T R E N D S • I N

Risk & Remediation

Summer 1999

Overview: Contaminated Sediments

Heightened awareness of sediment contamination has led to a variety of research efforts around this issue.

There is a growing focus on sediment contamination by regulators (U.S. EPA, 1999) and possibly by the scientific community, as well. Contaminated sediments can be found in many waters throughout the nation as a result of decades of human activities, including sewage and industrial discharges, agricultural and urban runoff, hazardous waste site leaching, and atmospheric deposition. But the growing focus on sediment contamination is not necessarily an indication of a growing problem; in fact, the problem may be decreasing (see figure) while regulatory sensitivity increases.

Perhaps the largest challenge being faced today in understanding the sediment contamination issue is the development of technically sound, widely applicable sediment criteria.

In 1997, U.S. EPA published a comprehensive analysis of existing sediment data aimed at defining the extent of sediment problems and at identifying the most critical sediment contamination areas in a four-volume Report to Congress entitled *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States* (U.S. EPA, 1997). About 65% of the nation's watersheds were studied, covering a period from 1980 to 1993. Of all the sediments studied, EPA judged only six to 12% to have definite adverse effects, although 75% of all stations were contaminated to at least a "possible effects" degree. The most common "probable effects" contaminants were PCBs, mercury, DDT, polycyclic aromatic hydrocarbons (PAHs), and divalent trace metals. Ninety-six "Areas of Potential Concern (APC)," the most intensive and widespread contaminated sediment areas, were identified across the nation. Although the large scope of the Report to Congress made it useful as a tool to appreciate the scope of the sediment issue, there were many assumptions and technical issues inherent in the analysis to suggest

continued on pg. 2

Letter to our Readers

July 1999

Dear Colleague,

In this issue of *Trends in Risk & Remediation*, we focus on the problem of contaminated sediments, which, although decades old, appears to be gaining increased attention from regulators and the scientific community. We review efforts underway to develop a stronger technical understanding of sediment contamination, as well as efforts to develop technically sound sediment quality criteria that can be widely applied to sediments from different sources. We examine the potential for human exposures to contaminated sediments, which is often expected to be secondary to ecological concerns. Finally, we present a guest opinion on the need for a sediment management policy based on scientific reasoning, not perception.

Contributors to this issue include Dr. Neil Shifrin, President and co-founder of Gradient. He is joined by Mr. Richard Blanchet, Senior Environmental Toxicologist, who specializes in ecological risk assessment and ecotoxicology, and Dr. Teresa Bowers, a Principal and expert in exposure modeling and negotiation of risk-based remedial targets. We are pleased to welcome to this issue Dr. Ralph Stahl, DABT, Senior Consultant with DuPont. We thank him for sharing his thoughts on risk management of contaminated sediments in a guest editorial.

We hope that you will find the information in this issue of *Trends* thought-provoking and relevant to your work.

Yours truly,

Neil Shifrin
President

I N S I D E

Trends in Risk & Remediation is a quarterly publication of Gradient Corporation. As a national leader in risk assessment and negotiation of risk-based remediation, Gradient offers this publication free of charge to interested groups and individuals. If you have a colleague who would benefit from this publication - or if you have comments or suggestions - please contact Carol Counihan, Editor, at 617-576-1555 or email us at *trends@cam.gradcorp.com.*

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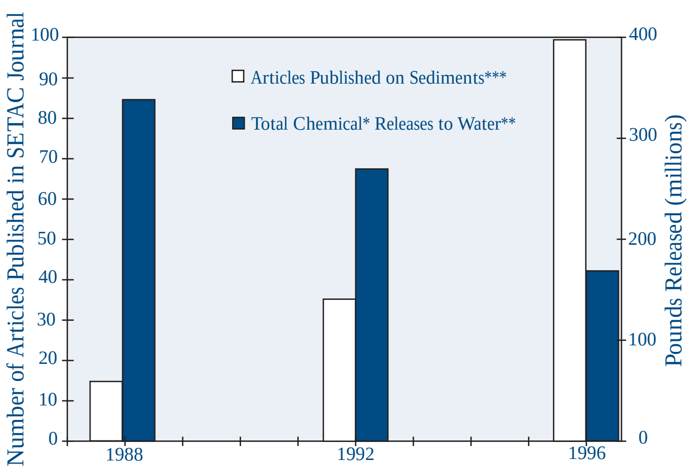
Overview: Contaminated Sediments

continued from pg. 1

caution before jumping to specific conclusions about any particular area or APC. For example, the Report did not consider bioavailability, and the sampling focused on areas where sediment contamination problems were expected, thereby biasing the conclusions regarding extent of contamination. Thus, while it is clear that some sediment contamination is evident, the question of its public health and ecological significance remains.

