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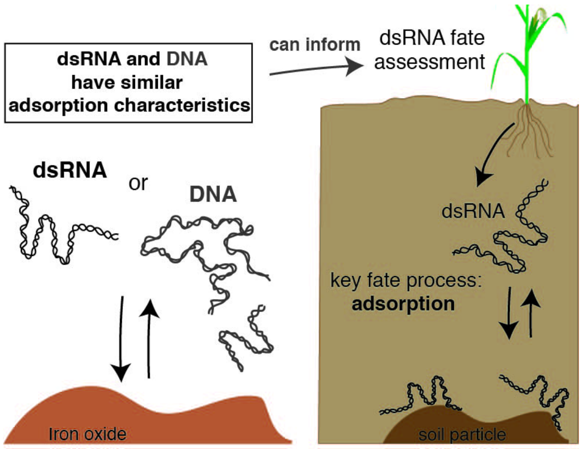

Adsorption of double-stranded ribonucleic acids and deoxyribonucleic acids in model soil systems

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Biomolecules, including nucleic acids (NAs), may be stabilized in soils through adsorption to mineral surfaces. While adsorption of DNA has been extensively studied, a detailed understanding of adsorption of double-stranded RNA to such minerals remains missing. Understanding dsRNA adsorption is critical because dsRNA molecules are used as novel insecticides in agriculture and therefore enter soil environments. Ecological risk assessment demands understanding the fate of dsRNA insecticides in soils. Here, we systematically assessed the adsorption of a model dsRNA and of two DNA molecules of varying length (as reference adsorbates) to the iron (oxyhydr-)oxides goethite, lepidocrocite, and hematite over a range of solution pH, ionic strength and ionic composition. We hypothesized comparable adsorption characteristics of dsRNA and DNA based on their structural similarities. In batch adsorption experiments, the adsorption of all tested NAs to the iron oxides decreased with increasing pH, consistent with weakening of electrostatic attraction to and inner-sphere complexation with increasing pH. NA adsorption capacities increased with increasing solution ionic strength and when adding Mg^{2+} ions, consistent with more compact NA conformations in adsorbed states -and hence smaller molecular footprints on the iron oxide surface- through attenuation of intra-NA electrostatic repulsion by screening of negative backbone charges and cation bridging, respectively. Phosphate competitively suppressed adsorption of all NAs to iron oxides. In column transport studies, NAs did not adsorb to like-charge quartz sand with NaCl as background electrolyte but adsorbed in the presence of dissolved Mg^{2+}, consistent with Mg^{2+}-bridging between the NAs and quartz sand surface. Adsorption to iron oxide coated sand (IOCS) showed the same dependence on solution pH and chemistry as observed for iron oxides in batch studies. Humic acids competed with NA for adsorption to IOCS. Taken together, our results highlight that iron oxides are important sorbents for NAs in soils and that electrostatics as well as inner-sphere complexation via the phosphodiester backbone with iron oxide surface hydroxyl groups govern overall NA adsorption. Furthermore, dsRNA and DNA had very similar adsorption characteristics, suggesting that existing knowledge on DNA adsorption can be used to predict dsRNA adsorption for dsRNA fate assessment in soils.