Natural attenuation of fluoride at a former aluminum smelter site

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Elevated fluoride (F^-) concentrations, from past activities including recycling of cryolite-containing materials, were found in the shallow alluvial aquifer beneath a former aluminum manufacturing facility located next to a large river in the northwestern United States. Extensive field and laboratory investigations, including subsurface stratigraphy, hydraulic testing, aquifer mineralogy, and hydrochemistry, provided the basis for developing a conceptual model for F^- in groundwater and parametrizing a 3-dimensional reactive transport model using PHAST to assess the viability of natural attenuation for long-term protection of ground and surface water quality. Pre-conditioning simulations were performed to generate spatially distributed dissolved, adsorbed, and solid-phase F^- concentrations reflecting present-day conditions, and used as starting condition for predictive simulations to evaluate effectiveness of remedial alternatives. Long-term (2,000 year) simulation results indicate that fluorite and fluorapatite precipitation, sustained by dissolution of detrital calcic plagioclase in the sediments and sodium-calcium cation exchange on clays, and F^- adsorption on aluminosilicate clays, effectively arrest the movement of F^- in groundwater downgradient of source areas, resulting in an essentially immobile groundwater plume. Reactive transport modeling quantitatively demonstrated the effectiveness of natural processes in regulating F^- concentrations in groundwater and provides support for continued protectiveness of surface water quality.