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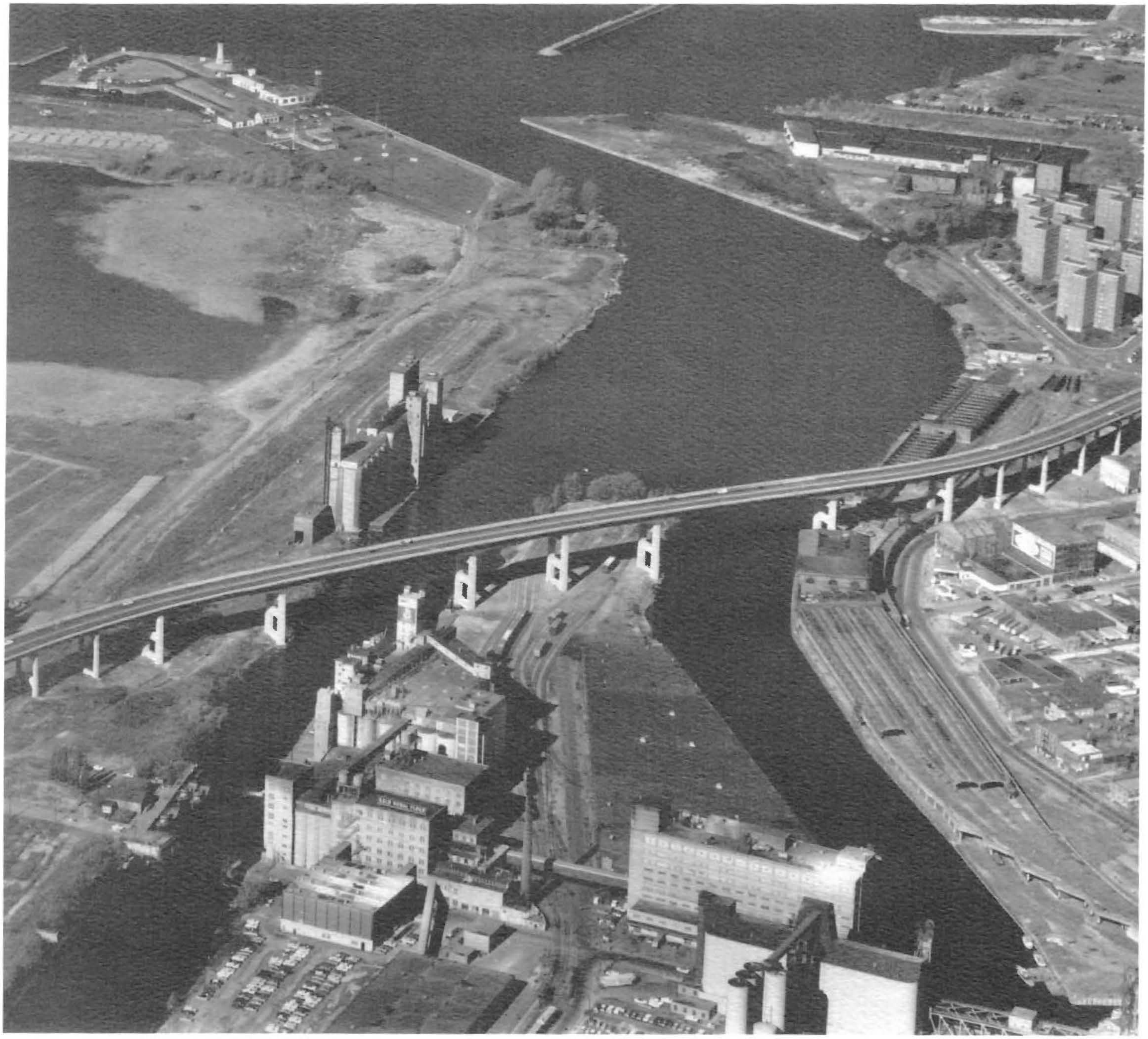


Focus On
Contaminated Sediments

Impact of Contaminated Sediments on Aquatic Systems

Development of Assessment Methodology Increases Understanding of Problems In the Great Lakes Ecosystem

By Joseph V. DePinto

Joseph V. DePinto

Dr. Joseph V. DePinto is a professor in the Department of Civil Engineering at State University of New York at Buffalo and director of the university's Great Lakes Program.

