# Effect of natural particles on the transport of sorbing organic compounds in saturated porous media

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## Summary

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 basically 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.

## Introduction

Groundwater is the most important water resource for drinking-water production throughout the world (WHO/UNICEF, 2011). A particular reason for this lies in its low vulnerability to pollution by chemical compounds, since the infiltrating water is filtered during the passage through soils and aquifers. However colloidal particles can act as carriers for sorbing compounds (Fang et al., 2011; Grolimund and Borkovec, 2005; Kanti Sen and Khilar, 2006; Sun et al., 2010; Yin et al., 2010) leading to fast contamination of groundwater.

The main objective of this study is to investigate the influence of natural particles on the subsurface transport of sorbing organic compounds through saturated porous media using the organo-chlorinated compound lindane and lignite particles. A quantitative understanding of separate and associated transport of lindane and particles is assessed by changing the size of the particles. Laboratory experiments are analyzed by numerical modeling.

## Materials and Method

Natural sand from an alluvial sedimentary deposit was used as porous medium. The middle sand fraction with a grain size ranging from 0.25 mm to 0.80 mm dominated the mixture and was used as porous medium for the experiments. Particles made of lignite were chosen for this study because lignite can be classified as a typical very strong sorbent that is also mobile, ensuring effective uptake of lindane (Kleineidam et al., 2002). Lindane, $C_6H_6Cl_6$, was used as test compound. Its solubility in water is approximately 10 mg $l^{-1}$ (IARC, 1979). Sodium chloride was used for conservative transport experiments in order to determine the porosity of the sandy porous medium. Batch sorption isotherms of lindane onto the lignite particles were determined in the laboratory. Column experiments were run to study the transport of lindane and the particles. A modified form of the system of equations of Simunek et al. (2006) was used to model particle-facilitated transport of lindane.

## Results

The results (Figure) show that the maximum normalized concentration increases when the size of the particle decreases, which indicates that particle-facilitated lindane transport occurred with the particles having the smallest size.

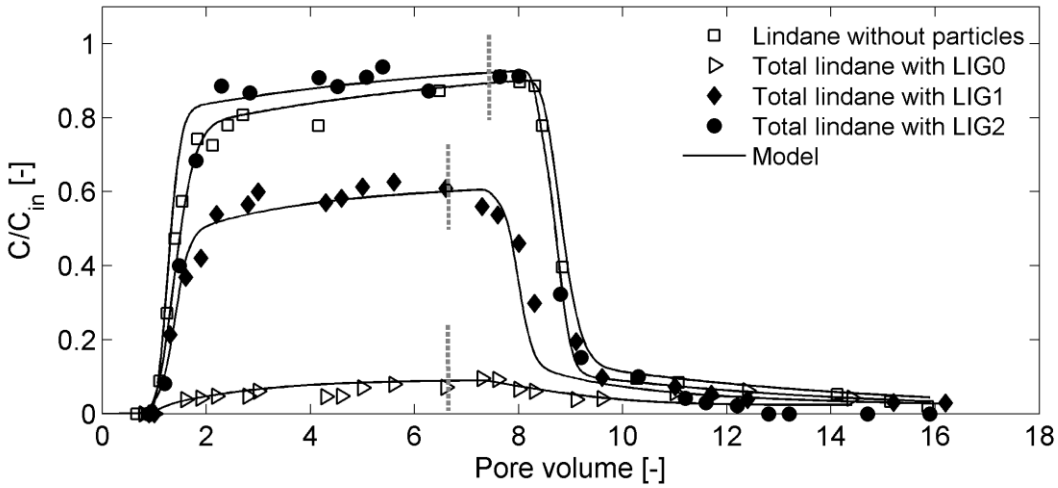


**Figure:** Summary of the breakthrough curves of lindane. The vertical dashed gray lines separate the injection (left) and elution (right) phases. LIG are denotations of particles and their size decreases from LIG0 through LIG1 to LIG2 (Ngueleu et al., 2013).

## Conclusions

The transport of lignite particles showed a clear dependence of particle retention on the size of the particles. Particle retention increased with increasing particle size. Facilitation of lindane transport was observed only with the particles with the smallest size. Only the smallest particles facilitated the transport of lindane.

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