



# Research Brief #17

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## Discovering the Mechanisms Involved in the Release of Contaminated Sediments into Our Nation's Waterways

### Introduction

Bottom sediments in the nation's lakes, rivers, and estuaries have become contaminated and may be resuspended during episodic floods and dredging. Once exposed to the water column, the contaminants may remain adsorbed to soil particles or may be desorbed and/or dissolved. The resulting mobilized contaminants may adversely affect the surrounding aquatic environment or move up the food chain to the human population.

The resuspension of sediments and associated contaminant mobilization in natural water systems are the least understood parts of the process of contaminant exposure in surface waters, yet they play a vital role and must be quantified if risks to aquatic life and humans are to be assessed and appropriate remedial actions recommended. Georgia Tech researchers T. Sturm, A. Amirtharajah, and C. Tiller are studying the physics and chemistry of the processes that determine the erosion of river and estuary sediments and the mobilization of heavy metal contaminants.

Both point and nonpoint sources of heavy metals are major contaminants of bottom sediments. Important nonpoint sources of heavy metal contamination are primarily associated with agricultural land use and include fertilizers, inorganic pesticides, and motor vehicle emissions. Point sources include discharge from wastewater treatment plants, power plants, paper, chemical, and metal plating industries, and landfill leachate.

Heavy metal contaminants such as copper and cadmium are often found adsorbed to clay particles in fine, cohesive sediments because of the large

surface area and reactivity of these particles. Understanding the potential for mobilization of these contaminants depends in part on understanding how cohesive sediments become resuspended. The interparticle cohesive forces that resist the resuspension forces of flowing water depend on many factors such as pH, ionic strength, organic matter, water content, and clay type. As a result, the resuspension potential is often measured on a site-specific basis by a variety of experimental techniques without any unifying theoretical framework. Improved models are needed to predict the fate and transport of contaminants and to assess the exposure risk to aquatic life and the human population.

In this study, the Georgia Tech researchers are applying a theoretical model of four microscopic forces that operate between clay particles in order to provide a more fundamental basis for determining the parameters involved in erosion/resuspension relationships among cohesive sediments. Batch studies are also being conducted to characterize the degree to which specific heavy metals are mobilized under varying chemical conditions in the water column. Flume and column studies are being used to verify the predicted sediment resuspension and metal mobilization behavior. A field study of the resuspension of barium in the sediments of the Etowah river near Atlanta is also being used to verify and refine these concepts in the field.

### Theoretical Studies

The interparticle forces between the sheet-like structures (called platelets) of clay minerals have been calculated

### Summary of the Problem

Contaminated runoff from agricultural and municipal sources is contributing to a marked increase in the concentration of heavy metal pollutants that collect in our nation's lakes, rivers and estuaries. Resuspension of these pollutants can easily occur as a result of cyclical floods or dredging and, once suspended in the water column, the mobilized contaminants can wreak havoc on the surrounding aquatic environment and migrate into the nation's water supply.

Georgia Tech researchers T. Sturm, A. Amirtharajah, and C. Tiller are studying the forces that come into play in determining the erosion and mobilization properties of the various components of river and estuary sediments. Their efforts combine laboratory flume and water column studies of sediment erosion and resuspension with bench-scale observations and field studies of heavy metal and sediment particle interactions.

The chemical environment of the water column varies considerably from site to site, so resuspension measurement techniques are often case specific and unsupported by any unifying theoretical framework. To counteract this situation, the researchers are using the field and bench scale flume and column studies to verify predictions of a theoretical model of interparticle forces within clay minerals.

The knowledge gained in these efforts will be used to develop a more robust methodology for predicting contaminant migration and will aid in evaluating improved remediation strategies.

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for different chemical environments. The structural relationships among these platelets can be visualized metaphorically as a deck of hexagonally shaped cards with the cards laid on edge forming an enclosure with their ends touching in an edge-edge structure, arranged in a lattice-like "house of cards" in an edge-face structure, or stacked in a deck one on top of the other in a face-face structure. The interparticle forces have different magnitudes in each structure and thus differing degrees of resistance to erosion. Force calculations have shown, for example, that the edge-face mode of interaction is more common at lower sediment pH values while edge-edge associations predominate at intermediate sediment pH values with an accompanying increase in erosion rates. These predictions have been confirmed by experimental observations in both flume and column studies. The advantage of the force calculations is that the clay structure and erosion resistance can ultimately be predicted without relying solely upon site-specific empirical relationships.

### Flume Studies

Researchers are using a large laboratory flume to simulate the turbulent flow responsible for overpowering interparticle forces in cohesive sediments and causing erosion and resuspension into the flow of rivers and estuaries. Erosion rates have been measured for kaolinite sediment samples placed at the bottom of the flume at varying values of fluid shear stress, sediment pH, and natural organic coating of the kaolinite particles. The relative magnitudes of erosion rates observed with variable pH are consistent with the particle interactions predicted by the interparticle force calculations. Similar observations have been made in column studies in which detachment of kaolinite particles from coarse media is used to simulate sediment bed fluidization encountered in hydraulic dredging.

Coating of kaolinite particles with natural organic matter also influences

particle interactions. Flume experiments have shown that organic molecules are attracted to positively charged edge sites on kaolinite particles. This interaction tends to disrupt edge-face particle associations with weaker mixtures of edge-face and face-face arrangements. At higher concentrations of organic matter, particle bridging by organic molecules increases erosion resistance. An interesting and complicating effect found from the flume experiments is that adding copper ions to kaolinite disrupts the action of organics. This disruption is apparently caused by a switch from face-face to edge-face particle associations and a return to erosion rates typical of kaolinite without organic coatings. Thus, the effect of organics on particles is modified by the concentration of cations.

### Field Studies

Field data are currently being collected on a stretch of the Etowah river containing barium contaminated sediments. This section of the river is influenced by daily hydropower releases from a dam located upstream. The result is a daily artificial flood that is ideal for studying sediment resuspension due to cyclical flooding. The concentration of barium resuspended into the water column has been shown to vary with increases in total suspended solids that occur with higher water discharges, and the sediment size becomes coarser after the hydropower wave has reached the sampling site. Similar behavior has been reproduced in flume experiments.

The results of this research will provide better tools for assessing the exposure risk associated with the resuspension of contaminated sediments and subsequent mobilization of heavy metals caused by turbulent events. Analysis of field tests and laboratory flume simulations will be used to evaluate various remediation strategies and improve the erosion and resuspension relationships used in current numerical models.



### 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

Georgia Institute of Technology  
T. W. Sturm  
A. Amirtharajah  
C. L. Tiller

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