Perhaps the largest challenge being faced today in understanding the sediment contamination issue is the development of technically sound, widely applicable sediment criteria. Sediment criteria development is a topic of intensive research and development at many agencies and in *ad hoc* study groups. EPA is leaning toward two highly simplistic approaches: based on equilibrium partitioning between the solid phase and interstitial water in the sediment bed for organics, which sets sediment levels such that the interstitial water will be nontoxic to animals (EqP), and a metal availability criterion based on a sulfide-binding-precipitation parameter ("Acid Volatile Sulfides"). To date, EPA has promulgated such criteria for four PAHs and two pesticides. Other approaches are based on observed biota impacts, *in situ* or in lab tests, as a function of sediment contaminant concentrations. Examples include the State of Washington's Apparent Effects Threshold (AET) criteria, and NOAA's "Effects Level" criteria developed from a compilation of various sediment criteria databases. An *ad hoc* group focusing on the Great Lakes is also developing sediment criteria.



* As defined by TRI
** Source: U.S. EPA Toxics Release Inventory (1987-1997)
*** Source: Society for Environmental Toxicology and Chemistry (SETAC)

While releases to water bodies have declined substantially, interest in the sediment issue has risen dramatically within the same time period.

A key issue confounding the development of widely-accepted sediment criteria is the high degree of variability of sediments – their physical structure, chemistry, and biology. It may be simple to observe when a sediment area is "dead," in the most extreme cases, but for the vast majority in the "gray area," it is difficult to define the appropriate benchmarks. Do we always draw the line by strict comparison to universal criteria, or do we need to perform site-specific studies? Either approach can be unnecessarily expensive unless there continue to be efforts to develop a strong technical understanding of sediment contamination. Generally, however, site-specific considerations will almost always be appropriate, especially considering that the earth's sediments have always been a sink and continuing sedimentation offers a natural sequestering mechanism.

Intellectual efforts to forge this strong technical understanding continue. In addition to the criteria development activities of many agencies, many Superfund sites have such potentially expensive sediment problems that they foster studies leading to a better understanding of contaminant biodegradation and cycling, bioaccumulation, sediment transport, and other important issues. An *ad hoc* Sediment Management Working Group recently formed by industrial and government stakeholders is dedicated to promoting and disseminating such information (National Academy of Science, 1999).

These types of focused scientific inquiries are the best route to developing an understanding of the appropriate course of action for protecting the nation's sediments. In the meantime, caution must be exercised to not act precipitously until the full significance of sediment contamination is understood.

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U.S. EPA. 1999. *Contaminated Sediments News*. http://www.epa.gov/ostwater/pc/csnews.

Understanding Ecological Risks from Sediments: The Sediment Quality Triad

Biology, chemistry, and toxicology must all be considered in the assessment of sediment contamination.

Sediments provide habitat for many aquatic organisms and play an important role both as a sink and as a source of contaminants to the overlying water and biota. Because contaminant concentrations in sediments can be several-fold greater than concentrations in the water column, organisms in or near the contaminated sediments can be affected, even though U.S. EPA's ambient water quality criteria are not exceeded (Long, 1989).

