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USGS Chesapeake Bay Activities

Antibiotics and Biogeochemical Cycling of Nutrients in Chesapeake Bay Sediments

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Collaborators: Chesapeake Bay Program (over 25 Federal Agencies, 6 States, the District of Columbia, and numerous local customers and partners)

Statement of Problem: It is widely recognized that excessive nutrients, organic chemicals and metals are contaminating water, soil and sediment of our Nation's hydrologic environments, including the Chesapeake Bay. To preserve our water resources, research is being done to understand the distribution and the environmental fate of these contaminants. As part of on-going research to determine the affect that contaminants have on abiotic and biotic processes, transport and transformation processes are being determined for nutrients, in particular phosphorus, organic chemicals and metals in watersheds of the Chesapeake Bay Basin. Phosphorus cycling is dependent on microbial processes. It is unknown whether antibiotics found in the chicken litter used to fertilize agricultural fields are transported to adjacent streams and, if transported, whether these compounds have an affect on natural microbial populations.

Objectives:

1. To determine how land use practices relate to the distribution and cycling of phosphorus in watersheds. Geochemical data for sediment and associated interstitial water from cores collected from tributary streams will be used to model the flux of phosphorus to the Chesapeake Bay.

2. To evaluate the relation between phosphorus cycling and the presence of antibiotics in sedimentary environments. Preliminary evidence indicates that there is a relation between the presence of iron oxyhydroxides, the cycling of phosphorus and the presence of antibiotics in sediments. The research hypothesis is that sediment geochemistry, in particular phosphorus geochemistry, regulates the occurrence of tetracycline antibiotics and their affect on sediment microbial communities.

3. To determine transport mechanisms for pharmaceuticals, particularly polar compounds known to bind with metals. Virtually nothing is known about the transport and fate of tetracyclines in agricultural watersheds where millions of pounds of the antibiotic are used in animal agriculture.

Approach: Over the past several years this project has completed studies which concluded that non-crystalline or amorphous iron oxide concentration in sediment, not total iron concentration in sediment, is a controlling factor in phosphorus (P) cycling in watersheds of the Chesapeake Bay Basin. A research goal for the project in the immediate future is to identify specifically how amorphous or non-crystalline oxyhydroxides of iron affect the fate and transport of P.

Fieldwork in 2004 includes collaboration with the Potomac River Basin and Delmarva Peninsula study unit and will include sampling at Nutrient Enrichment Effects Team (NEET, program of NAWQA) sites.

In the laboratory, questions to be answered include:

- Is the phosphate sorbed to amorphous or non-crystalline iron oxides bioavailable?

- What is the relation among aqueous concentrations of phosphate, iron geochemistry, and the presence of tetracycline antibiotics in bottom sediment? Data collected to date suggest that a relation exists.

A major effort is planned to prepare reports to include the entire data set for all samples collected to date for this project.

Selected Reports and Other Products:

Bricker, O.P., Newell, W.L., and Simon, N.S., 2003, Bog iron formation in the Nassawango Watershed, Maryland: U.S. Geological Survey Open-File Report 03-346. http://pubs.usgs.gov/of/2003/of03-346/

Simon, Nancy, 2003, Sources and bioavailability of oxytetracycline in bottom sediment from the Pocomoke River, MD, USA: New York, 226th American Chemical Society National Meeting, Division of Environmental Chemistry Preprints of Papers, v. 43, no. 2, p. 1,293-1,297.

Relevance and Benefits: Reports in the literature show that pharmaceuticals are present in soils, sediments, surface water and ground water in agricultural areas throughout the western world. Little is known about the affect of these pharmaceuticals on the environment. The use of antibiotics in animal husbandry in United States has increased from 16 million pounds per year during the 1980's to between 17.8 million pounds per year, according to the Animal Health Institute, and 25 million pounds per year, the value reported by the Union of Concerned Scientists (Hileman, 2001). The 3 million pounds of one antibiotic, tetracycline, used in animal production, is equivalent to the total amount of all antibiotics used by humans in the United States. Close to half of all of the antibiotics used in agriculture is used in poultry production. In 1997 more than 256 million broilers were produced in the Pocomoke River, MD, watershed. This was more than 5% of all of the broilers produced in the United States. For economic reasons, poultry litter produced in a watershed is used as fertilizer within the watershed.

Tetracyclines (TCs), antibiotics used widely in poultry production, bind strongly with metals. Metal binding partitions TCs from the aqueous to the solid phase in soils and sediments. TCs are sorbed to sediments by ion exchange processes in addition to binding with metals. When desorbed, TCs retain their efficacy as antibiotics. Phosphate can be used to desorb TCs in sample analysis. Phosphate produced in the sediment phosphorus cycle could play a role in tetracycline desorption processes.

Reports in the literature concerning the impact of pharmaceuticals (TCs) on environmental systems are limited to documenting the concentrations of oxytetracycline in sediments under fish farms and providing evidence that tetracycline is stable in fields fertilized with manure. Nothing is known about the degradation pathways, method of transport, and bioavailability of TCs in riverine and estuarine environments. This project is addressing challenging questions concerning not only the distribution of, but also the affects of, pharmaceuticals in the environment.