Effect of Natural Particles on the Transport of Sorbing Organic Compounds in Saturated Porous Media

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Abstract

Colloidal particles are ubiquitous in the subsurface and are particles with a size ranging between less than 10-8 m and 10-5 m (Stumm, 1977). Their introduction in groundwater can originate from various sources (McDowell-Boyer et al., 1986; Mills et al., 1991; Pelley and Tufenkji, 2008) such as detachment from the soil matrix (e.g., clay and silicate particles), mineral precipitation from supersaturated solution (e.g., iron oxides), leaching from landfills (e.g., dissolved organic carbon) and from industrial waste deposits (e.g., engineered nanoparticles). These particles can act as carriers for sorbing organic compounds such as hydrocarbons and organo-chlorinated compounds, resulting in the enhancement of their mobility in the subsurface. In this study, the influence of colloidal particles on the transport of sorbing organic compounds through saturated porous media is investigated by column experiments. The test particles and organic compound are lignite particles (brown coal) and lindane (gamma-hexachlorocyclohexane), respectively. The results are analyzed with the help of numerical modeling in order to understand the processes involved in the separate and associated transport of the particles and lindane. The transport of lindane without particles can be described by advective-dispersive transport coupled to linear three-site sorption, one site being in local equilibrium and the others undergoing first-order kinetic sorption. The transport of particles without lindane can be described by advective-dispersive transport coupled to reversible attachment and irreversible straining. As lindane sorbed strongly onto lignite particles, its transport was controlled by the behavior of these particles. In the presence of mobile particles, the total concentration of lindane is increased, that is, lindane is transported not only in aqueous solution but also sorbed onto the smallest, mobile particles. The models developed to simulate separate and associated transport of lindane and the particles reproduced the measurements very well and showed that the adsorption/desorption of lindane to the particles could be expressed by a common first-order rate law, regardless whether the particles are mobile, attached, or strained. The properties of lindane are similar to those of compounds that are found in petroleum-contaminated sites since lindane is manufactured using benzene. Therefore, the results of this study are of relevance for the understanding of unexpected fast transport of hydrocarbons in aquifers of these sites, where particle facilitated transport could significantly contribute to their overall mass flux in groundwater.

References Cited

Fang, J. et al., 2011. Transport of copper as affected by titania nanoparticles in soil columns. Environmental Pollution, 159(5): 1248-1256.

Grolimund, D. and Borkovec, M., 2005. Colloid-Facilitated Transport of Strongly Sorbing Contaminants in Natural Porous Media: Mathematical Modeling and Laboratory Column Experiments†. Environmental Science & Technology, 39(17): 6378-6386.

IARC, 1979. IARC Monographs on the evaluation of the carcinogenic risk of chemicals to humans. Some halogenated hydrocarbons. International Agency for Research on Cancer, Lyon. 20: 195.

Kanti Sen, T. and Khilar, K.C., 2006. Review on subsurface colloids and colloid-associated contaminant transport in saturated porous media. Advances in Colloid and Interface Science, 119(2–3): 71-96.

Kleineidam, S., Schüth, C. and Grathwohl, P., 2002. Solubility-Normalized Combined Adsorption-Partitioning Sorption Isotherms for Organic Pollutants. Environmental Science & Technology, 36(21): 4689-4697.

McDowell-Boyer, L.M., Hunt, J.R. and Sitar, N., 1986. Particle Transport Through Porous Media. Water Resour. Res., 22(13): 1901-1921.

Mills, W.B., Liu, S. and Fong, F.K., 1991. Literature-review and model (comet) for colloid metals transport in porous-media. Ground Water, 29(2): 199-208.

Ngueleu, S.K., Grathwohl, P. and Cirpka, O.A., 2013. Effect of natural particles on the transport of lindane in saturated porous media: Laboratory experiments and model-based analysis. Journal of Contaminant Hydrology, 149: 13-26.

Pelley, A.J. and Tufenkji, N., 2008. Effect of particle size and natural organic matter on the migration of nano- and microscale latex particles in saturated porous media. Journal of Colloid and Interface Science, 321(1): 74-83.

Simunek, J., He, C.M., Pang, L.P. and Bradford, S.A., 2006. Colloid-facilitated solute transport in variably saturated porous media: Numerical model and experimental verification. Vadose Zone Journal, 5(3): 1035-1047.

Stumm, W., 1977. Chemical interaction in particle separation. Environmental Science & Technology, 11(12): 1066-1070.

Sun, H.M. et al., 2010. Kaolinite and Lead in Saturated Porous Media: Facilitated and Impeded Transport. Journal of Environmental Engineering-Asce, 136(11): 1305-1308.

WHO/UNICEF, 2011. Drinking Water Equity, Safety and Sustainability: Thematic Report on Drinking Water 2011, WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP). World Health Organisation (WHO)/United Nations Children's Fund (UNICEF), Geneva/New York.

Yin, X. et al., 2010. Colloid-facilitated Pb transport in two shooting-range soils in Florida. Journal of Hazardous Materials, 177(1-3): 620-625.