadmium (Cd), zinc (Zn), and nickel (Ni) were measured using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Phytoremediation effectiveness was assessed through removal efficiency, translocation factor, and bioaccumulation factor. Results showed significant reductions ($p < 0.01$) in all soil metals, with cadmium removal exceeding 97%. Nerium oleander exhibited substantially higher metal uptake and translocation capacity than cabbage, achieving a maximum cadmium translocation factor of 9.99 and bioaccumulation factors up to 5.67. In contrast, cabbage showed lower translocation efficiency, indicating limited remediation potential but suitability as a food crop after soil treatment. These findings highlight Nerium oleander as an effective, sustainable, and community-acceptable phytoremediation solution.

Keywords: phytoremediation; heavy metals; soil contamination; Nerium oleander; brassica oleracea

1. Introduction

Heavy metal contamination of soil is a global environmental and public health concern driven by industrialization, mining, and improper waste disposal. Toxic elements such as lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and chromium (Cr), particularly hexavalent chromium (Cr^{6+}), persist in the environment and can accumulate in biological systems [1–5]. These contaminants are of particular concern because they can enter the food chain through crop uptake, posing risks such as neurological damage, kidney dysfunction, carcinogenic effects, and developmental disorders in humans [6–10]. Due to their persistence and bioaccumulative nature, even low-level exposure can result in long-term health impacts [1].

Industrial and petrochemical regions represent hotspots for such contamination. Pascagoula, Mississippi, located along the Gulf Coast, is one of the most industrialized areas in the southeastern United States, with extensive shipbuilding, petroleum refining, and chemical manufacturing activities [11,12]. Fence-line communities in close proximity to these facilities are disproportionately exposed to environmental pollutants through air emissions, stormwater runoff, and soil contamination. In particular, residential areas such as the Cherokee Forest subdivision are situated adjacent to industrial complexes, raising environmental justice concerns related to long-term exposure risks [13].

Recent studies have demonstrated that urban and community garden soils near industrial zones frequently contain elevated concentrations of heavy metals, increasing the risk of human exposure through direct soil contact and consumption of contaminated produce [14–16]. While these findings highlight the need for intervention, there remains a lack of field-based studies evaluating practical, community-level remediation strategies under real-world conditions.

Phytoremediation, the use of plants to remove or stabilize contaminants, has emerged as a promising, low-cost, and environmentally sustainable remediation approach [17]. However, its effectiveness depends strongly on plant species selection, site conditions, and contaminant characteristics. Although some studies have reported successful metal uptake using ornamental and crop species, others have noted limitations in translocation efficiency and biomass production, particularly for food crops [18–20]. This creates a key challenge in balancing remediation effectiveness with food safety, especially in residential gardening contexts. As a result, there is ongoing debate regarding the suitability of edible versus non-edible plants for remediation in contaminated soils.

Nerium oleander, a hardy ornamental shrub, has shown considerable tolerance to environmental stress and potential for heavy metal accumulation [18–22]. In contrast, edible crops such as cabbage (Brassica oleracea) may accumulate metals in edible tissues, raising food safety concerns despite their potential role in phytoremediation systems. Despite these insights, there is limited research evaluating the comparative performance of ornamental and food crops under field conditions in petrochemical-impacted communities.

Therefore, this study aimed to evaluate the phytoremediation potential of Nerium oleander and cabbage (Brassica oleracea) in a residential fence-line community in Pascagoula, Mississippi. Specifically, the study assessed soil metal reduction, plant uptake, and translocation dynamics under natural conditions. The results demonstrate that N. oleander is a more effective phytoremediation species, exhibiting higher metal uptake and translocation efficiency, while cabbage shows limited remediation capacity but potential suitability following soil treatment. These findings support the use of ornamental species as sustainable, community-acceptable solutions for reducing heavy metal contamination and associated exposure risks.

2. Materials and Methods

2.1. Study Area and Experimental Design

The phytoremediation pilot study was conducted in the Cherokee Forest subdivision of East Pascagoula, Mississippi (30.359° N, 88.511° W). This residential neighborhood, consisting of approximately 120 households, is located immediately west of the Bayou Casotte Industrial Park, a heavily industrialized zone that includes petroleum refineries, liquefied natural gas (LNG) facilities, shipyards, and chemical processing plants [13]. The area represents a documented fence-line community with long-term exposure to industrial emissions, particularly heavy metals associated with petrochemical refining and shipbuilding activities.

