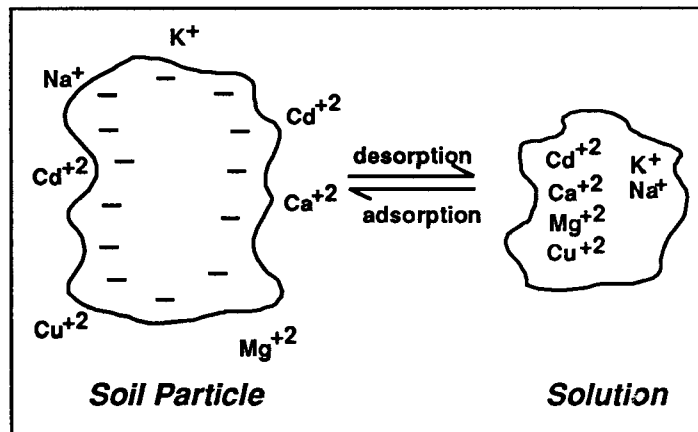


EPA Summary Paper

Basic Concepts of Contaminant Sorption



Introduction

The Robert S. Kerr Environmental Research Laboratory (RSKERL) has developed a number of *Issue Papers* and *Briefing Documents* which are designed to exchange up-to-date information related to the remediation of contaminated soil and ground water at hazardous waste sites. In an attempt to make the content of these documents available to a wider audience, RSKERL is developing a series of *Summary Papers* which are condensed versions of the original documents.

Understanding the processes which dictate transport and fate characteristics of contaminants in soil and ground water is of paramount importance in designing and implementing remediation systems at hazardous waste sites. Sorption is often the most significant of these processes. This summary paper addresses the basic concepts of sorption in soil and ground water with an emphasis on organic contaminants having the characteristics of those often found at existing hazardous waste sites.

The Concept of Sorption

Sorption can be defined as the interaction of a contaminant with a solid. More specifically, the term can be further divided into adsorption and absorption. The former refers to an excess contaminant concentration at the surface of a solid while the latter implies a more or less uniform penetration of the solid by a contaminant. In most environmental settings, this distinction serves little purpose as there is seldom information concerning the specific nature of the interaction. The term sorption is used in a generic way to encompass both phenomena.

There are a number of factors which control the interaction of a contaminant with soil or aquifer materials. These include chemical and physical characteristics of the contaminant, composition of the surface of the solid, and the fluid media encompassing both. By gaining an understanding of these factors, logical conclusions can often be drawn about the impact of sorption on the movement and distribution of contaminants in the subsurface. The failure to take sorption into account can result in a significant underestimation of the amount of a contaminant at a site as well as the time required for it to move from one point to another.

Soil and aquifer materials are primarily composed of sand, silt, clay, water, and a highly variable amount of natural organic carbon, the presence of which profoundly complicates a soil's sorptive properties. The combination of these characteristics describe the surfaces offered as sorptive sites to contaminants in water passing through the subsurface matrix.

It can be deduced that sandy materials offer little in the way of sorptive surfaces to passing contaminants while silts and clays, particularly those having substantial amounts of organic matter, provide a rich sorptive environment for many types of contaminants. Even the most porous and highly productive aquifers, composed of sands and gravels, usually have some fine grained material, small amounts of which can result in a substantial increase in the sorptive behavior of the aquifer material.

Most organic contaminants of environmental concern have a limited solubility in water and therefore tend to be associated with the solid rather than the water phase. But even with limited solubilities, many hazardous chemicals can be detected at

measurable, and often toxic concentrations in water. One of several ways used to describe the distribution of contaminants between the solid aquifer matrix and water is the sorption coefficient K_p :

$$K_p = \frac{\text{Concentration}_{\text{Solid Phase}}}{\text{Concentration}_{\text{Solution}}}$$

The value of K_p is dependent upon the characteristics of the contaminant, the type of aquifer material, and the amount of soil organic carbon. In order to better understand the utility of this concept, assume $K_p = 1.0$ which dictates that the contaminant is equally distributed between the liquid and solid phases. Since soil is about 2.5 times more dense than water, 2 liters of aquifer would contain 1 liter of water and 2.5 kg of soil. Therefore, 1.0 mg/l of the contaminant would be associated with the water and 2.5 mg (70 percent) would be sorbed to the solid phase.

As can be seen from this example, sorption tends to complicate remediation techniques that require pumping water to the surface for treatment. The slow desorption of contaminants from the solid to the liquid phase can significantly reduce the effectiveness of a pump-and-treat system by progressively lowering contaminant concentrations in water pumped to the surface. It is not uncommon to pump a system until contaminant concentrations in the pumped water meet a mandated restoration level, while the aquifer's solid phase still contains a substantial contaminant mass. Therefore, when the pumps are turned off, concentrations in the ground water soon return to their previous level.

The quantity and distribution of contaminants in the subsurface is of paramount importance in designing extraction or in-situ remediation systems. In this regard, it is necessary to obtain the best information possible on contaminant sorption. Therefore, tests to determine a sorption coefficient (K_p) should be made with the contaminants of concern, as well as soils and aquifer material from the specific site.

This *Summary Paper* has been developed from the *Ground-Water Issue Paper* titled "Basic Concepts of Contaminant Sorption at Hazardous Waste Sites." EPA/540/4-90/053, October 1990.

For further information about the Technology Support Center at RSKERL, contact:

Mr. Don Draper, Director
Technology Support Center
U.S. Environmental Protection Agency
Robert S. Kerr Environmental Research Laboratory
P.O. Box 1198
Ada, OK 74820

(405) 436-8603

United States
Environmental Protection Agency
Center for Environmental Research Information
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