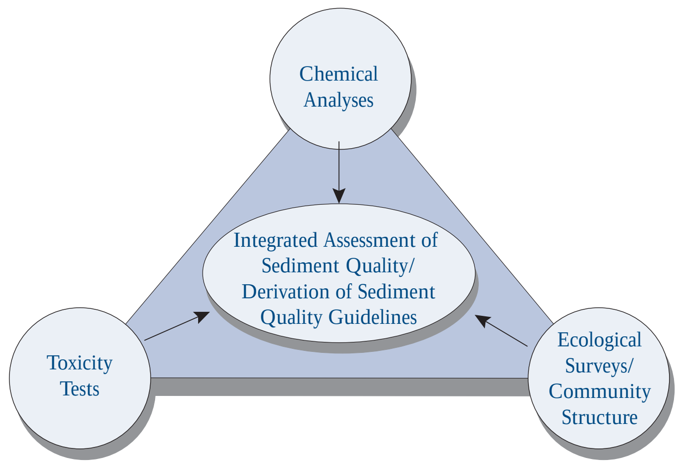
"Exceedance of any particular sediment quality guideline means very little with regard to sediment toxicity." (O'Connor, 1999)

The development of technically sound sediment quality criteria that can be widely applied to sediments from different sources is a difficult task (see related article). Chemical contaminant interactions in sediments are complex and often poorly understood. Contaminants associated with sediments may partition into dissolved and particulate fractions, which render them more or less bioavailable to biota than contaminants in the water column (Neff, *et al.*, 1988).

While there are several different approaches presently being used or developed to determine sediment quality guidelines, some of the sediment quality guidelines have come under criticism. Most recently, Thomas O'Connor of NOAA (O'Connor, 1999) stated that "exceedance of any particular sediment quality guideline means very little with regard to sediment toxicity." This is particularly true for those sediment quality guidelines that are based on only one or two parameters. For example, classification approaches that rely only on chemical data provide no evidence that the chemicals are bioavailable and biologically damaging. Similarly, classification approaches that rely on bioassay data alone may overestimate the poor quality of sediments. Finally, classification approaches that rely only on benthic community data, may be obfuscated by naturally occurring alterations in benthic communities, such as changes in depth or sediment structure. This suggests the need for an integrated approach (Long, 1989).

Ideally, a comprehensive assessment of sediment quality will include concurrent analyses of chemical concentrations, sediment toxicity, and the composition of resident benthic populations (Neff, 1988; Long, 1989). The complimentary nature of these three measures provides a spectrum of empirical evidence of both contamination and effect that can be used to classify the relative quality of sediments (Long, 1989). The Sediment Quality Triad (the Triad), developed in the mid 1980s, is just such an approach that uses toxicological data derived directly from sediments (*i.e.*, *in situ* effects and sediment bioassays) in concert with chemical analyses and biological studies of community structure to develop the necessary sediment quality criteria (see figure) (Chapman, 1986). The Triad approach is based on the assumption that the biological responses observed in sediment bioassays and *in situ* studies are a function of the concentration of certain chemicals sorbed to the study area sediments (Chapman, 1986).

Sediment Quality Triad



Chemistry, toxicology, and ecology combine to form an integrated approach to sediment evaluation.

Information obtained from the Triad approach can be used in several different ways. First, the information can be used in a descriptive mode, where the relative quality of sediments among sampling sites are evaluated and classified. Sites can be ranked independently for each of the Triad components to determine both geographic and temporal trends in sediment quality. Triad data can also form the basis for predictive models in which the relationships between collected biological and chemical data are used to estimate the relative degree of contamination that may be associated with biological effects. The Triad has been used as

continued on pg. 5

Human Exposures to Sediments

Human health risks from sediment exposure can occur as a result of fish ingestion and/or direct contact.

As a general rule, sediment cleanup actions are driven by ecological rather than human health concerns (see related article). And, the human health risks posed by contaminated sediments are often negligible compared to the human health risks *via* other media. However, there are two categories of potential exposure of humans to sediments that sometimes need to be assessed. First, for large water bodies, such as rivers and large lakes, exposure to contaminants in submerged sediments can occur indirectly through fish ingestion, when the fish have accumulated contaminants from the sediments. Second, for small water bodies, such as creeks, ponds and small rivers, there may be additional opportunities for direct contact, leading to ingestion and dermal exposure to sediments.

> *...although the potential for human exposures to contaminated sediments exists, risks from these pathways are difficult to quantify and are often expected to be secondary to ecological concerns.*

Variability in both ingestion rate and contaminant uptake by fish make human health risks arising from fish ingestion difficult to quantify. Considerable uncertainty exists in estimates of fish ingestion rates, which vary tremendously from one individual to another as a result of personal tastes or recreational habits, and also vary among populations. For example, U.S. EPA's *Exposure Factor Handbook* (1997) estimates that Native American subsistence fishermen consume three to four times the amount of fish as does the general U.S. population. However, the presence of a sensitive subpopulation for any particular sediment system needs to be demonstrated, not merely assumed.