In spite of major efforts to reduce the impacts of toxic chemicals on human health and aquatic communities, continued problems of toxicity to aquatic organisms and bioaccumulation in aquatic food chains persist. One of the factors contributing to the persistence of degraded conditions in many systems is the presence of contaminated bottom sediments. Bottom sediments in many aquatic ecosystems have become contaminated through a gradual process which involves the deposition of external inputs by subjecting these externally derived contaminants to a variety of physical, chemical and biological water column and sediment processes. Although the ultimate fate of most of these "in-place pollutants" is to be inactivated by natural processes and burial in bottom sediments, this is a very slow succession which allows for shorter time scale impacts to occur.

The Great Lakes Ecosystem is a prime example of a situation where years of toxic chemical contamination have left sediments as a potentially significant source of detrimental impacts on the system. Contaminated sediments have been implicated as a causative factor of use impairments in all but one of the 43 Great Lakes Areas of Concern. Sediment cores collected throughout the basin reflect peak external inputs of heavy metals and synthetic organic chemicals in the 1960s and 1970s, followed by gradual declines through the 1980s. However, the concentrations of toxic substances in water, sediments, and biota seem to have leveled off at unacceptably high values.

This quasi-steady-state situation that exists in the Great Lakes is attributed to continued input of toxic substances from the atmosphere and other nonpoint sources, as well as from previously contaminated sediments. The extent to which biological exposure to in-place pollutants represents a significant source of ecosystem degradation is a critical, yet very complex, question facing regulatory and remediation managers.

In an effort to establish a sound scientific basis for making rational, site-specific management decisions regarding contaminated sediments in the Great Lakes, its research management community began to focus research on the development of a general methodology for addressing questions relative to exposure and biological effects of in-place pollutants in harbors, embayments, estuaries, connecting channels, and other nearshore areas in the Basin. One such integrated exposure/effects study on in-place pollutants was conducted from 1985-88 as part of the overall Upper Great Lakes Connecting Channels Study. It involved research on the relative significance and biological impact of in-place metals and toxic organics in the Trenton Channel of the Detroit River. This study has served as a paradigm for subsequent research, regulatory, and remediation programs aimed at determining the sources, transport, fate and biological effects of in-place sediment contaminants. Programs such as ARCS (Assessment and Remediation of Contaminated Sediments), a program established by EPA's Great Lakes National Program Office to demonstrate the assessment of the relative importance of contaminated sediments and implement rational remediation programs at specific Great Lakes Areas of Concern, drew heavily on the findings of the Trenton Channel In-Place Pollutant Study. The purpose of this article is to review the findings of the Trenton Channel Study and to generalize those findings towards assessment of the impact of contaminated sediments on aquatic systems. A much more detailed treatment of this Study can be found in the full report (Kreis 1988) and its appendices, which comprise the individual researchers' project reports.

Research and Management Questions

The Trenton Channel In-Place Pollutants Study was conducted by the USEPA Large Lakes Research Station, located in Grosse Ile, MI, with the participation of several cooperative research institutions, including Clarkson University, Indiana University, Manhattan College, Michigan State University, Ohio State University, Roswell Park Memorial Institute, University of California-Santa Barbara, University of Michigan, Raytheon-Grosse Ile, Michigan DNR, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers-Detroit

District, and Computer Science Corporation. The overall problem addressed by this group can best be stated in the form of a hypothesis:

> Through a series of fate and transport processes, including sorption by viable and non-viable suspended solids followed by settling from the water column, toxic substances entering a water body may tend to concentrate in the bottom sediments of the system. Once bottom sediments are contaminated (termed in-place pollution), depending on their characteristics and contaminant levels, they represent a potential source of toxicity and other biological effects. These effects can manifest themselves as direct effects on benthic organisms and bottom feeders or indirectly, through resuspension of this sediment particulate matter, as acute or chronic effects on water column organisms. The spatial and temporal distribution of particulate matter caused by resuspension can be predicted from measurable hydrologic factors and sediment properties. The actual exposure level and subsequent biological uptake and toxicity during a resuspension event depend on the phase/speciation changes in the contaminant of interest that take place and how these changes affect the contaminant bioavailability. The rate at which and extent to which the phase/speciation altering interfacial processes occur are significant in predicting exposure and effects. The rate and extent of these processes can be predicted from measurable water chemistry and bottom sediment properties.

