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# Lavender as a Bioindicator: Bioaccumulation Assessment of Cd, Pb, and Zn

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**Abstract**

This study explores the bioaccumulation behavior of heavy metals (cadmium (Cd), lead (Pb), and zinc (Zn)) in lavender (*Lavandula* spp.) cultivated under controlled greenhouse conditions to assess its potential in sustainable phytoremediation. The plants were grown in pots filled with either unpolluted soil or soil artificially enriched with cadmium, lead, or zinc at concentrations exceeding the normal (Cd 1 mg/kg d.w.; Pb 20 mg/kg d.w.; Zn 100 mg/kg d.w.), alert (Cd 3 mg/kg d.w.; Pb 50 mg/kg d.w.; Zn 300 mg/kg d.w.), and intervention (Cd 5 mg/kg d.w.; Pb 100 mg/kg d.w.; Zn 600 mg/kg d.w.) thresholds set for sensitive land use. A comparative analysis of two lavender varieties (lavender and lavandin) over a four-month period revealed an accumulation trend of Pb > Cd > Zn. Empirical modeling indicated that cadmium uptake followed a linear pattern, lead accumulation conformed closely to the Mitscherlich model, while zinc uptake did not align well with any of the tested models. Overall, the results emphasize the potential of lavender species in developing biomimetic approaches for heavy metal remediation and contribute valuable insights into sustainable soil decontamination practices.

**Keywords:** phytoremediation; bioaccumulation; heavy metals; *Lavandula* spp.; soil contamination; environmental remediation



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## 1. Introduction

Across the globe, the rapid pace of industrialization, urban sprawl, and agricultural expansion has resulted in heavy metal accumulation in soils, often surpassing established regulatory thresholds [1]. To mitigate such contamination, various remediation techniques have been introduced, some of which also contribute to improving air quality in densely populated urban areas. In cities, vehicular traffic remains the predominant source of heavy metal pollutants, with fuel combustion identified as a significant contributor. These emissions settle on the surfaces of plants and soils [1–4]. Meanwhile, in rural regions or on the outskirts of urban zones, facilities such as wastewater treatment plants, waste incinerators, and composting centers also play a major role in the buildup of heavy metals in the soil [5–9].

**Table 7.** *Cont.*

| Empirical Model | Expression | Parameters | $R^2$ |
|---|---|---|---|
| **Cd, Lavandin (Linear, all data)** | $y = A \cdot x + B$ | A = 0.8577<br>B = 0.2679 | 0.658 |
| **Pb, Lavender (Linear, all data)** | $y = A \cdot x + B$ | A = 0.8797<br>B = 0.5894 | 0.953 |
| **Pb, Lavender (Mitscherlich, all data)** | $y = A - B \cdot \exp(-C \cdot x)$ | A = 34.82<br>B = 35.46<br>$C = 3.599 \times 10^{-2}$ | 0.964 |
| **Pb, Lavandin (Linear, all data)** | $y = A \cdot x + B$ | A = 0.8714<br>B = 1.253 | 0.957 |
| **Pb, Lavandin (Mitscherlich, all data)** | $y = A - B \cdot \exp(-C \cdot x)$ | A = 35.79<br>B = 36.50<br>$C = 3.856 \times 10^{-2}$ | 0.976 |

## 4. Conclusions

This study demonstrated that lavender plants have the capacity to accumulate lead and cadmium from contaminated soils, while zinc uptake remained limited, with both lavender species acting as excluders at concentrations below the alert threshold. Notably, zinc accumulation commenced only when soil concentrations exceeded the alert level. The bioaccumulation efficiency for the tested metals followed the order: Pb > Cd > Zn.

Empirical modeling further revealed that cadmium accumulation is best described by a linear model, whereas lead uptake aligns more closely with the Mitscherlich model. The modified Mitscherlich model, however, did not provide satisfactory fits for any of the tested data sets.

These findings highlight the potential application of lavender species in phytoremediation strategies targeting cadmium- and lead-contaminated soils. Additionally, the results provide a valuable framework for assessing the safety of cultivating lavender for pharmaceutical and cosmetic purposes in moderately polluted environments.

Future research could focus on expanding the scope to multi-metal contaminated soils and evaluating the influence of soil microbiota on the bioaccumulation dynamics in lavender species to enhance the understanding and application of phytoremediation techniques.

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