Figure 1. Map and photographs of the study site showing proximity to industrial sources.

The experiment was established in two residential garden plots: Lot A (front location) and Lot B (back location). Each plot measured approximately 4 m × 6 m and was subdivided into four equal treatment subplots (≈1.5 m × 2.0 m) arranged in a rectangular grid (Figure 2). The treatments included:

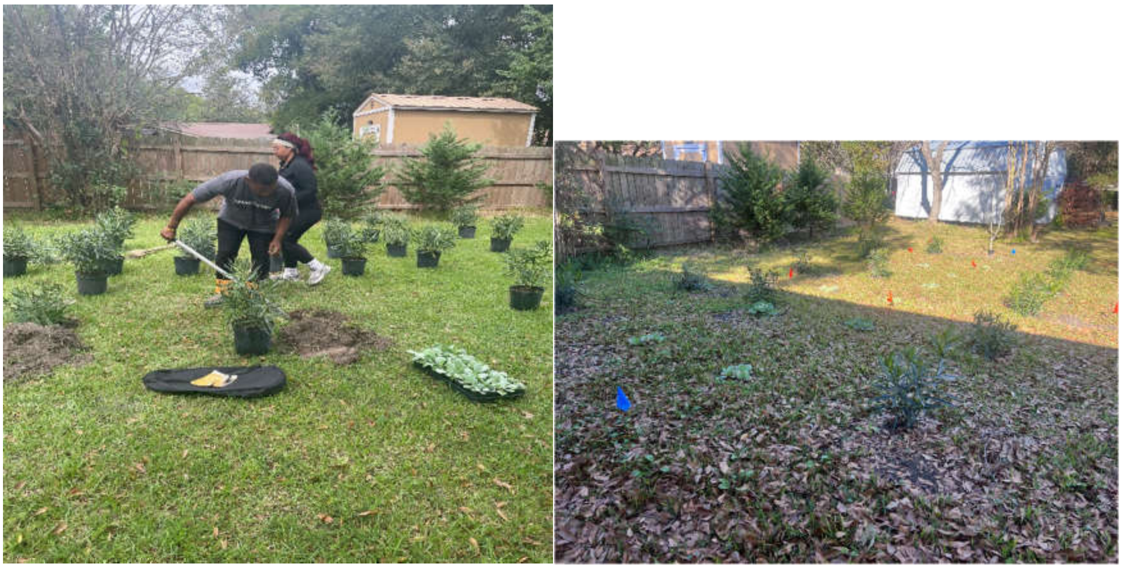
T_1 (Control): Bare soil with no vegetation (pre-treatment reference)

T_2 (Cabbage only): Brassica oleracea var. capitata planted at 30 cm spacing within rows and 40 cm between rows

T_3 (Oleander only): Nerium oleander saplings spaced 1 m apart

T_4 (Mixed planting): One centrally placed oleander plant surrounded by six cabbage plants at ~30 cm spacing

All subplots were separated by 50 cm buffer zones to prevent root interaction and cross-contamination. Each treatment was replicated three times across both locations, resulting in a total of 24 subplots (4 treatments × 3 replicates × 2 sites). The study followed a completely randomized design under natural field conditions. No fertilizers or chemical amendments were applied. Irrigation with clean groundwater was conducted twice weekly.



Lot (A) Lot (B)

Figure 2. Experiment Design layout and set up.

2.2. Soil Sampling and Analysis

Soil samples were collected at two time points: pre-treatment (before planting) and post-treatment (after 13 weeks). At each plot, five subsamples were collected from the top 0–20 cm using a stainless-steel auger and composited into a representative sample. Samples were air-dried at room temperature (25 ± 2 °C), homogenized, and sieved through a 2 mm mesh.

Target metals included nickel (Ni), zinc (Zn), cadmium (Cd), and lead (Pb), which are commonly associated with refinery and shipyard emissions [17,24]. Samples were stored in acid-washed polyethylene containers prior to analysis.

2.3. Plant Sampling and Preparation

At the end of the experimental period, plants were carefully uprooted and washed with deionized water to remove adhering soil particles. Samples were separated into root and shoot components, oven-dried at 70 °C to constant weight, and ground using a stainless-steel grinder. Processed samples were stored in desiccators until analysis.

Control plants of both species were grown in uncontaminated soil under similar conditions to determine baseline metal concentrations.