Once a basic understanding of the impacts of contaminated bottom sediments has been gained through the accomplishment of integrated research such as the Trenton Channel Project, a number of very important management questions can be addressed. The types of questions managers must address include:

1) What are the best measures of biological exposure and effects from bottom sediment and how can these measures be used in the development of sediment quality criteria?

2) What is the best approach for the establishment of site-specific remediation goals and for the design of a remediation program?

3) What are the most appropriate and sensitive measures of the success of a remediation program?

4) What is the best approach for performing a quantitative assessment of the relative significance of "in-place pollutants" as a downstream source of contamination (*e.g.*, an additional source to be considered in performing toxic Waste Load Allocations?

5) How should contaminated sediments be dealt with as a potentially significant internal feedback process in system-wide toxic mass balance modeling efforts?

In establishing a sediment remediation program, it is not only necessary to prioritize among systems, but there are decisions that must be made as to what areas within a systems require remediation. Once this decision has been made, the question of selection of the most appropriate remedial technique must be addressed. In making these remediation decisions the "no-action" option should always be one of the alternatives. It is possible that detrimental impacts will diminish over time due to burial of contaminated sediments with uncontaminated sediment being deposited from upstream. There is also the possibility that a dredging operation will uncover underlying sediment with more contamination than those being removed.

Approach

There were two approaches taken in the Trenton Channel Study in addressing the above hypothesis (Figure 1). The first approach was a direct assessment of whether sediments collected from various locations within the study area would elicit toxic responses from test organisms in a variety of bioassays. This approach would allow comparison of the effectiveness and sensitivity of the end-points of each bioassay as well as

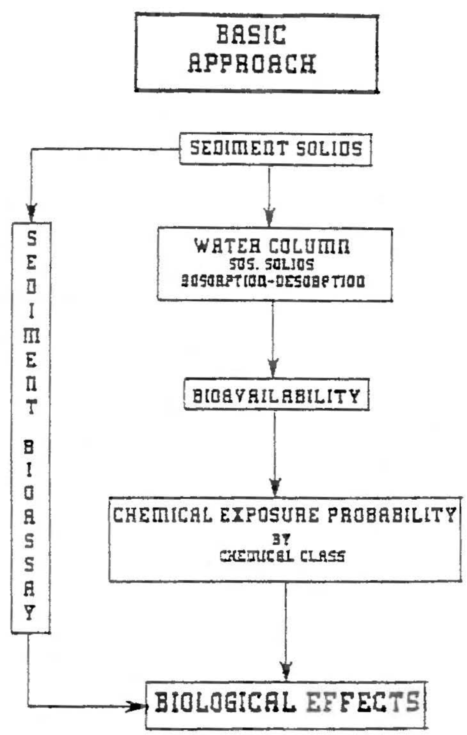


Figure 1. Schematic of dual-pronged approach applied in the Trenton Channel In-Place Pollutant Study. (from Kreis in 1988)

an assessment of the areal distribution of contamination/toxicity within the study site (*i.e.,* identification and quantification of "hot-spots" in need of remediation).

The need for a predictive capability in addressing the above management questions led to the concurrent utilization of the second, process-oriented approach. This approach was necessary for evaluating regulatory and remediation alternatives. It would also allow the understanding of cause-effect linkages.

In assessing the impact of contaminated bottom sediments, one of the major pathways for expression of water column effects is through the physical resuspension of bottom sediments. This particular cause-effect linkage requires the application of the process-oriented approach in order to gain a quantitative understanding of four coupled processes:

- ❑ prediction of the resuspension flux of particulate matter as a function of controlling environmental conditions;
- ❑ prediction of the advective and dispersive transport of resuspended sediments in the water column;
- ❑ prediction of the contaminant phase redistribution during a resuspension event;
- ❑ prediction of the biological exposure and effects of contaminants associated with a resuspension event.

