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Distribution of arsenic and heavy metals, and associated health risk assessment in groundwater wells of Haridwar, India

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Arsenic (As), a naturally occurring carcinogenic metalloid, has been a severe public health threat globally for a few decades. India is recognized as one of the worst affected countries for groundwater arsenic pollution. The present study was aimed to investigate the spatial distribution and associated health risk of As and other heavy metals in groundwater. A total of 208 groundwater samples were collected from 6 blocks of Haridwar district in Uttarakhand, India. Fe was found to be the major contaminant (~50% samples exceeding the WHO limit of 0.3 mg/L in drinking water), followed by Mn, As, Cu, Ni, Pb, Cr, and Cd. As concentration ranged between 0.10 to 102.01 µg/L with ~17% samples exceeding the WHO safe limit (10 µg/L) in drinking water. In shallow wells (<30 m), the mean concentration of As, Mn, and Cr is comparatively high, while the remaining heavy metals, i.e., Fe, Cd, Cu, Ni, and Pb, exhibit higher concentrations in deep wells (>30 m). The heavy metal pollution indices, i.e. (HPI) and (HEI) indicated a medium to a low degree of pollution with heavy metals. The geochemistry of groundwater is predominantly controlled by silicate weathering and carbonate dissolution processes. Approximately 25% of groundwater samples were associated with non-carcinogenic health risks caused predominantly by As, Fe, Pb, and Cd contamination, while almost all samples had carcinogenic health risks due to As, Cd, and Cr contamination. High As groundwater samples with comparatively high Fe, HCO_3^- and low NO_3^- and SO_4^{2-} concentrations indicated the reductive dissolution of iron oxyhydroxide as the dominant mechanism of As mobilization. The findings of this study can be used to enhance and develop the quality of drinking water, which directly affects consumers' health.