2.4. Metal Analysis by ICP–OES

Metal concentrations in soil and plant tissues were determined using Inductively Coupled Plasma–Optical Emission Spectrometry (ICP–OES) following USEPA Method 3050B [25]. Approximately 0.5 g of dried sample was digested using a mixture of concentrated nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) in a 3:1 (v/v) ratio on a hotplate at 95 °C until complete digestion was achieved. The digest was filtered through Whatman No. 42 filter paper and diluted to 50 mL with deionized water prior to analysis.

2.5. Phytoremediation Indices and Statistical Analysis

Metal removal efficiency (RE%) was calculated to determine the reduction in soil metal concentrations:

$$RE\ (\%) = [(C_i - C_f) / C_i] \times 100 \quad (1)$$

where C_i is the initial (pre-treatment) concentration and C_f is the final (post-treatment) concentration [24].

Translocation Factor (TF) and Bioaccumulation Factor (BAF) were calculated as:

$$\boldsymbol{TF = Cshoots/Croot} \quad (2)$$

$$\boldsymbol{BAF = Cplant/Csoil} \quad (3)$$

These indices were used to evaluate the efficiency of metal uptake and translocation within plant tissues [26].

Statistical analyses were performed using Microsoft Excel. Paired t-tests were used to compare pre- and post-treatment soil concentrations, while one-way analysis of variance (ANOVA) was applied to assess differences between treatments and locations. Statistical significance was determined at $p < 0.05$.

2.6. Ethical and Community Considerations

All experimental procedures were conducted with the consent and cooperation of residents from the Cherokee Concerned Citizens group. Soil sampling and planting were performed on private property with permission from homeowners. Study findings were communicated to community members to support environmental awareness and local decision-making regarding soil safety and gardening practices.

3. Results and Discussion

3.1. Soil Heavy Metal Removal Efficiency

The phytoremediation efficiency of heavy metals contaminated soil was evaluated across two sampling locations (Lot A - Front Location and Lot B - Back Location) over the experimental period. Pre-treatment and post-treatment soil samples were analyzed for four priority heavy metals: Nickel (Ni), Zinc (Zn), Cadmium (Cd), and Lead (Pb) to assess the effectiveness of phytoremediation intervention using *Nerium oleander* and Cabbage (Brassica oleracea).

3.1.1. Pre-Treatment Soil Contamination

Baseline analysis showed substantial heavy metal contamination across both experimental locations (Table 1). Lot A contained the most lead (7.80 mg/kg), along with cadmium (3.95 mg/kg), zinc (3.68 mg/kg), and nickel (0.121 mg/kg). Lot B exhibited a distinct contamination pattern, with lead (5.08 mg/kg), zinc (3.49 mg/kg), cadmium (2.68 mg/kg), and notably higher nickel (0.816 mg/kg). Nickel in Lot B was about 6.7 times higher than in Lot A, showing that contamination sources varied across the site. Lead levels were above safety standards at both locations, with Lot A having 53% more lead than Lot B, reflecting different pollution sources or histories at each area.

3.1.2. Post-Treatment Soil Metal Concentrations and Removal Efficiency

After growing Nerium oleander and Cabbage on contaminated soil, we observed major reductions in all tested metals (Table 1). Cadmium showed the best removal results, decreasing by 97.4% in Lot A ($p = 0.0003$) and 96.0% in Lot B ($p = 0.0002$), resulting in final concentrations of 0.104 and 0.107 mg/kg. Zinc removal was also highly effective, with 81.8% reduction in Lot A ($p = 0.001$) and 83.1% in Lot B ($p = 0.0001$), leaving 0.668 and 0.589 mg/kg, respectively. Nickel decreased by 67.0% in Lot A ($p = 0.003$) and 80.9% in Lot B ($p = 0.0002$), even though starting concentrations differed greatly between sites. Lead had the lowest but still significant removal, at 44.1% in Lot A ($p = 0.0006$) and 34.9% in Lot B ($p = 0.007$), with final levels of 4.36 and 3.31 mg/kg.

Table 1. Pre-treatment and post-treatment soil heavy metal concentrations with removal efficiency.