While many contaminants bioaccumulate in fish and shellfish, bioaccumulation varies by contaminant, by fish species, and by waterbody. This variability is in part a function of the bioavailability of a contaminant; that is, the extent to which a contaminant is available to an organism for uptake. Further confounding the analysis is the fact that bioavailability of a contaminant to humans does not necessarily equal its bioavailability to fish.

Human health risks arising from direct contact with sediment generally occur as a result of recreational activities along shorelines or in small creeks. Direct contact exposures to sediments are generally limited to older children and adult populations *via* incidental ingestion and dermal contact. Exposure for very young children may be minimal for these types of activities, as adult supervision is likely to limit their contact.

Dermal exposure to sediment contaminants is a function of dermal adherence and dermal absorption. Dermal adherence of soils and sediments is correlated with soil moisture and inversely correlated with particle size, as many contaminants concentrate in small soil particles. Moreover, adherence varies with activity. A recent study by Kissel, *et al.* (1996) showed that the highest adherence corresponded to contact with wet soils, such as might occur during wading or other shoreline activities. However, increased dermal adherence alone does not necessarily imply increased risk. Many contaminants, including metals, have little to no dermal absorption. Even those contaminants with measurable dermal absorption may be absorbed from only the first few monolayers of material contacting the skin, and increased uptake may not be directly related to increased dermal adherence.

In summary, although the potential for human exposures to contaminated sediments exists, risks from these pathways are difficult to quantify and are often expected to be secondary to ecological concerns. This is especially true for metals, which, with limited exception, do not substantially bioaccumulate in fish and pose limited dermal contact risks.

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References:

Kissel, J., K. Richter, and R. Fenske. 1996. Field measurements of dermal soil loading attributable to various activities: Implications for exposure assessment. *Risk Anal.* 16(1):116-125.

U.S. Environmental Protection Agency. 1997. *Exposure Factors Handbook*. Office of Research and Development. Washington, D.C. EPA/600/P-95/002Fa.

By The Way...

ATSDR has developed a new toxicity criterion for mercury that is three times less restrictive than EPA's recently revised health effects standard for mercury.

Source: Research Triangle Institute. 1999. *Toxicological Profile for Mercury (Update).* U.S. Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR). National Technical Information Service (Springfield, VA) NTIS PB99-142416. March.

What's New at Gradient

Recent and Upcoming Presentations

Durham, NC. June 14. Barbara Beck. "A Probabilistic Version of the O'Flaherty Physiologically Based Pharmacokinetic Model for Lead: Calibration and Validation," at the U.S. EPA Workshop on Lead Model Development: Probabilistic Risk Assessment and Biokinetic Modeling.

Durham, NC. June 17. Teresa Bowers. "Comparison of Various Models for Calculation of Permissible Exposure Levels for Protection of Children," at the U.S. EPA Workshop on Lead Model Development: Probabilistic Risk Assessment and Biokinetic Modeling.

Washington, D.C. June 24. Eric Butler. "Forensic Applications of Petroleum Hydrocarbon Fingerprinting at a Wood-treating Site," luncheon talk at 2nd Annual IBC Executive Forum on Environmental Forensics.

New Orleans, LA. Sept. 15-17. Eric Butler. "Comments on Forensic Applications in U.S. Coast Guard Spill Sampling and Analysis," invited participant in the Greater New Orleans Barge Fleeting Association River and Marine Seminar.

Recent Articles

Conolly, R.B., B.D. Beck, and J.I. Goodman. 1999. Stimulating research to improve the scientific basis of risk assessment. *Toxicological Sciences* 49:1-4.

Goering, P.L., H.V. Aposhian, M.J. Mass, M. Cebrian, B.D. Beck, and M.P. Waalkes. 1999. The enigma of arsenic carcinogenesis: Role of metabolism. *Toxicological Sciences* 49:5-14.

To request copies of articles or presentations, please contact us at trends@cam.gradcorp.com or telephone Carol Counihan at (617) 576-1555.

