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Human Risk Assessment of Arsenic and Heavy Metals via Exposure Pathways of Soil, Water and Crop Plant in the Abandoned Metal Mine Sites

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ABSTRACT

In typical metal mine districts, massive stockpiles of sulfide containing refuse and tailings in the inactive mines are weathered and oxidized over long term atmospheric exposures. The acidic mine drainage with elevated levels of heavy metals are discharged to contaminate the downstream water bodies, agricultural soils and food crops. The fugitive metals in the receiving water and soils may pose a potential health risk to the residents in the vicinity of the mines. There is a need to accurately quantify the toxicological risk to the resident populations in the contaminated environments. Current assessment models derive the total human exposure by evaluating the fate and transport of toxic elements through exposure pathways such as drinking water, food intake, dust inhalation and hand-to-mouth soil ingestion. In order to investigate the contamination levels of heavy metals and assess the risk of adverse health effects on human exposure to heavy metals influenced by past mining activities, environmental geochemical surveys were undertaken around two abandoned metal mine sites (Dokok Au-Ag-Cu and Hwacheon Au-Ag-Pb-Zn mines).

Tailing, soil and crop plant samples in the vicinity of the Dokok and the Hwacheon mines were collected from agricultural land around the mine sites. Rice samples were taken from paddy fields. Groundwaters used as a drinking water were collected around the tailings in these mine areas. After appropriate sample preparation, these samples were analyzed for As, Cd, Cu, Pb and Zn by ICP-AES and ICP-MS. Risk assessment of toxic heavy metals has been performed with chemical analytical data for environmental media.

High concentrations of heavy metals were found in tailings from the Dokok (98.2 Cd mg/kg, 2,550 Cu mg/kg, 4,200 Pb mg/kg, 18,020 Zn mg/kg) and the Hwacheon (12.4 Cd mg/kg, 580 Pb mg/kg, 1,300 Zn mg/kg) mines. These significant concentrations can impact on soils and waters around the tailing dumps. Elevated levels of As, Cd, Cu, Pb and Zn were also found in agricultural soils from these mine areas. Risk assessment is the process of characterizing the adverse health effects of human exposure to environmental hazards. Risk compounds deriving from mine sites either constitute a toxic risk or a carcinogenic risk. Toxic risks are indicated in terms of a hazard quotient (H.Q.). H.Q. is ADD (average daily dose)/RfD (reference dose). A toxic risk exists for H.Q.>1. To calculate the hazard index (H.I.) the ADD from three identified pathways (soil, groundwater and food (rice grain) pathways) compared to the relevant RfD obtained from the US-EPA database *IRIS* is summed. The hazard index of As in the Hwacheon mine area was higher value more than 1.0. Therefore, toxic risk for As exists via exposure (ingestion) of contaminated soil, water and rice grain in this mine area. The carcinogenic risks of being exposed to As by the rice ingestion and drinking water routes in the Hwacheon mine area are 1E-3 (9.8×10^{-4}) and 1E-4 (1.4×10^{-4}), respectively. The As cancer risk via exposure pathways of rice and drinking water exceeded the acceptable risk of 1 in 100,000 for regulatory purposes. Thus, the daily intake of rice and water by the local residents can pose a potential health threat due to long-term arsenic exposure.

Key words: Arsenic, Heavy metals, Exposure pathway, Hazard index, Carcinogenic risk

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