Metal	Lot	Pre-treatment (mg/kg)	Post-treatment (mg/kg)	Reduction (%)	p-value
Ni	Lot A	0.121	0.040	67.0	0.003
Ni	Lot B	0.816	0.156	80.9	0.0002
Zn	Lot A	3.68	0.668	81.8	0.001
Zn	Lot B	3.49	0.589	83.1	0.0001

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Metal	Lot	Pre-treatment (mg/kg)	Post-treatment (mg/kg)	Reduction (%)	p-value
Ni	Lot A	0.121	0.040	67.0	0.003
Ni	Lot B	0.816	0.156	80.9	0.0002
Cd	Lot A	3.95	0.104	97.4	0.0003
Cd	Lot B	2.68	0.107	96.0	0.0002
Pb	Lot A	7.80	4.36	44.1	0.0006
Pb	Lot B	5.08	3.31	34.9	0.007

The observed removal hierarchy (Cd > Zn > Ni > Pb) corresponds with established metal bioavailability patterns in soil-plant systems. Cadmium and Zinc, existing predominantly as exchangeable cations (Cd2+ and Zn2+), demonstrated superior phytoextraction efficiency exceeding 80% due to their higher solubility and plant uptake potential [24]. These metals form weak complexes with soil organic matter, facilitating ready desorption and root absorption through specific metal transporter proteins. The moderately efficient nickel removal (67-81%) reflects its intermediate mobility in soil matrices, while lead exhibited the lowest removal efficiency (35-44%), consistent with its strong adsorption to soil organic matter and clay minerals through formation of stable inner-sphere complexes and precipitation with phosphate and carbonate minerals [25]. Notably, nickel removal efficiency in Lot B exceeded that of Lot A by 13.9 percentage points despite the initial concentration being 6.7-fold higher, suggesting concentration-dependent enhancement of metal transporter expression or increased root biomass allocation in response to elevated substrate availability [26]. The statistical significance of all reductions ($p < 0.01$) confirms treatment-induced metal depletion rather than natural attenuation processes, with the highly significant p-values indicating less than 1% probability that these results occurred by chance, thereby validating the effectiveness of the dual-species phytoremediation approach [27].

3.2. Heavy Metal Accumulation in Plant Tissues

3.2.1. Baseline Metal Concentrations in Control Plants

To establish baseline metal concentrations, control plants of both species were grown in uncontaminated soil (Tables 2 and 3). Control N. oleander exhibited low metal concentrations in both shoots (Ni: 0.047, Zn: 7.88, Cd: 0.015, Pb: 0.051 mg/kg) and roots (Ni: 0.030, Zn: 2.34, Cd: 0.005, Pb: 0.042 mg/kg). Similarly, control cabbage showed minimal accumulation in shoots (Ni: 0.013, Zn: 3.42, Cd: 0.005, Pb: 0.020 mg/kg) and roots (Ni: 0.247, Zn: 5.01, Cd: 0.008, Pb: 0.153 mg/kg). These baseline values confirm that elevated metal concentrations in experimental plants resulted from soil contamination rather than inherent accumulation capacity.

Table 2. Heavy metal concentrations in control Nerium oleander plants.

Plant Parts	Ni (mg/Kg)	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Shoot	0.047	7.88	0.015	0.051
Root	0.030	2.34	0.005	0.042

Table 3. Heavy metal concentrations in control Cabbage plants.

Plant Parts	Ni (mg/kg)	Zn (mg/kg)	Cd (mg/kg)	Pb (mg/kg)

Shoot	0.013	3.42	0.005	0.020
Root	0.247	5.01	0.008	0.153

3.2.2. Metal Accumulation in Front Location

In the shoots, N. oleander exhibited significantly higher accumulation of cadmium (10.43 mg/kg), zinc (7.45 mg/kg), and lead (5.45 mg/kg) compared to Cabbage (Cd: 4.59 mg/kg, Zn: 6.62 mg/kg, Pb: 5.24 mg/kg), whereas nickel uptake was similar between species (0.47 vs. 0.28 mg/kg) (Figure 3a). This suggests that oleander has a stronger tendency to accumulate cadmium and lead in aerial tissues, supporting its potential use in phytoextraction of these metals. Previous studies have also highlighted the ability of oleander to tolerate and accumulate toxic metals, owing to its deep root system and efficient translocation mechanisms [28]

In the roots, a similar pattern was observed, with oleander roots showing higher cadmium (6.30 mg/kg) and lead (2.73 mg/kg) uptake while cabbage roots accumulated more zinc (3.89 vs. 2.95 mg/kg in oleander) (Figure 3b). Nickel concentrations remained low in both species (0.08 vs. 0.07 mg/kg). The higher retention of zinc in cabbage roots suggests limited translocation to shoots, in line with earlier findings that Brassica species often immobilize metals in roots to reduce toxicity in edible parts through complexation with organic acids and phytochelatins [29].

