

Unraveling the Role of EDTA in Enhancing the Heavy Metal Accumulation Capacity of Maize (*Zea mays*)

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Abstract

This study investigated the efficacy of EDTA as a chelating agent in enhancing the phytoextraction capacity of maize (*Zea mays*) for nickel (Ni), cadmium (Cd), and lead (Pb) from contaminated soils. A three-factor greenhouse experiment was conducted based on Taguchi's design, exposing plants to metal concentrations of 0, 50, and 100 mg/kg. Following harvest, metal accumulation in roots, stems, and leaves was quantified using atomic absorption spectroscopy (AAS), and phytoremediation efficiency was assessed through transfer factor (TF), bioconcentration factor (BCF), and bioaccumulation coefficient (BAC). The findings revealed significant differential accumulation patterns among plant organs ($P \leq 0.05$), indicating tissue-specific metal partitioning. Notably, Ni uptake exhibited a concentration-dependent increase, with TF values rising from 0.79 at 50 mg/kg to 1.66 at 100 mg/kg, demonstrating enhanced root-to-shoot translocation at higher contamination levels. In contrast, Cd absorption showed an inverse trend, with TF remaining relatively stable (~ 0.80), suggesting reduced bioavailability or competitive inhibition at elevated concentrations. Lead demonstrated consistently high TF values (~ 1.36 – 1.39) across all treatments, indicating efficient translocation and strong chelate-assisted mobility. These results confirm that EDTA significantly improves maize performance for heavy metal remediation, particularly for Ni and Pb, positioning this combination as a promising, cost-effective strategy for bioremediation of multi-metal contaminated agricultural soils.

Keywords: *Zea mays* L., Transfer Factor, Bioaccumulation Coefficient, Soil Contamination

Introduction

Heavy metal contamination in agricultural soils, particularly from industrial activities, poses a serious threat to food security and human health. Conventional remediation methods are often costly and may reduce soil fertility, highlighting the need for cost-effective biological approaches. EDTA, a strong chelating agent, has been widely used to enhance heavy metal bioavailability and phytoextraction efficiency. Given the high level of industrial pollution in southwestern Iran (e.g., Khuzestan province) and the region's extensive maize cultivation, this study (2026) investigated the efficacy of EDTA in improving the uptake of nickel, cadmium, and lead by maize (*Zea mays*) under different contamination concentrations.

Experimental

This study was conducted as a three-factor factorial experiment based on a completely randomized design (CRD) with three replications under greenhouse conditions in 2026. Soil samples were collected from the surrounding areas of Ahvaz, Iran, at a depth of 0–60 cm, then air-dried and passed through a 2-mm sieve. Heavy metal treatments included nickel (as NiSO_4), cadmium (as $\text{Cd}(\text{NO}_3)_2$), and lead (as $\text{Pb}(\text{NO}_3)_2$) at concentrations of 0, 50, and 100 mg/kg soil, and EDTA was applied at 12 mmol/kg as a chelating agent one month after soil contamination, followed by a 45-day equilibration period. Corn seeds (*Zea mays* L.) were planted in 3-kg pots (three plants per pot) and grown for 100 days under controlled conditions with regular irrigation using distilled water and weekly pot rearrangement to ensure uniform growth. After harvest, plants were separated into roots, stems, and leaves, and following thorough washing, the tissues were digested according to the Jackson (1958) method. The concentrations of Ni, Cd, and Pb were quantified using an Agilent 240 AA furnace atomic absorption spectrometer (AAS). Phytoremediation efficiency was evaluated by calculating the transfer factor (TF), bioconcentration factor (BCF), and bioaccumulation coefficient (BAC), and data were analyzed using one-way ANOVA and Pearson correlation tests, with statistical significance set at $P \leq 0.05$.

Conclusion

EDTA significantly enhances maize efficiency for Ni and Pb uptake (TF: 0.79→1.66 for Ni; ~ 1.38 for Pb), while Cd uptake decreased at higher concentrations (TF: ~ 0.80). Tissue-specific accumulation (Ni/Cd in roots, Pb in leaves) and indices >1 confirm maize as a suitable phytoremediator. This EDTA-assisted approach offers a cost-effective bioremediation strategy for multi-metal contaminated soils, particularly in industrial regions of southwestern Iran.

