

FTIR-based insight into nickel binding mechanisms in soil containing polystyrene microplastics

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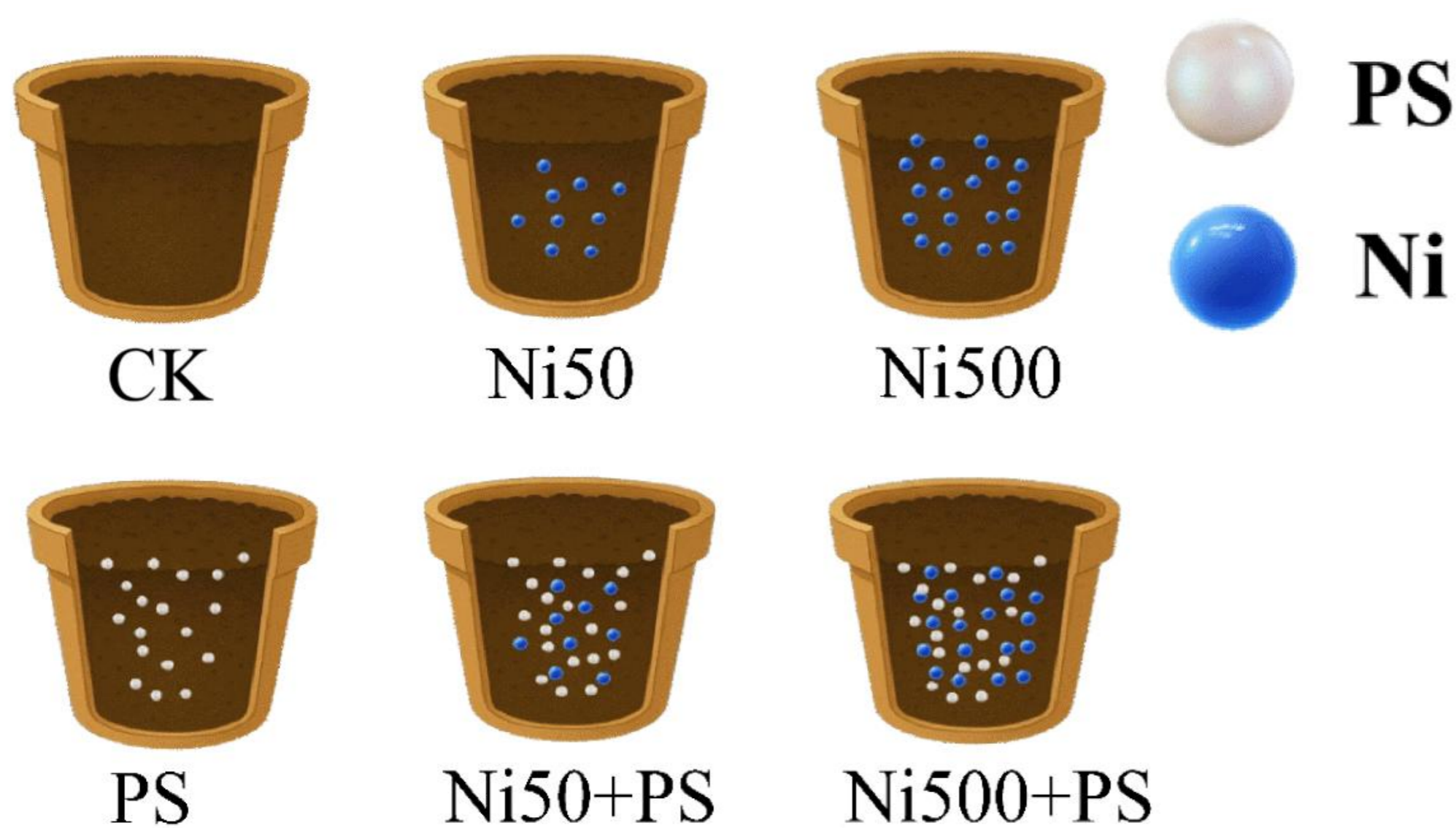
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INTRODUCTION & AIM

Modern anthropogenic activities have intensified the accumulation of both microplastics (MPs) and heavy metals (HMs) in soils, leading to their frequent coexistence in terrestrial ecosystems. Because heavy metals pose significant risks to soil biota and plants, the interactions between MPs and HMs have attracted growing attention. Microplastics can interact with metals through physical adsorption, electrostatic attraction, chemical co-precipitation, and surface complexation processes. Such interactions may modify metal mobility and bioavailability by influencing their partitioning among soil geochemical fractions. Despite increasing evidence of these effects, the molecular mechanisms underlying MP–HM associations remain poorly characterized. To address this knowledge gap, this study examined surface chemical transformations of polystyrene (PS) microplastics in soil and evaluated their role in nickel (Ni) binding using Fourier-transform infrared spectroscopy (FTIR).