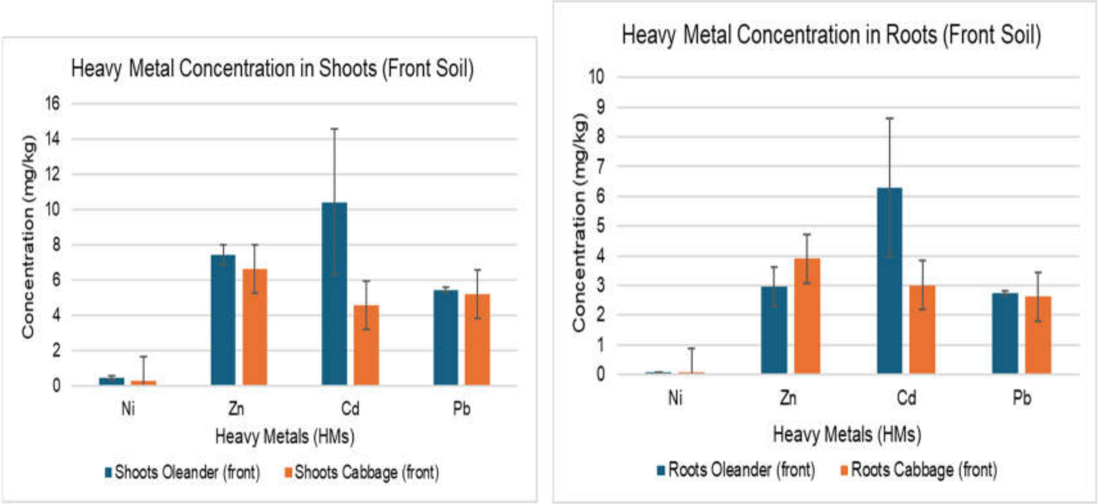

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Figure 3. a: Heavy metal concentrations in shoots of Oleander and Cabbage grown in front location soil. b: Heavy metal concentrations in roots of Oleander and Cabbage grown in front location soil.

Translocation Factor (TF) evaluation demonstrated efficient root-to-shoot metal mobilization in both species, with statistically significant interspecies differences ($t = 1.56$, $p = 0.047$) (Figure 4a). Oleander displayed the most elevated TF for nickel (6.00), indicating remarkably efficient upward transport, followed by zinc (2.52), lead (1.99), and cadmium (1.66). Cabbage exhibited more consistent translocation characteristics with nickel TF of 3.83, lead (2.00), zinc (1.70), and cadmium (1.53). All TF values exceeded unity, confirming effective metal mobilization from roots to aboveground tissues. The significantly superior translocation efficiency in oleander ($p < 0.05$) suggests enhanced xylem loading mechanisms, presumably attributable to upregulated expression of metal transporter proteins in root vascular tissues [30]. This efficient translocation, particularly for cadmium combined with substantial shoot concentrations, establishes oleander's potential for phytoextraction applications where metal removal occurs through periodic biomass harvesting [31].

Bioaccumulation Factor (BAF) analysis revealed species-specific accumulation characteristics, though differences lacked statistical significance ($t = 1.24$, $p = 0.72$) (Figure 4b). N. oleander exhibited maximum BAF values for cadmium (5.67) and nickel (5.30), demonstrating robust bioaccumulation capacity from contaminated substrates. Zinc showed intermediate accumulation (2.67), while lead displayed the minimum BAF (1.60). Conversely, cabbage demonstrated relatively uniform accumulation across metals, with maximum BAF for zinc (2.90) and nickel (2.77), followed by lead (2.31) and cadmium (1.11). The absence of significant interspecies differences ($p > 0.05$) indicates that both plants exhibit comparable root uptake capabilities from soil. However, all BAF values exceeding unity confirm active metal uptake mediated by specific membrane transporters rather than passive diffusion, indicating energy-dependent accumulation mechanisms in both species [32].

