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Performance of various metal-oxide nanoparticles in removing fluoride from contaminated groundwater in arid regions of Rajasthan, India

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Fluoride (F^-) contamination in groundwater is a widespread and persistent problem in Rajasthan, India, which lies predominantly in arid and semi-arid climatic zones. Natural geochemical attributes such as silicate weathering, dissolution of fluoride-bearing minerals has resulted in high F^- concentration in the regional groundwater. Several studies have demonstrated excellent performance of different metal based nanomaterials (NPs) for F^- removal; however, majority of the studies have assessed their performance under laboratory conditions using F^- spiked deionized or synthetic groundwater waters. In natural groundwater systems, presence of co-existing ions are expected to influence sorption behaviour of F^- by different NPs. Thus, the main focus of the present study is to evaluate F- removal efficiency by a range of metal nanoparticles under F^- contaminated natural groundwater conditions. To achieve the objectives, eleven metal NPs such as ZnO, $ZnFe_2O_4$, MgO, Al_2O_3, CeO_2, Fe_2O_3, La_2O_3, CeO_2–ZrO_2, $MgO·Al_2O_3$, Al_2TiO_5, and $AlCeO_3$ were selected. Then, F-contaminated groundwater were collected from twenty-four locations in and around Pali and Ajmer district of Rajasthan. A series of batch experiments were conducted to evaluate the F^- removal efficiencies by the selected NPs under all the collected natural groundwater conditions. The outcome of this study indicates that the under F^- contaminated natural groundwater conditions, nLa_2O_3 nanoparticle shows the best performance (14±2.0 mg/g). The analysis probably indicates that the sorption of F^- by nLa_2O_3 is likely to be governed by the formation of La-F bonding. The sorption of F^- by nAl_2O_3, nMgO, and $nCeO_2$ is mainly attributed to ion exchange, hydroxyl substitution, where the reduction in sorption capacities are much higher (>48%) under natural conditions. Amongst the water quality parameters, Ca^{+2}, Mg^{+2}, hardness, and TDS have the most adverse effect on F^- sorption. Low F^- concentration in the groundwater is another factor limiting the F^- sorption capacities.