Predictive model for Pb(II) adsorption on soil minerals (oxides and low crystalline aluminum silicate) consistent with spectroscopic evidence

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Mobility of Pb(II) in surface condition is governed by the adsorption processes on soil minerals such as iron oxides and low crystalline aluminum silicates. It has been documented that the adsorption effectiveness and the surface complex structures of Pb(II) sensitively varies with the solution conditions such as pH, ionic strength, Pb(II) loadings and electrolyte anion types. Present study aims to construct the quantitative model for Pb(II) on the soil minerals, which can predict the adsorption effectiveness and surface complex structures under any solution conditions by means of extended triple layer model (ETLM).

The Pb(II) adsorption data on goethite, ferrihydrite, quartz and low crystalline aluminum silicate (LCAS) were analyzed with ETLM to retrieve the surface complextion reactions and these equilibrium constants. The adsorption data on goethite, ferrihydrite and quartz come from previous studies. Those on LCAS were measured in present study under wide range of pH, ionic strength and Pb(II) loadings in $NaNO_3$ and NaCl solutions. All adsorption data can be reasonably regressed by ETLM with the assumptions of inner-sphere bidentate complexation and inner-sphere monodentate ternary complexation with electrolyte anions, which are consistent with the previously reported spectroscopic evidences. The predictions of surface speciation under wide range of solution conditions by ETLM revealed that the inner-sphere bidentate complex is predominant species at neutral to high pH conditions. The inner-sphere monodentate ternary complex becomes important at low pH, high surface Pb(II) coverage and high electrolyte concentrations, of which behavior is consistent with the spectroscopic evidences.

The comparisons of the obtained adsorption constants on goethite, ferrihydrite and quartz exhibited good linear relationships between the reciprocals of dielectric constants of solids and adsorption constants. The linear relationships enable the predictions of the adsorption constants of all oxides based on Born solvation theory. The adsorption constants of LCAS are comparable to those of goethite. The comparisons of the adsorption constants of soil minerals suggest that the ferrihdyrite, goethite and LCAS are three most important sorbents for Pb(II). Ferrihydrite and goethite are ferric oxides which are unstable in reducing conditions while LCAS is insensitive to the redox changes. The present study also implies that adsorption of Pb(II) in subsurface soil conditions may be governed by LCAS.

Keywords: soil minerals, surface coplexation modeling, Pb(II), oxides, low crystalline aluminum silicate