

**Heavy metal (loid)s in the groundwater of Shabestar area (NW Iran): source identification
and health risk assessment**

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Abstract

The aims of this study are to investigate the potential origin of selected heavy metal(loid)s in the Shabestar plain, NW Iran, by using multivariate statistical techniques (cluster analysis and factor analysis), as well as to determine the dominant factors that affect groundwater quality and to assess the health risk of metal(loid)s with the use of hazard quotients (HQ). Totally, ۲۹ groundwater samples were collected from wells in August ۲۰۱۶ and measured the values of ۲۳ parameters, namely pH, electrical conductivity, concentration of major elements (Ca^{۲+}, Mg^{۲+}, Na⁺, K⁺, HCO_۳⁻, SO_۴^{۲-}, Cl⁻), minor elements (NO_۳⁻, F⁻, B and Br⁻) and heavy metal(loid)s (Fe, Al, Cr, Mn, As, Zn, Pb, Cu and Ni). The results indicate that some samples in regards with As, Pb and Zn concentrations exceed WHO standards for drinking water. Results of correlation coefficients between measured variables reflect the occurrence of weathering and dissolution of rocks especially silicate and evaporites, ion exchange and similar geochemical characteristics to the release of some heavy metal(loid)s. According to hierarchical cluster analysis, samples of cluster ۱ are affected by alkalinity and accompanied by compatible elements with alkaline ambience (CO_۳^{۲-} and Ni). Samples of subcluster ۲-۱ demonstrate the effect of salinity, attributed to evaporates, agricultural water

return and influx of Urmia Lake's brine; whilst, samples of sub-cluster ۲-۲ are influenced by agricultural activities. Factor analysis results state the effect of five factors on the quality of groundwater. The factor analysis accounts for the ۷۱.۹% of total variance of groundwater quality for geogenic impacts, while ۱۰% of the groundwater quality variance is controlled by agricultural activities which produce excessive amounts of NO_3^- along with Zn which is contained in fertilizers and agrochemicals. The results of the human health risk assessment showed that As is the most effective metalloid in total non-carcinogenic risk among the all heavy metal(loid)s. Based on HI, ۴۵% and ۱۴% of the samples for children and adults, respectively, are in high risk category.

Keywords: Groundwater, Heavy metal(loid)s, Multivariate statistics, Non-carcinogenic risk, Shabestar plain, Iran