Research Brief #27

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Bioavailability of Desorption-Resistant Contaminants

Introduction and Objectives

Bioavailability measures a contaminant's propensity to break free from sediment bonds and become absorbed into aquatic organisms. Current environmental regulations are based on the assumption that all contaminants are completely available for uptake by aquatic organisms; however, scientists have recently shown that a fraction of many contaminants resists desorption. They have observed such behavior under normal physico-chemical conditions in microbial assays, but they have only recently begun to measure desorption resistance in cases when sediment particles are ingested and metabolized by deposit-feeding benthic organisms (burrowing worms). Better understanding of this process is essential, because benthic organisms are a primary means of introducing contaminants into the food chain.

Researchers at the Louisiana State University (LSU) are conducting a three-year evaluation of the bioavailability of desorption-resistant contaminant fractions. The LSU project is characterizing the release rates of polynuclear aromatic hydrocarbons (PAH's) when the contaminant is eaten or absorbed by a species of benthic organism known as *Tuboficid oligochaetes*. Previous research studies at LSU have shown that when PAH's are consumed by benthic organisms: 1) there is less uptake into benthic organisms by the desorption-resistant fraction of PAH's than by the rest of the contaminant; and 2) the rate of uptake of this desorption-resistant fraction by benthic organisms is rapid due to the intense processing activity of these organisms. Researchers concluded that the PAH concentration in sediment porewater could be used to predict steady state uptake in organisms regardless of whether uptake is via ingestion or absorption from porewater.

The current study aims primarily to confirm the former experiments and also extend the database of contaminant compounds and sediment types in which bioavailability mechanisms are understood. This work will provide a model explaining the route and extent of uptake of desorption-resistant contaminant fractions. Researchers intend to test the model's applicability for other hydrophobic contaminants, such as polychlorinated benzenes (PCB's).

The project's ultimate aim is to develop a predictive model of biological availability that accounts for the desorption-resistant fraction in contaminants. Such a tool would allow sediments to be managed by their actual physico-chemical characteristics rather than treating all contaminants as if they are completely bioavailable.

Methodology

The LSU group's fundamental approach has been to prepare sediments containing only their desorption-resistant fractions and monitor the accumulation of contaminants in benthic organisms such as *Ilyodrilus templetoni*. Deposit-feeding *oligochaetes* represent an intense processing environment for sediments and, thus, bioavailability tests using these organisms have not been complicated by the mass-transfer resistances that are associated with microbial assays of bioavailability.

The LSU group removed readily desorbed contaminants from laboratory sediment microcosms. Team members compared uptake by sediment inges-

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Summary of the Problem

Sediment quality is determined by the availability of contaminants for release into the food chain, where they can threaten the health of ecosystems and human communities. Until recently, scientists assumed that contaminants in sediments were completely available for uptake by organisms through ingestion of sediment particles or porewater absorption. Recent research, however, has shown that a significant amount of the organic contaminants in soils and sediments may not be readily available for release and uptake into the food chain. Researchers have observed a desorption-resistant fraction of contaminants that releases more slowly and in lesser amounts than has been previously thought to be the case. If scientists can understand and characterize these desorption-resistant fractions, they may be able to develop a predictive model of biological availability in contaminated sediments. Such a tool could allow sediments to be managed according to the actual availability of contaminants rather than on the assumption that contaminants are fully available for release.

Scientists are investigating desorption resistance of polynuclear aromatic hydrocarbon (PAH) contaminants when they are ingested or absorbed by benthic organisms (sediment-burrowing worms), which are an important mechanism for introducing contaminants into the food chain. Preliminary laboratory studies have shed light on the route and amount of PAH uptake by benthic organisms. A more comprehensive investigation is needed to confirm these findings and to extend the database of compounds and sediment types for which bioavailability is understood.

tion and by water alone to evaluate the influence of the exposure route on the rate and extent of contaminant accumulation in the organism.

The researchers plan to evaluate the results obtained in field-contaminated sediments. Models are under development to relate desorption induced by physico-chemical processes with observed uptake and accumulation of contaminants in the benthic organisms. Team members also are developing methods to evaluate the relationship between bioavailability of contaminants to bioturbating worms and the likelihood of their transfer up the food chain.

Output/Accomplishments

In the past year, the researchers have focused their efforts on:

- Increasing the number of contaminants and sediments evaluated using the team's bioavailability model for desorption-resistant fractions;
- Comparing the uptake of contaminants by benthic organisms via porewater absorption or sediment ingestion to determine which is the dominant means of transfer for particular organic compounds; and
- Developing a model of physico-chemical sorption and desorption that relates desorption and uptake.

The effort to develop a mathematical model of sorption and desorption in the various organic phases of the sediment grew out of a need to improve understanding of the factors leading to desorption resistance and the relationship between physico-chemical desorption and uptake in the benthic organisms. The model currently undergoing development and testing assumes that: 1) contaminant sorption and desorption into natural organic matter are reversible and at rates controlled by diffusion in the pore space of this phase; and 2) contaminant sorption and desorption into condensed phase organic matter are controlled by diffusion in a solid organic phase. Thus, the model has two adjustable parameters that can be calibrated to a particular sediment. The group assumes that the model can be: 1) calibrated to kinetic information on sorption and desorption for a particular compound and sediment; and 2) used to predict sorption and desorption characteristics for other time periods and contaminants, at least in the same contaminant class. It appears that the model can predict porewater concentrations as a function of the time of sorption and desorption and therefore predict contaminant accumulations in the benthic organism.

Conclusions & Future Work

Key conclusions from the study can be summarized as follows:

- Measurements of the availability of PAH contaminants to benthic organisms support the LSU model that the ultimate accumulation of the contaminant—even in its desorption-resistant fraction—is predicted by porewater concentrations;
- The kinetics of contaminant uptake are determined by the route of exposure and associated parameters such as the organism's assimilation efficiency and the rate at which it eliminates ingested sediments; and
- Porewater concentrations of contaminants appear to be predictable by a biphasic diffusion model.

These conclusions are well-supported by collected data but are limited to a relatively small set of contaminants, sediments and organisms. Proposed work seeks to test the generality of the results by examining a broader range of sediments, including field-contaminated sediments, and evaluate other hydrophobic organic compounds. Research with field-contaminated sediments has been limited due primarily to the difficulty of separating sufficient quantities of dissolved contaminant from the sediment and suspended colloidal phases for analysis. Researchers believe they have overcome these problems and can now analyze both porewater concentrations and accumulation of lipids of contaminants from the field sediments.

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