



Research Brief #16

1997

How Clean is Clean Enough if Contaminants are Irreversibly Adsorbed?

Introduction

There is a point in soil remediation when it is acceptable and even preferable to leave contamination remaining in the soil. Studies in sediment clean-up have led scientists to the conclusion that, although most contamination can be remediated using traditional methods such as those based on standard kinetic and equilibrium solubility and transport relationships, some percentage of the contaminant is still left in the soil. Massive amounts of time, energy, and money have been spent attempting to remediate these residual contaminants, but efforts have been largely unsuccessful. Scientists have also been unsure about the effects of this remaining amount on the environment. If this contamination followed the rules and patterns which scientists predict for the majority of the contamination, then it would eventually desorb into the water and cause damage to the environment, as well as create a public health hazard. Scientists at Rice University have observed, however, that the contamination seems to resist this desorption, indicating that it may be irreversibly bound to the soil.

Rice University researcher Mason Tomson and his colleagues Amy Kan, Gongmin Fu, and Margaret Hunter are researching the possibility that these residual contaminants are relatively harmless because they will never desorb into the water in significant amounts. Their experiments were complicated by the difficulty of differentiating between irreversibly adsorbed contaminants and contaminants that are affected by other properties such as chemical solubility, surface charge, or the presence of hydro-

gen or electronegative atoms. Yet in their experiments, Tomson and his colleagues were able to use data that ruled out most of the properties that could cause conditions which mimic irreversible adsorption. They have so far determined that, because of the limited benefits of clean-up, these residual amounts of contamination should be left in the soil to be effectively contained by natural processes.

Experiment Design and Implementation

The researchers mimicked the natural adsorption and desorption cycles by applying chemicals such as naphthalene and polychlorinated biphenyl (PCB) to both natural and synthetic surrogate sediments. (Naphthalene functions as the starting point for many organic syntheses, while PCB can be found in paints, inks, adhesives and batteries.) The solution was then mixed in a shaker bath for one to three days, which allowed the contaminant to adsorb to the sediment. Next, the sediment and adsorbent were separated by centrifugation, and the adsorbent was replaced by an electrolyte solution, which induced desorption. During this desorption, the solution was typically incubated for one to three days, with exceptions ranging from nineteen to 180 days. The scientists then repeated the adsorption/desorption cycle one to five more times. The solutions were ultimately analyzed to determine how much of the contaminant remained adsorbed to the sediment.

Experiment Results

In both the naphthalene and the PCB studies, a significant amount of the contaminants resisted desorption

Summary of the Problem

In an effort to determine "how clean is clean enough" in soil remediation, Rice University principal investigators Mason Tomson and Amy Kan explored the possibility of a contaminant becoming irreversibly adsorbed to the soil. With irreversible adsorption, a contaminant does not desorb to the surrounding waterways and, therefore, cannot be easily remediated by using traditional methods such as those based on standard kinetic and equilibrium solubility and transport relationships. Massive amounts of time and energy have been expended in attempts to clean up these residual contaminants, but Kan and Tomson propose that the irreversibly adsorbed contaminants should be left in the soil to be effectively contained by natural processes.

Tomson's and Kan's research reveals that a finite amount of contamination will irreversibly bind with the soil. Once this amount is satisfied, that is, the "compartment" is filled, further contamination will then desorb to surrounding waterways. The size of the compartment holding the contamination varies depending on the type of soil and contaminant. Future studies by the researchers will examine how the parameters of the irreversible compartment can be determined using simple methods such as examining a soil's pH level or knowing a contaminant's ability to bond with water.

continued on back

and remained adsorbed to the sediment. The researchers discovered that even when higher concentrations of naphthalene and PCB were added to the solutions, nearly equal amounts of contaminants were irreversibly adsorbed at each step up to a fixed maximum. They concluded that the same percentage of the applied contamination adsorbs to the soil at each step until the compartment is saturated. After five steps of adsorption for the naphthalene and six to seven steps for the PCB, the irreversible compartments were saturated, and all the subsequently adsorbed contamination was able to desorb. Because there were no significant differences in the adsorption level when the mixtures were incubated for varying lengths of time, scientists were able to determine that once this level of saturation is reached, the amount of adsorbed contaminant remains constant.

For naphthalene, the scientists concluded that the irreversible compartment could sometimes hold up to fifty percent of the total adsorbed mass. For PCBs, the compartment could hold up to seventy-nine percent of the total adsorbed mass.

Future Research

Now that the existence of an irreversible compartment has been established, the next step is to develop a semi-empirical correlation to predict its dimensions. Although the researchers are still ascertaining which properties of the contaminant and the sediment are instrumental in determining the size of the irreversible compart-

ment, Kan says that they have concluded that the adsorbed contaminant, and thus the irreversible compartment, is determined by both the adsorption energy (a chemical property) and the organic carbon content of the sediment. The contaminant's ability to either dissolve in water or resist dissolution can affect the size of the compartment as well.

In present experiments, the researchers have begun using naturally occurring sediments that have been contaminated for ten to over fifty years. This method should give them a better understanding of existing natural conditions than their previous method of using both natural and synthetic sediments that had been chemically treated in the lab.

These experiments will allow the researchers to determine the maximum amount of contamination that a sediment can contain before the contaminant desorbs significantly to surrounding waterways. The scientists predict that they will be able to determine the size of the irreversible compartment by examining easily observed parameters of the sediment and the contaminant, such as pH level, salt content, and ability to dissolve in water.

Kan states that finding this level of negligible risk and defining it as the acceptable clean-up end point will result in "a concomitant saving of from fifty to eighty percent of the typical remediation time and money with no reduction in health and environmental protection."



Director:

Danny D. Reible, Ph.D.

Louisiana State University
Baton Rouge, Louisiana 70803
Phone: 504/388-6770
FAX: 504/388-5043

Co-Directors:

F. Michael Saunders, Ph.D.

Georgia Institute of Technology
Atlanta, Georgia 30332
Phone: 404/894-7693
FAX: 404/894-9724

C. Herb Ward, Ph.D.

Rice University
Houston, Texas 77251
Phone: 713/527-4086
FAX: 713/285-5203

Training & Technology Transfer Director:

John C. Nemeth, Ph.D.

Georgia Tech Research Institute
Atlanta, Georgia 30332
Phone: 404/894-8076
FAX: 404/894-6199

Principal Investigators

Rice University
Mason Tomson
Amy Kan

Project Title: *Desorption of nonpolar organic pollutants from historically contaminated sediments and dredged material*