Addressing the first three aspects of this problem required an integrated set of process experimental studies related to: physical and chemical characterization of bottom sediments; sediment resuspension, deposition and transport; and toxic substance sorption/desorption equilibrium and kinetics. It also required the synthesis of these findings into an overall assessment modeling framework. The fourth aspect was addressed in the Trenton Channel Study by conducting an array of 15 different bioassays, representing a range of test organisms and end-points and including both acute and chronic testing. These bioassays are summarized in Table 1.

***Table 1**. Inventory of bioassays used in the Trenton Channel In-Place Pollutant Study.*

Organism	Assay	End-point
Bacteria	1. Microtox®	Metabolism-Physiology
	2. Ames Test	Mutagenicity
	3. Glucose Uptake	Metabolism-Physiology
Phytoplankton	4. Carbon Uptake	Metabolism-Physiology
Zooplankton	5. *Daphnia pulicaria*	Ingestion Rates
	6. *Ceriodaphnia dubia*	Reproduction
	7. *Daphnia magna*	Survival
Oligochaetes	8. *Stylodrilus heringianus*	Avoidance-Behavior
Insects	9. *Chironomus tentans*	Movement-Behavior
	10. *Chironomus tentans*	Survival, Growth
	11. *Hexagenia limbata*	Survival, Growth
Mollusks	12. *Lampsilis radiata*	PCB Accumulation, Depuration
Fish	13. Channel Catfish	Feeding Rates
	14. Larval Yellow Perch (Passage Study)	Feeding Rates
	Rainbow Trout Eggs	Survival, Carcinogenicity

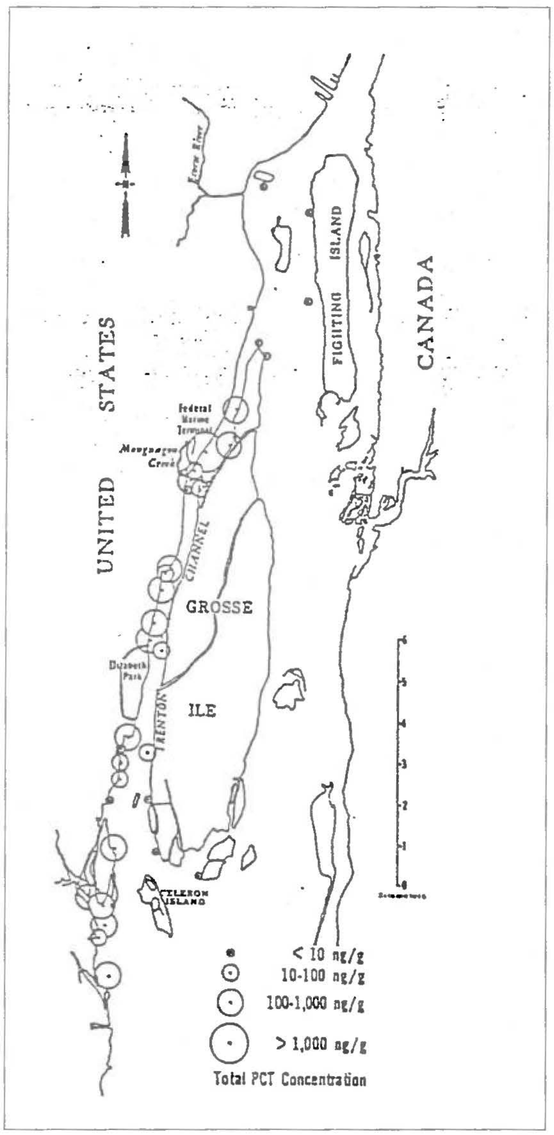
Results

Based on a preliminary survey of the study site, thirty (30) primary sediment stations were selected. Sampling and analysis was conducted at most of the thirty stations; however, some more difficult and time-consuming experiments were done at fewer while a relatively easy bioassay, the Microtox test, was conducted at many more locations.

In the chemical survey, sediments of the Trenton Channel were found to be heavily contaminated with a complex mixture of heavy metals and synthetic organic chemicals. Twenty-two of the 30 primary stations exceeded U.S. EPA dredging guidelines for heavily polluted sediments for at least one metal. Zinc, lead, and copper represented the heaviest relative contamination, although nickel, chromium, cadmium, cobalt and mercury were occasionally detected at excessive levels. Four stations exceeded guidelines for all metals tested, while eight stations did not exceed the guidelines for any of the eight metals tested. These results reinforced the observation that total metals concentrations in the sediments tended to correlate very well with each other. In other words, if a station was contaminated with one metal, it was more likely to be contaminated with others.