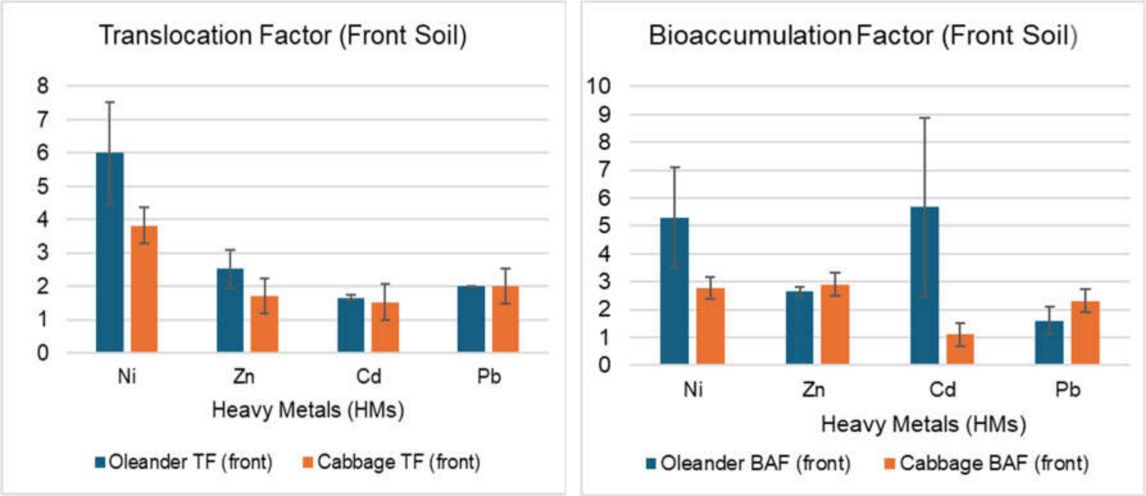

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Figure 4. a: Translocation Factor (TF) values for heavy metals in Oleander and Cabbage from front location. b: Bioaccumulation Factor (BAF) values for heavy metals in Oleander and Cabbage from front location.

3.2.3. Metal Accumulation in Back Location

Shoot tissue examination at the back location demonstrated distinct species-specific metal preferences (Figure 5a). N. oleander accumulated greater lead quantities at (5.53 mg/kg) compared to (4.61 mg/kg) in Cabbage. This pattern is inverted for cadmium, where cabbage concentrated (4.59 mg/kg) while oleander showed negligible uptake at (0.032 mg/kg). Zinc concentrations remained similar between species, measuring (5.90 mg/kg) in oleander and 5.26 mg/kg in cabbage, suggesting parallel zinc transport mechanisms [30]. Nickel levels remained minimal in both species.

Root tissue metal distribution patterns exhibited substantial variation between the two species (Figure 5b). Cabbage roots demonstrated greater retention of both cadmium (2.35 mg/kg) and zinc (3.35 mg/kg). Conversely, oleander roots preferentially accumulated lead, attaining (2.90 mg/kg) compared to (1.81 mg/kg) in cabbage. The most remarkable observation was the exceptionally low cadmium concentration in oleander roots (0.003 mg/kg) despite considerable accumulation in shoots, indicating that oleander efficiently translocates cadmium from roots to aerial tissues rather than retaining it in root cells [29]. Nickel remained at trace levels in both species.

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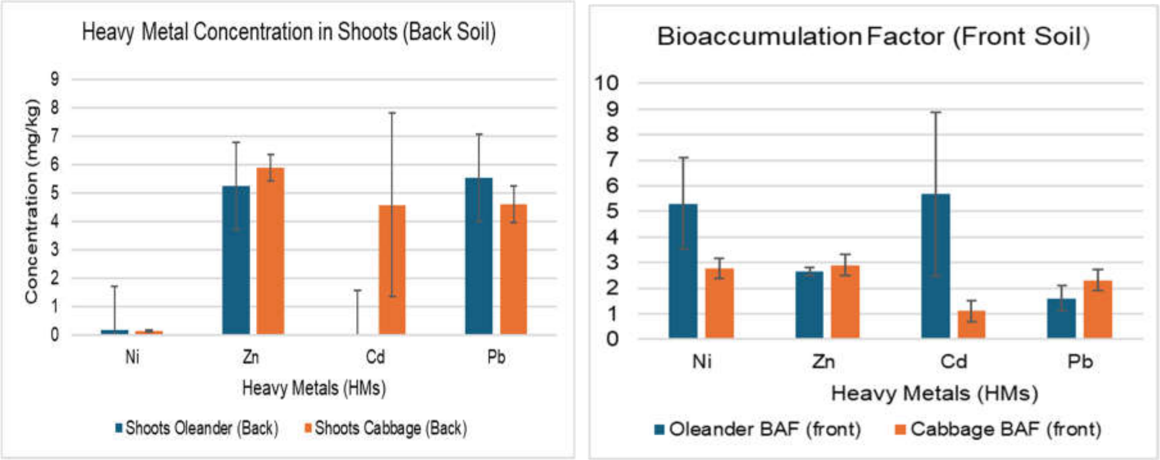

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Figure 5. a: Heavy metal concentrations in shoots of Oleander and Cabbage grown in back location soil. b: Heavy metal concentrations in roots of Oleander and Cabbage grown in back location soil.

