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Prediction of Heavy Metal Emissions from Uranium Mines to Water Resources During Flood Disasters Using Fick's Second Law Modeling

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During floods, heavy metal releases from mining pose serious environmental problems that require rapid and effective treatment [1]. Advanced modeling approaches enable cost-effective monitoring and detection, ensuring efficient and cost-effective management of this critical problem [2]. The Příbram Ore Region (Czech Republic), situated ~60 km southwest of Prague, is drained by the Litavka River (56 km, 630 km² watershed). In the region under study, smelting, sediment erosion, and historical silver and base metal ore-field mining all contribute to heavy metal contamination, which is made worse by periodic floods that carry pollutants downstream [3].

To address this, the present study applied Fick's second law technique in MATLAB 2019b simulations to find emissions of the heavy metals based on time and spatial variations in the case study. The present simulation assumes: (1) constant diffusion coefficients for heavy metals in flood condition is assumed equal to 0.8 km²/day; (2) initial concentrations derived from flux-to-suspended particulate matter (SPM) ratios (Cd: 74 kg, Pb: 2954 kg, Zn: 5811 kg with SPM 2400 tons) [3]; (3) a uniform spatial distribution initially set to zero; (4) boundary concentrations at the source (Cd/SPM = 0.0308 mg/L, Pb/SPM = 1.231 mg/L, Zn/SPM = 2.421 mg/L) [3]; (5) Fick's Second Law solved *via* explicit finite difference; (6) no external sources or sinks within the 2 km, 2 h simulation.

The simulation demonstrates the dispersion of heavy metals (Cd, Pb, Zn) in a river during a flood event, assuming a uniform flux rate of 0.8 km²/day for all metals. Initial concentrations at the source are determined from flux-to-SPM ratios: Zn has the highest concentration (2.42 mg/L), followed by Pb (1.23 mg/L) and Cd (0.03 mg/L). As dispersion progresses, concentrations decrease and spread downstream, with the uniform flux rate ensuring comparable dispersion rates across all metals. Spatial profiles reveal a rapid decline in concentrations within the first 2 km, with Zn maintaining the highest overall spread due to its larger initial flux. Temporal heat maps show that, despite equal diffusion rates, Zn and Pb exhibit more extensive downstream spread due to their higher initial concentrations, while Cd remains more localized. These results emphasize the role of initial fluxes and source concentrations in determining heavy metal distribution during flood events. The uniform flux rate assumption simplifies the transport dynamics, providing insights into contamination spread and highlighting the need for monitoring strategies to mitigate environmental risks in mining-impacted regions.

Keywords: *Uranium mining; Early-Warning; Hazardous materials; Fate and Transporte;*

Flood.

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