Major chlorinated compounds identified in the sediment extracts included: polychlorinated biphenyls (PCBs), hexachlorobenzene, polycyclic aromatic hydrocarbons (PAHs), octachlorostyrene, polychlorinated naphthalenes, and a series of polychlorinated terphenyls (PCTs). The highest contamination was located in the same general areas as the heavy metals. By way of example, the results of the sediment survey of PCT is presented in Figure 2. It demonstrates, as do the similar surveys for metals and other organics, that the most heavily contaminated area of the study site was a narrow "ribbon" of sediments along the western, nearshore zone of the upper Trenton Channel. The identification of high levels of contamination along the western shore is consistent with a number of physical and hydrodynamic characteristics of the system that would lead one to suspect contamination in this area. First, the area is located adjacent to a heavily industrialized land area. Also, the nearshore areas of the river tend to accumulate sediment during non-resuspension periods because of the lower river velocities in the shallow, nearshore zone. That is not to say that these contaminated sediments are not subject to resuspension events when bottom shear stresses are high enough. On the contrary, sediments in this area tended to be among the finest particle sized and highest porosity in the study site. Sediment resuspension potential studies found that sediments in this area had a high resuspension potential to be "stirred up" by wind- or wave-induced bottom shear stress. Resuspension probability modeling studies, however, indicated a relatively low occurrence of wind driven resuspension events in the impacted area; and since the flow variability of the Detroit River is minimal, water column toxicity in this system could not be linked to resuspension events.

Several sediment bioassays were used to assess relative toxicity of the study stations. Of the tests conducted, the *Chironomus tentans* (benthic worm) growth assay proved to be the best approach to resolve relative toxicity over the range of complex-mixture concentrations present in sediments of the study area. While only slightly less discriminatory, the Microtox test was much quicker and easier to conduct. For this reason, it could be applied to a much larger number of stations, thus obtaining a better spatial resolution of toxicity. Shown in Figure 3 are the results of the Microtox assay of the sediments in the Lower Detroit River. These results indicate significant areas of the Detroit River that are relatively unimpacted. They also corroborate the chemical analyses in the severely impacted zone along the western shore of the Trenton Channel. Tumors and pretumorous lesions were observed in five species of Detroit River fish at a rate of about 10% of the fish surveyed. Both external (oral/dermal) and internal (liver) tumors were observed. Tumorous conditions were not restricted to bottom-