METHOD

PS surface morphology was characterized by SEM (JEOL JSM-IT300), while surface chemistry was analyzed using ATR-FTIR (Nicolet iS10, Thermo Fisher Scientific, USA). Soil was amended with 1% (w/w) PS and spiked with Ni at 0, 50, or 500 mg kg⁻¹ using Ni(CH₃COO)₂·4H₂O. Each treatment consisted of pots containing 400 g soil and was incubated in a growth chamber for 65 days (Figure 1).



CK	Control
Ni50	50 mg kg ⁻¹ of Ni ²⁺
Ni500	500 mg kg ⁻¹ of Ni ²⁺
PS	1% PS
Ni50+PS	1% PS + 50 mg kg ⁻¹ of Ni ²⁺
Ni500+PS	1% PS + 500 mg kg ⁻¹ of Ni ²⁺

Figure 1. Experimental design

RESULTS & DISCUSSION

SEM analysis of virgin PS (Figure 2) showed a relatively smooth particle morphology prior to soil exposure. FTIR spectra of recovered PS revealed pronounced surface modifications compared with pristine PS (Figure 3).

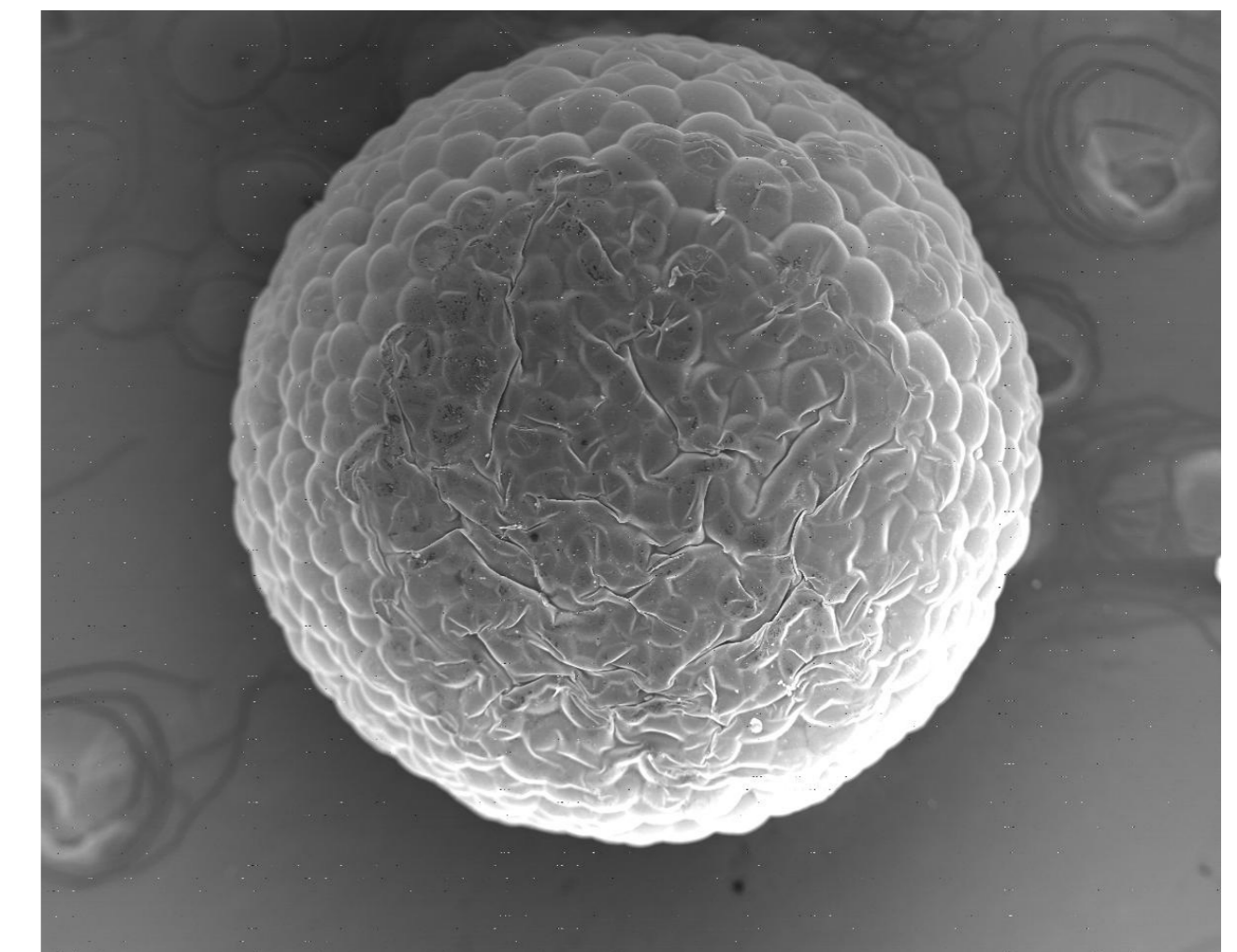


Figure 2. SEM image of virgin PS

Enhanced Al–O (914 cm⁻¹), Fe–O/Mn–O (<650 cm⁻¹), and Si–O–Si (1026 cm⁻¹) vibrations indicated the formation of PS–soil associations.