Translocation Factor (TF) examination revealed distinctive metal mobility patterns at the back location, though overall interspecies differences were not statistically significant ($t = 0.91$, $p = 0.47$) (Figure 6a). The most prominent finding was oleander's exceptionally elevated cadmium TF of 9.99, indicating nearly complete translocation from roots to shoots. This value substantially exceeded that of cabbage (1.95). For the remaining metals, both plants demonstrated comparable translocation efficiency. Zinc TF values measured 1.71 in oleander and 1.76 in cabbage, while nickel values were 1.94 and 1.79, respectively. Lead showed marginally higher translocation in cabbage (2.55) compared to oleander (1.90).

Bioaccumulation Factor (BAF) values remained comparable between the two species ($t = -1.12$, $p = 0.68$) (Figure 6b). Both plants exhibited similar zinc uptake capacity, with a BAF of 2.67 in oleander and 2.73 in cabbage. Lead accumulation also remained comparable between species (1.52 vs. 1.35). However, cadmium displayed a divergent pattern. Oleander exhibited extremely low cadmium BAF (0.013) while cabbage demonstrated substantially higher values (3.34). Nickel uptake remained minimal in both plants, presumably due to the restricted bioavailability of nickel in the soil at this location.

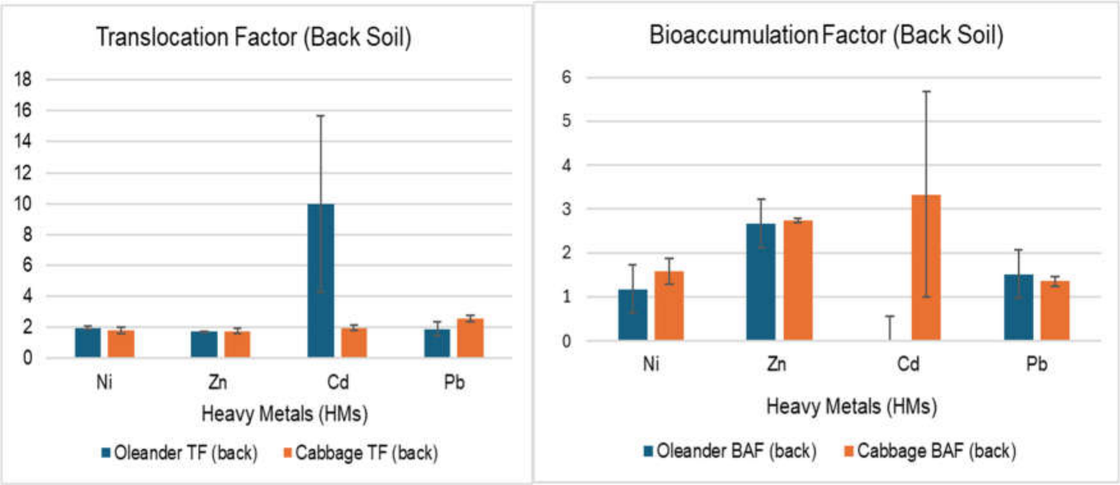

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Figure 6. a: Translocation Factor (TF) values for heavy metals in Oleander and Cabbage from Back location. b: Bioaccumulation Factor (BAF) values for heavy metals in Oleander and Cabbage from back location.

2.4. Comparative Analysis and Implications

3.2.4. Species Performance and Metal Management Strategies

Nerium oleander proved more effective than cabbage for extracting lead and cadmium through harvestable biomass. The species exhibited significantly elevated translocation factors, particularly for cadmium (TF = 9.99 at back location), confirming highly efficient root-to-shoot metal transport. This exceptional upward mobility likely stems from enhanced expression of membrane transporter proteins in root vascular tissues (Ibrahim & El Afandi, 2020). Oleander's extensive root network extends deeper into the soil layers than that of shallow-rooted vegetables, allowing it to access contamination zones unavailable to herbaceous crops. The evergreen foliage enables year-round metal sequestration independent of seasonal changes, while leaf surface morphology captures atmospheric metal particles, addressing both soil and air contamination pathways simultaneously (Seridou & Kalogerakis, 2021). Notably, the plant maintained vigorous vegetative growth despite substantial bioaccumulation of toxic elements, confirming robust physiological stress tolerance mechanisms suitable for long-term remediation applications [33].