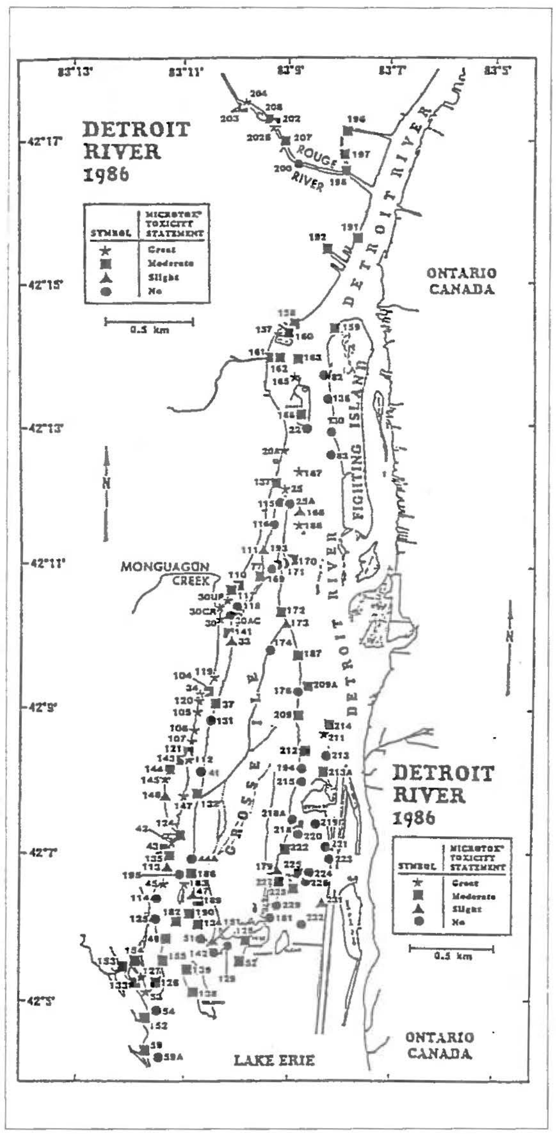


***Figure 2**, left.* *Distribution of total polychlorinated terphenyls in lower Detroit River surfical sediments, 1986.* ***Figure 3**, Surfical sediment toxicity as determined from the Microtox Assay on Lower Detroit River sediments, 1986. (Both from Kreis, 1988)*

feeding species; walleye were observed to have both external and internal tumors.

As was mentioned earlier, it is important for decision-makers to be able to identify the sediment zones within a given system that represent the most significant contaminated sediment hazard. In an effort to develop a means of identifying the toxic "hot spots" in a system, the project coordinator developed a sediment quality index by integrating the various sediment characterization factors used in this study (Kreis 1988). The approach involved numerically ranking each of the sediment stations relative to each other for a series of eight equally weighted physical, chemical, and biological sediment measures (total sediment metals levels, pore water metals, synthetic organic chemical levels, organic carbon, cation exchange capacity, grain size, mutagenic potential (Ames test), and overall toxicity). The results of the ranking system identified four numerically-defined sets of stations; these four groups ranged from the most-severely degraded to the least degraded. The results of this grouping is presented in Figure 4. As with several of the individual measures, this integration of data also identified the western shore of the upper Trenton Channel as the most-severely degraded zone. From a management perspective, sediment quality indexing techniques such as the one employed in this study can be very useful in designing a remediation strategy.

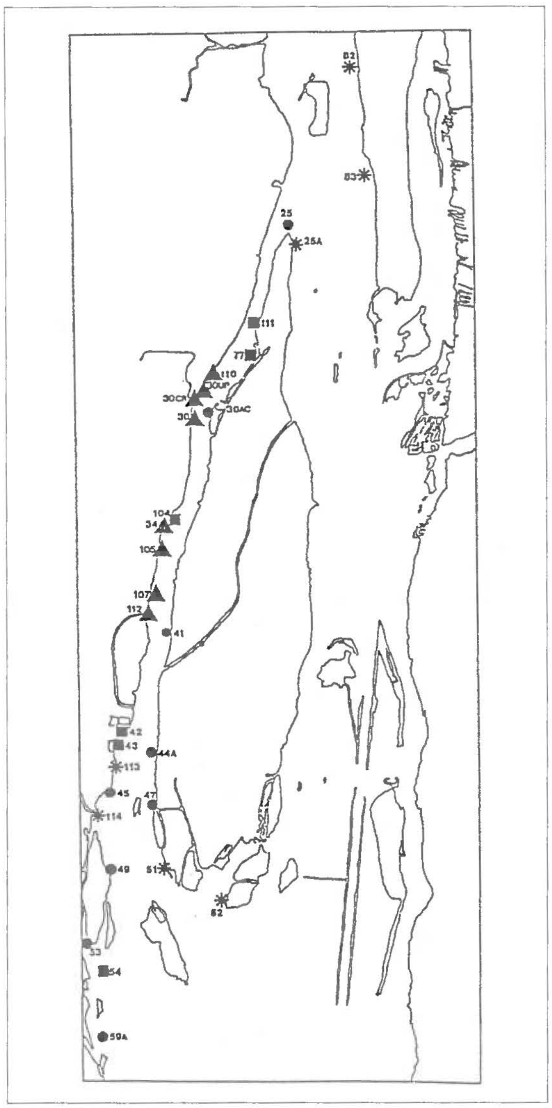


Figure 4. *Distribution of relative sediment degradation in the Trenton Channel as determined from the numerical ranking system applied to the Trenton Channel IPP Study. Degradation key: ▲ = severe, ■ = great, ● = moderate, ★= low. (Kreis, 1988)*

One other observation from the chemical analyses and bioassays of sediment cores is of interest. There were situations in which deeper sections of a core were more highly contaminated than the surface layers. The resolution of vertical contaminant distribution in the core is essential in order to assess the potential for dredging (as a remedial measure) to uncover more contamination than it removes.