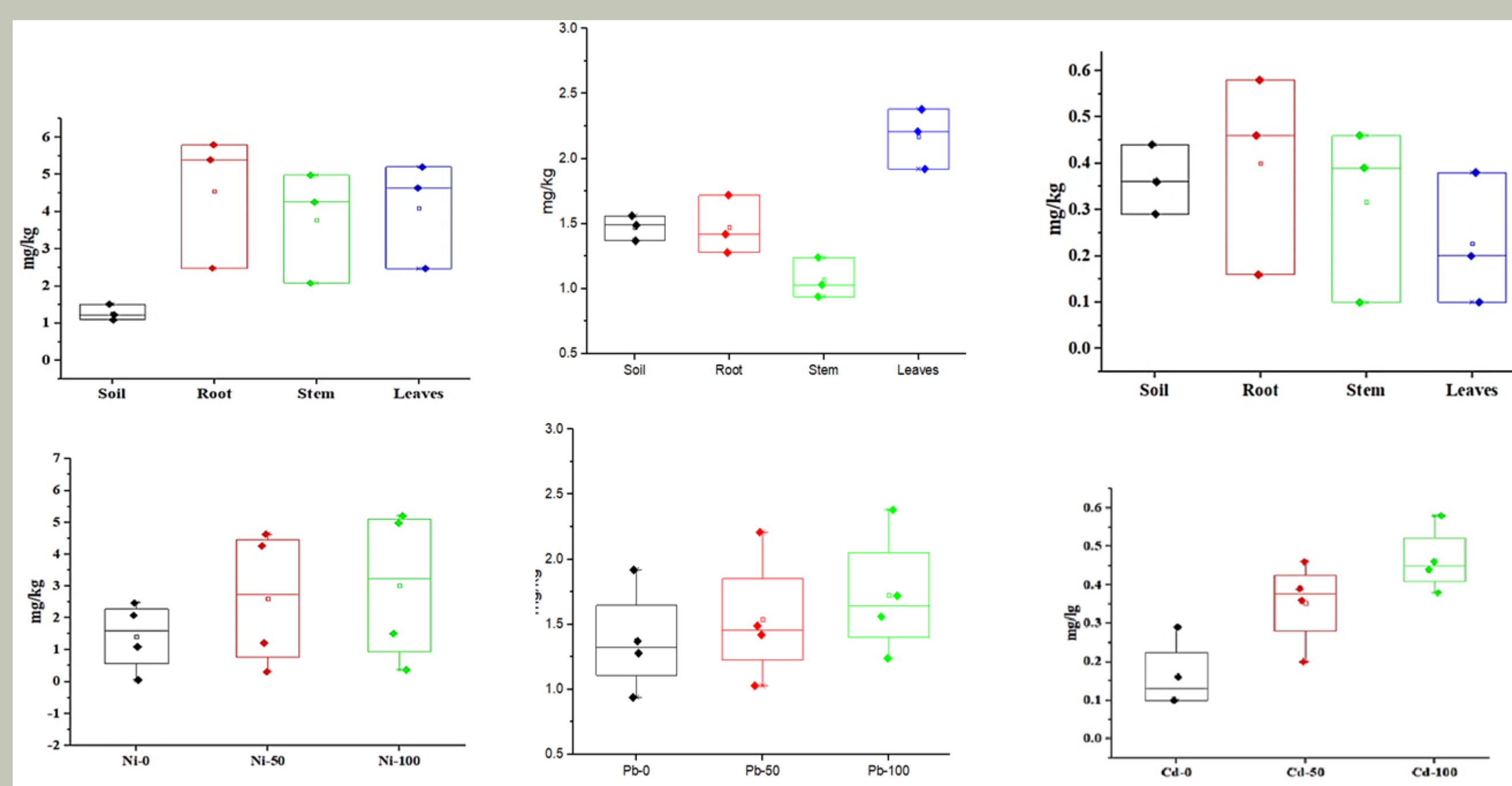


Figure 1. Comparison of measured amounts of metal in samples (soil samples, corn plant samples)

