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Land use alters the alignment of Arsenic and Chromium co-contamination in the unconsolidated aquifer under reducing environments of the Mid-Gangetic Plains

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The Indo-Gangetic plain, well-known for its Alluvial landscape for human settlement, is currently facing unprecedented industrialization, and urbanization population, leading to high stress on its aquifer. On the other hand, co-contamination of arsenic (As) and chromium (Cr) in shallow aquifers has been showing an alarming global presence that varies with redox conditions, geochemical signatures, and human activities. We aim to address the influence of the suburban and urban land use on the co-contamination of As and Cr, using various geostatistical tools, models, and indices. Among twenty-six (n=26) groundwater samples, the majority of water types were found to be Mg^{2+}-HCO_3^- and Na^+-K^+ exhibiting carbonate weathering and evaporation enrichments with saturation indices depicting the supersaturation of calcite and dolomite. The aquifer conditions in both suburban and urban settings were identified as reducing, facilitating the desorption of arsenic. Probability exceedance implied inverse correlation between contaminant concentrations and the probability of their likelihood of surpassing regulatory thresholds. Factor analysis indicates that the natural alignment of contaminants, particularly As and Cr, is maintained under suburban land use but significantly altered in urban settings. The influences of oxidation-reduction potential (ORP), dissolved oxygen (DO), pH, and iron (Fe) concentration on As and Cr co-contamination are effective in suburban environments, while urban aquifers face additional confounding factors, including artificial sources from industries and subsurface leaching. An integrated cluster heatmap has identified a trifecta of As, Cr, and lead (Pb), closely linked to pH, DO, and K^+, highlighting the effects of increased anthropogenic activities in alluvial floodplains. Finally, a conceptual model was developed to clarify the common processes in these environments, facilitating the creation of universal management strategies for aquifers impacted by As and Cr co-contamination.

Keywords: *arsenic; chromium; redox; mid-Gangetic plains; co-contamination*