Conclusions

The Trenton Channel Study demonstrated a high degree of correlation among various physical, chemical, and biological measures of sediment contamination. It suggested that a very useful sediment screening survey could be devised by judicious selection of a few key analyses that exhibited the best sensitivity and resolution in this study. Such a screening survey could identify sediment "hot spots" where further study and assessment could be focused. The study also revealed that sediment bioassays are largely unstandardized and, therefore, comparisons among different studies on different ecosystems should be made with great caution.

The model-oriented assessment track employed in this study showed some promise for aiding in the design and evaluation of site-specific remediation projects. Further research and development was indicated, however, in order to gain confidence in the field applicability of the modeling framework. The continued development of this approach has been a goal in subsequent studies of contaminated sediments. The successful completion of the ARCS program should provide a more refined and thoroughly tested modeling framework. Research on contaminated sediments is still ongoing within the Great Lakes ecosystem and in many areas throughout the world; and assessment techniques will continue to improve as knowledge of these systems increases.

Additional Reading

Kreis, R.G., Jr. (ed). 1988. Integrated study of exposure and biological effects of in-place sediments pollutants in the Detroit River, Michigan: An Upper Great Lakes Connecting Channel. Final report to the Upper Connecting Channels Study activities workgroup, U.S. EPA, ORD, ERL-Duluth, MN, and Large Lakes Research Station, Grosse Ile, MI, 153 pp.

Great Lakes Water Quality Board. 1987. Guidance on Characterization of Toxic Substances Problems in Areas of Concern in the Great Lakes Basin. Report of the Surveillance Workgroup to the Great Lakes Water Quality Board, IJC, Windsor, Ont. Canada, 129 pp.

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Acknowledgment

This research review article was written with permission from William L. Richardson, Director of the EPA Large Lakes Research Station in Grosse Ile, MI and Dr. Russell Kreis, research scientist at LLRS and project coordinator for the Trenton Channel In-Place Pollutant Study.

Recycled Paper Receives Seal From NYSDEC

This publication is printed on the first paper to be recognized as meeting the New York State definition of "recycled."

The New York State Department of Environmental Conservation awarded its official recycled seal to Mohawk Paper Mills earlier this year in recognition of two new lines of paper, one coated and one uncoated, that meet the state's requirement for 50 percent recycled fiber.

Mohawk's chairman and chief executive officer, Thomas D. O'Connor, says that the products already meet the state's 1994 DEC requirement for paper to contain at least 10 percent post-consumer waste.

Mohawk resisted pressure to introduce a recycled line until it perfected technology that would allow production of a premium paper that included a high proportion of non-deinked, post-consumer waste. De-inking produces sludge that must be landfilled or burned.

Several well-known organizations and corporations used the new Mohawk papers for their 1990 annual reports, among them the Audubon Society, Southwestern Bell, Niagara Mohawk Power Corporation, The Adirondack Council, Land's End, and the American Chemical Society.

The *Waste Management Research Report* has been printed on the uncoated recycled product from Mohawk Mills throughout 1991.

Buffalo Center Names New Board Members

George T. Berry

Gerald R. Ehrman

Two new members have been appointed to the executive board of the New York State Center for Hazardous Waste Management headquartered at the State University of New York at Buffalo.

George T. Berry, chief executive officer of the Delta Group in New York City, was appointed by William Greiner, president of the State University of New York at Buffalo.

Gerald R. Ehrman, plant manager of DuPont Chemicals in Niagara Falls, was appointed by the New York State Senate.

At the Delta Group, Berry is one of 15 semi-retired professionals who offer their management expertise to electric generating utilities. Clients include utilities in Massachusetts, Minnesota, Pennsylvania, New York and other states. Berry also teaches a course at Rensselaer Polytechnic Institute in Troy, NY.

At DuPont, Ehrman is responsible for maintaining environmentally sound production techniques while achieving optimum quality. He has developed programs for satisfying the requirements of several government agencies in matters of safety, health and the environment.