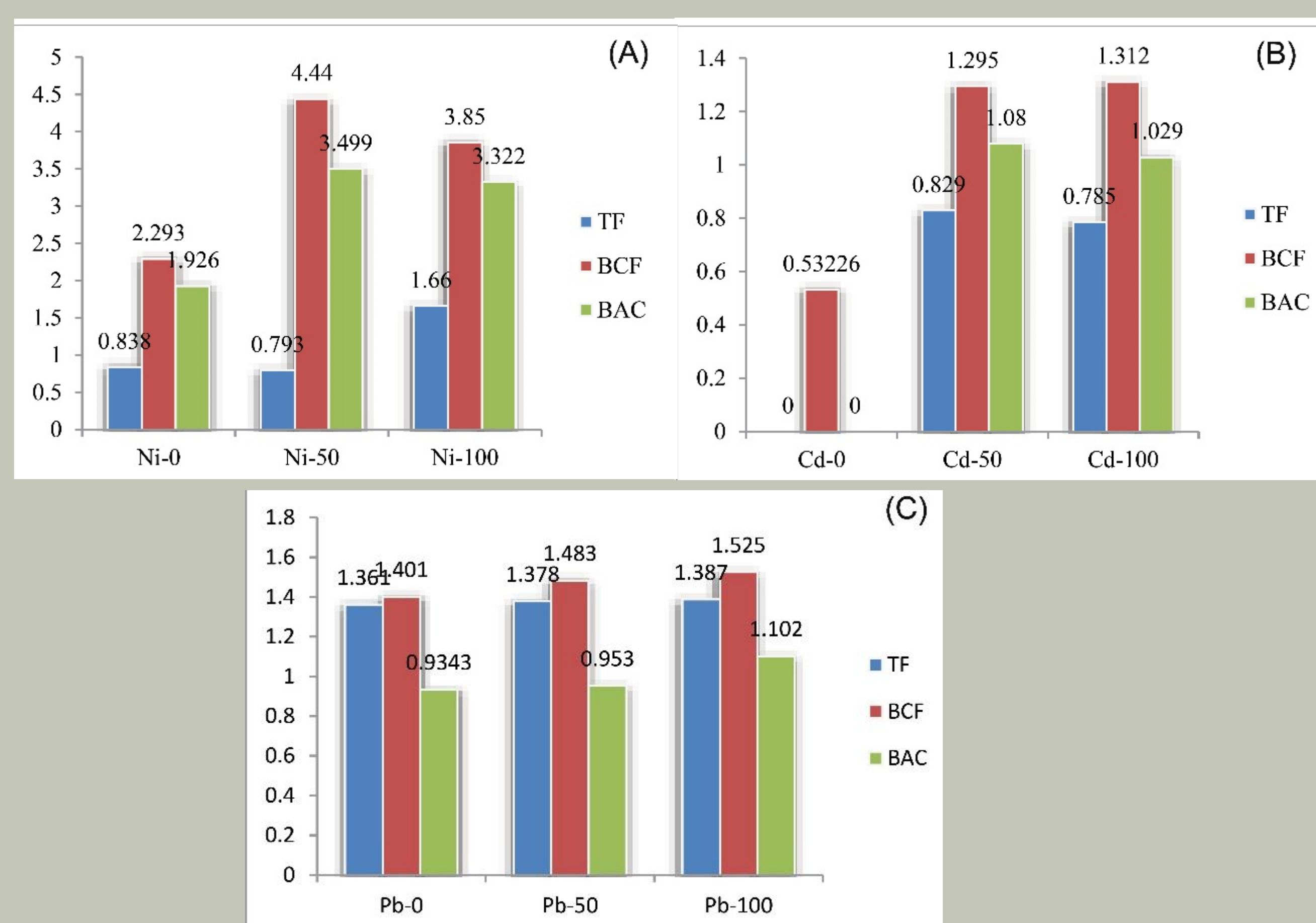


Figure 2. Comparison of absorption of heavy elements based on TF, BCF, and BAC indices in different concentrations of heavy element pollution (A: Cadmium-B: Nickel-C: Lead)

References

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