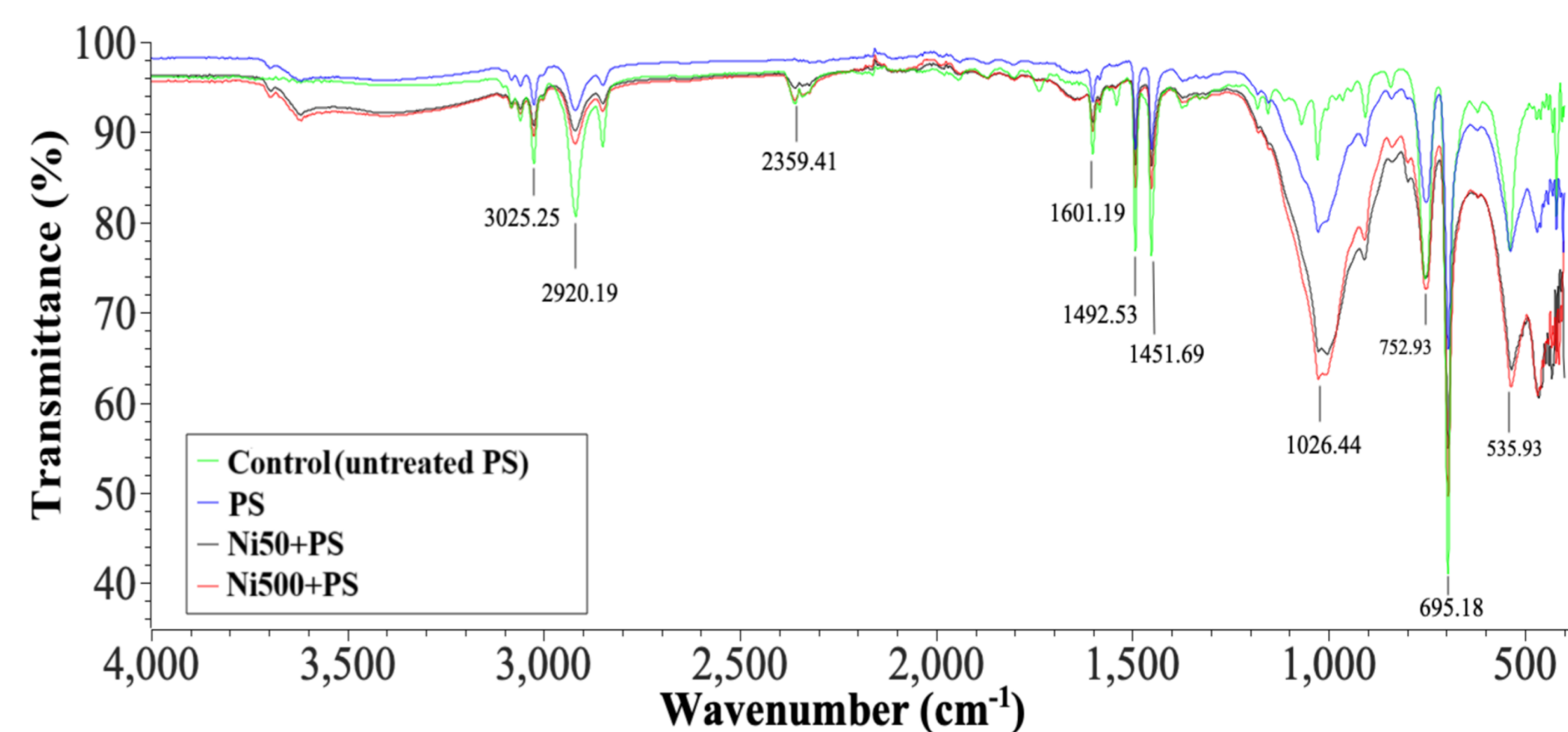


Figure 3. ATR-FTIR spectra of PS from treatments PS, Ni50+PS, and Ni500+PS

Increasing Ni concentrations resulted in:

- Stronger mineral-associated bands, indicating preferential Ni binding to oxygen-containing mineral sites (Si–O, Al–O, and Fe/Mn–O).
- Changes in PS-specific aromatic vibrations (1601, 1492, 1451, and 695 cm⁻¹) suggested partial Ni association with PS surfaces.
- Potential electrostatic and π–metal interactions between Ni species and PS.
- Possible competition for binding sites and enhanced Ni mobility through desorption processes.

CONCLUSION

Spectroscopic findings provide mechanistic evidence that MPs modify metal binding pathways in soil and act as active geochemical agents in contaminated terrestrial environments.