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In vitro bioaccessibility, phase partitioning, and health risk of potentially toxic elements in dust of an iron mining and industrial complex

Naghmeh Soltani [a], Behnam Keshavarzi [a,*], Farid Moore [a], Mark Cave [b], Armin Sorooshian [c,d], Mohammad Reza Mahmoudi [e], Mohammad Reza Ahmadi [f], Reza Golshani [g]

[a] Department of Earth Sciences, College of Science, Shiraz University, 71454 Shiraz, Iran
[b] British Geological Survey, Nicker Hill, Keyworth, Nottinghamshire NG12 5GG, UK
[c] Department of Chemical and Environmental Engineering, University of Arizona, Tucson, AZ 85721, USA
[d] Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ 85721, USA
[e] Department of Statistics, Faculty of Science, Fasa University, Fasa, Fars, Iran
[f] Gol-E-Gohar Iron Ore and Steel Research Institute, Gol-E-Gohar Mining and Industrial Co., Sirjan, Iran
[g] Department of the Environment, Tehran, Iran

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ABSTRACT

Dust emitted from mining, ore processing, and tailing dumps have direct effects on miners who work close to these operations. The Gol-E-Gohar (GEG) mining and industrial company is one of the most important iron concentrate producers in the Middle East. The objective of the present study was to estimate the distribution, fractionation, and oral bioaccessibility of potentially toxic elements (PTEs) in dust generated by the GEG mining and industrial company. Total PTE content including Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, V, and Zn was quantified for suspended particulate matter (PM) in $PM_{2.5}$, PM_{10}, and total suspended particulate matter (TSP). As, Cd, Co, Cu, Fe, Ni, and Pb were quantified in fallout dust samples for oral bioaccessibility using in vitro Unified BARGE (UBM) Method and modified BCR fractionation analysis. Enrichment factors (EF) were calculated for the studied elements in PM; Cu, Fe, and As were found to be extremely enriched. Oral bioaccessibility of selected PTEs in fallout dust samples ranged from 0.35% to 41.55% and 0.06–37.58% in the gastric and intestinal phases, respectively. Regression modeling revealed that the bioaccessibilities of the PTEs could mostly be explained by total concentrations in dust particles. Average daily intake (ADI) calculations revealed that the intake of PTEs did not exceed the tolerable daily intake (TDI) values and as such was not considered a significant risk to workers. Additionally, the hazard quotients (HQ) and carcinogenic risk (CR) values were lower than the acceptable level. This study can provide further risk assessment and management of PTE pollution in occupational environments.

1. Introduction

Mining and processing of mineral commodities impact the environment by polluting air, water, and soil. These practices are known to generate large amounts of potentially toxic elements (PTEs), which can enter the body via their association with particulate matter through ingestion, inhalation, and dermal pathways thereby leading to serious health effects. The total (or pseudo-total) metal(loid) content in dust is usually taken into consideration for health risk assessment. However, not all of the PTE fraction in dust is available for absorption in the body (Cave et al., 2003). Thus, it is important to investigate bioavailability, which is the quantity of elements that reach the circulatory system and human organs (Delbeke et al., 2020). Bioaccessibility is also defined as that portion of ingested/inhaled/dermal inorganic and organic substances potentially available to biological fluids. It is important to measure the bioaccessible fraction of contaminants rather than the total concentration to avoid overestimation in health risk assessment. Bioaccessibility tests are commonly performed by considering inhalation, ingestion, and dermal exposure pathways on broad geomaterial matrices including soil (van der Kallen et al., 2020), urban street dust (Huang et al., 2014), airborne particulate matter (Hu et al., 2012), tailing dust (Ettler et al., 2019), pure metal compounds, and metal alloys (Dutton et al., 2020). Oral bioaccessibility, as defined by Wragg and Cave (2003), is the fraction of a substance released from solid matrices into

* Corresponding author.
E-mail address: bkeshavarzi@shirazu.ac.ir (B. Keshavarzi).

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