

ABSTRACT

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Title: Phytoremediation of metal-contaminated chromium asbestos mines of Jharkhand: Ecological recycling through vermicomposting

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Chromite-asbestos mining generates substantial amounts of toxic waste (CAMW), leading to the contamination of adjacent agricultural lands with potentially toxic elements (PTEs). This study investigates PTE concentrations, identifies their sources, assesses associated health-dietary risks through probabilistic models and examines the combined impact of soil alkalinity and bioavailable PTEs on microbial diversity in the chromite-asbestos mining region of India. The soil, tailings, and rice grains samples were collected and studied across the region. The results revealed that the PTEs concentration was significantly above the permissible limit in site 1 (mine waste dumping area) and site 2 (mine waste contaminated soil) as compared with site 3 (uncontaminated soil). The Positive matrix factorization, Self-organizing map, and spatial distribution map analysis identified the source of PTEs pollution in this region. The Free ion activity model (FIAM) was applied to detect the solubility of PTEs in polluted soil and their probable transfer from soil to rice grain. The hazard quotient values were significantly higher than the safe (FIAM-HQ < 0.5) for Cr (1.50E+00), and Ni (1.32E+00). Severity adjustment margin of exposure (SAMOE) results indicates that raw rice grains contaminated with PTEs pose a high health risk to humans [Cr: 0.001; Ni: 0.002]. Boiled rice showed a moderate risk (Cr: 0.011; Ni: 0.013), while rice (without husk) reflected a high (class 5) dietary risk. Compared to adults (5.08E-05), children (1.88E-03) were more vulnerable to total carcinogenic risk via the ingestion pathway. The study observed a decline in microbial attributes, with *Proteobacteria* constituting 57.18% of the bacterial community, highlighting their predominance in the contaminated soil. Therefore, efficient management is necessary for the mitigation of PTEs.

In recent decades, bio-based approaches (mycophytoremediation and vermi-technology) present a promising strategy for environmental restoration worldwide. Furthermore, the present investigation assessed the impact of AMF (*Glomus hoi*, *Funneliformis coronatum*, *Claroideoglomus claroideum*, and *Claroideoglomus etunicatum*) on the growth and PTEs accumulation abilities of vetiver (*Chrysopogon zizanioides*) in a soil contaminated with CAMW. *Glomus hoi* showed high efficiency in improving soil quality, mitigating PTEs stress, accumulating PTEs in the roots (Ni: 27.44%, Cr: 21.74%), and promoting healthy plant growth. This study also explores the post-remediation management of PTE-enriched vetiver plants (PTE-EV) obtained after myco-phytoremediation, where significant accumulation of PTEs occurred in plant tissues. To prevent re-contamination from exposed shoot parts, PTE-EV was vermi-remediated with cow dung, effectively neutralizing acidity, boosting NPK levels, and stabilizing organic carbon mineralization. Another critical aspect is the widespread generation of CAMW, rich in PTEs, poses a major environmental threat and currently lacks sustainable recycling solutions. This study also introduces vermi-remediation technology to sustainably and efficiently transform CAMW into a valuable organic fertilizer, offering a practical solution for waste management and soil restoration. The findings revealed bioavailable PTEs levels were significantly reduced up to 80% in vermibeds. Therefore, this study highlights the potential of vermicomposted PTE-EV and vermicomposted CAMW as effective organic amendments for diverse agricultural systems, including crops like tomato, chilli, sesame, and rice. Results showed that combining vermicomposted PTE-EV/CAMW with chemical fertilizers led to negligible PTE levels in edible crops, supporting their use as sustainable alternatives to traditional manure for long-term soil health and waste management. Overall, we believe this study represents a foundational step toward advancing eco-friendly bioremediation of toxic CAMW, supporting sustainable management, and promoting long-term ecosystem health.

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