Understanding Ecological Risks from Sediments: The Sediment Quality Triad

continued from pg. 3

a way to rank sites for remedial action, as was done in the Puget Sound in Washington State (Long, 1989). If sufficient data exist, the Triad can be used to estimate chemical thresholds above which biological thresholds are always observed (*e.g.*, apparent effects threshold or AET).

Although the Triad requires more intensive *in situ* data collection and expertise in three disciplines, this process has been accepted as the best approach to sediment evaluation in recent years. This concurrent examination of sediment toxicity and chemistry within the context of the observed sediment community structure provides an understanding of the significance of sediment contamination; and, hence, can form the basis for determining whether any remedial measure need be considered.

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Chapman, P. 1986. Sediment quality criteria from the sediment quality triad: An example. *Environmental Toxicology and Chemistry* 5:957-964.

Long, E. 1989. The use of sediment quality triad in classification of sediment contamination. In: *Contaminated Marine Sediments: Assessment and Remediation*. Committee on Contaminated Marine Sediments. National Research Council. National Academy Press. Washington, D.C.

Neff, J., B. Cornaby, R. Vaga, T. Gulbransen, J. Scanlon, and D. Bean. 1988. An evaluation of the screening level concentrations approach for validation of the sediment quality criteria for freshwater and saltwater ecosystems. In: *Aquatic Toxicology and Hazard Assessment: 10th Volume*, ASTM STP 971. Adams, W., G. Chapman, and W. Landis (Eds.). American Society for Testing and Materials, Philadelphia. pp. 115-127.

O'Connor, T. 1999. Sediment quality guidelines do not guide. Learned Discourses: Timely Scientific Opinions. *SETAC News* 19(1). January.

Guest Editorial: Risk Management of Contaminated Sediments

Addressing the results of decades of contamination requires a thoughtful approach.

In recent years, we have witnessed the beginning of a national debate on the significance of contaminated sediments. It's reasonable to say that many in the regulatory and regulated communities understand that there are sediments in river and estuarine systems which will need to be addressed in some manner. However, it is not clear yet whether all parties see the need for sediment management to be guided by scientific reasoning, and not by perception.

Before any decisions are made regarding a national sediment management approach, scientists and policy makers need to recognize that a number of these contaminated aquatic areas are the result of years of industrialization and economic growth, both of which have been key to improving the quality of life for many Americans. This is not an excuse for the contaminated sediment challenges we now face as a nation, nor does it suggest we should ignore the issue, but merely underscores that important, societal decisions were made over years and decades that contributed to the present situation.

> *...it is critical to determine whether the planned action will lead to a net improvement of the environment, and whether it will be sustainable...*

While implicit decisions led to the current situation, we need equally explicit decisions to guide our thinking on how we manage this issue. I'd like to suggest these guiding principles:

- First, the approach to restoring those systems most at risk should consider the best available scientific information, and weigh the risks of the current situation against those posed by the implementation of remedial actions. Remedial actions themselves have environmental consequences that have to be examined and quantified before a clear picture of the total risks and benefits of a particular action are fully understood.
- Second, the full range of remedial alternatives should be considered when selecting a remedy. Just as capping or natural attenuation may not be the technological fixes of choice for every management action, neither should dredging be viewed as a risk management panacea for every contaminated sediment site. Dredging, while a method of choice in some cases, also brings with it the need for disposal. The issue of disposal carries a high degree of uncertainty given the generally negative public opinion likely to accompany plans for any disposal location. Although no one technology will satisfy every situation, all should be considered based on their effectiveness, environmental risks, costs, and feasibility.
- Finally, it is critical to determine whether the planned action will lead to a net improvement of the environment, and whether it will be sustainable, rather than reversed over time by an inability to mitigate the continued input of aquatic contaminants. Of greatest concern in this respect is the ongoing societal tolerance for continued inputs from municipal and non-point sources that can impact sediment quality.

Even given the uncertainties and complexities associated with sediment remediation, I believe the public and private sectors can come together and develop a reasoned and balanced approach for addressing contaminated sediments.

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In the next issue:

Environmental Forensics: Who? What? When? Where?

Use of Transport Modeling as a Forensic Tool

Non-petroleum Forensic Chemistry

Guest Editorial: Lawyer's Perspective on the Importance of Environmental Forensics

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