Conversely, cabbage exhibited preferential root accumulation with limited upward translocation. This root-focused sequestration occurs through biochemical chelation involving organic acids and sulfur-rich peptides, which immobilize metals belowground [34]. While protecting photosynthetic tissues, this strategy fundamentally restricts the applicability of phytoextraction, as contaminants remain in the root matrices rather than harvestable shoots, preventing effective soil contamination reduction through biomass removal.

3.2.5. Food Safety Implications and Ornamental Advantages

Utilizing edible crops for contaminated soil treatment introduces substantial human health hazards. Measured cadmium concentrations in cabbage shoots substantially exceeded maximum permissible limits (0.05-0.2 mg/kg) established for safe vegetable consumption in international food safety standards [35]. Population-based epidemiological studies demonstrate that dietary intake of vegetables cultivated in metal-polluted substrates produces chronic exposure scenarios with hazard quotients exceeding unity, indicating unacceptable health risk levels [36]. Post-remediation plant tissues containing elevated metal concentrations cannot safely enter food or feed supply chains, necessitating regulated disposal via thermal destruction or hazardous waste containment.

Non-edible ornamental species eliminate food safety concerns while providing operational advantages. *Nerium oleander* exemplifies this approach through its exceptional capacity to extract cadmium and lead from polluted substrates, achieving optimal performance through dense planting configurations with 1.0 to 2.0 meter spacing that maximizes root zone coverage [25]. Contaminated urban sites typically remain abandoned due to pollution liability. Ornamental plantings transform these sites into functional green infrastructure, accomplishing simultaneous soil decontamination and landscape enhancement [37]. Oleander's minimal maintenance requirements and striking floral presentations make it particularly suitable for resource-constrained municipal programs, where it can deliver sustained remediation performance over multiple harvest cycles spanning two-to-three-year intervals [33]. Public acceptance increases substantially when ornamental species replace food crops, reflecting reduced exposure risk perception. These projects generate economic value through landscape maintenance and environmental education programs, offsetting operational costs while creating multifunctional green spaces with recreational and aesthetic co-benefits, particularly valuable in high-density urban environments.

4. Conclusions

This study evaluated the effectiveness of phytoremediation using Nerium oleander and Brassica oleracea (cabbage) in a fence-line residential community impacted by long-term petrochemical and industrial activity in Pascagoula, Mississippi. The results demonstrated that phytoremediation under real field conditions can significantly reduce heavy metal concentrations in contaminated soils. Notably, cadmium removal exceeded 97%, and statistically significant reductions ($p < 0.01$) were observed for all analyzed metals (Pb, Cd, Zn, and Ni).

Among the tested species, Nerium oleander exhibited superior phytoremediation performance, with higher bioaccumulation and translocation factors, indicating strong capacity for both metal uptake and internal transport. In contrast, cabbage showed comparatively low translocation efficiency, suggesting limited suitability as a remediation species under contaminated conditions. However, its use as a food crop may be appropriate following prior soil remediation.

These findings highlight the importance of species selection in phytoremediation strategies and demonstrate the potential of ornamental, non-edible plants such as N. oleander as effective, low-cost, and community-acceptable solutions for mitigating soil contamination. Importantly, this study provides field-based validation of phytoremediation in a real-world residential setting, addressing a critical gap between laboratory research and practical application.

Overall, phytoremediation represents a sustainable approach for reducing environmental contamination and associated human exposure risks in vulnerable fence-line communities [38–40]. Future research should explore long-term remediation efficiency, multi-species systems, and integration with community-based environmental management practices.

Author Contributions: Conceptualization, N. I.; methodology, N.I.; Z.S. and C.S..; validation, N.I. and V. R. formal analysis, N.I. and U. B..; investigation, N.I..; resources, N.I..; data curation, N.I. and U.B.; writing—original draft preparation, N.I. and U.B.; writing—review and editing, N.I. and U.B.; visualization, V.R. and N.I..; supervision, N.I..; project administration, N.I.; funding acquisition, N.I. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Ethical review and approval were waived for this study because it did not involve human subjects, human data, or animal experimentation. The research consisted of environmental sampling conducted on private property with the permission and cooperation of the resident.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.

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