Recycling Conference and Waste Reduction Workshop Scheduled in November

The Division of Solid Waste of the New York State Department of Environmental Conservation (DEC) will sponsor its third annual Recycling Conference and New York RECYCLExpo November 12 and 13 in the Genesee Plaza Holiday Inn in Rochester, NY. The Cornell Waste Management Institute will sponsor a Commercial and Institutional Waste Reduction Workshop the following day, November 14, in the same location, with the "Garbage Cannes Film Festival" linking the two events from 7:30 to 9:30 p.m. November 13.

The DEC conference will focus on the needs of government officials, recycling management professionals, the recycling industry, environmental groups, private citizens, and scientific, technical, and academic professionals.

The Cornell Workshop will focus on the needs of businesses and institutions with discussion of regulations, waste generation and reduction, and ways to implement change in the business or institutional setting.

Interested persons may call Debbie Jackson at (518) 457-7337 for information about the NYSDEC event and Carin Rundle at (607) 255-5940 for information about the Cornell Waste Management Institute workshop.

Pilot Study of Sediment Remediation Technology

The Sheboygan River Case Study Tests Armoring and Dredging

By Mark P. Brown and Dawn S. Foster

Mark P. Brown

Dawn S. Foster

The Sheboygan River and Harbor Superfund Site has been a fertile area for the engineering of remedial alternatives for contaminated sediment. Although there are as yet unanswered questions about the effectiveness of dredging, sediment armoring, and bioremediation, the particular circumstances of this PCB-contaminated site have led to valuable hands-on experience with these sediment remediation techniques.

The Sheboygan River is 173 miles long and drains 105 square miles of eastern Wisconsin discharging to Lake Michigan. The lowermost 14 miles of river and a 100-acre harbor are a Superfund site due to the presence of PCBs and metals released by a number of industrial sources. Upstream of the Harbor, the site is a series of alternating sections of free-flowing river and impoundments.

The circumstances which led to the pilot study of sediment remediation technologies include:

- ❑ determination by the EPA that certain PCB "hot-spot" sediments needed to be removed
- ❑ the decision of Tecumseh Products Company (the only one of four potentially responsible parties) to conduct the work;
- ❑ the relatively small volume of sediment that posed a concern;
- ❑ the ability to manage the risks of the proposed activities to a high degree.

A total of 2500 cubic yards of sediment in nine separate areas were targeted for removal as part of the Pilot Study, based upon the presence of PCB concentrations greater then 700 ppm. Collectively these areas comprised approximately 25,000 square feet of river bottom. In addition to dredging, a total of 15,000 square feet of river bed in five separate areas were slated for armoring. These areas contained maximum PCB concentrations ranging from 36 to 580 ppm. Average water depths in areas for dredging and armoring were in the range of two-to-three feet. Recent research findings which established the potential benefits of anaerobic dechlorination of PCB in sediments, including Sheboygan River sediments, were incorporated into the planning and design of both sediment armoring and dredged sediment disposal.

Dredging activities were highly controlled. Areas to be dredged were completely enclosed by two separate silt curtains. Chains along the bottom of the curtains conformed to the river bed and anchored the curtains. A barge-mounted clam-shell dredge, in addition to a backhoe, were used to remove sediments. The backhoe was used in areas inaccessible by the clam shell. The clam shell was specially modified to minimize spillage.

Operational protocols guided the dredging operation to efficiently remove the contaminated layer and minimize the risks of transferring and transporting the sediment. Two complete passes of the clam shell were effective in reducing residual contamination to less than 10 ppm. The backhoe was less successful in reducing PCB concentrations to acceptable levels. Consequently, four areas which were dredged were also armored to contain the residuals. The sediment was transferred to a specially-designed confined treatment facility (CTF) for biotreatment.

Sediment armoring was installed in nine areas to prevent contaminant release via erosion and to retard any chemical flux while accommodating the ongoing anaerobic dechlorination of PCB in the sediment bed. These areas were completely enclosed by silt curtains during the installation. The sediment armor is a sandwich of run-of-bank gravel between layers of geotextile fabric capped at the surface by cobbles. This layered system was anchored to the river bed and river banks by rock-filled steel cages known as gabions.

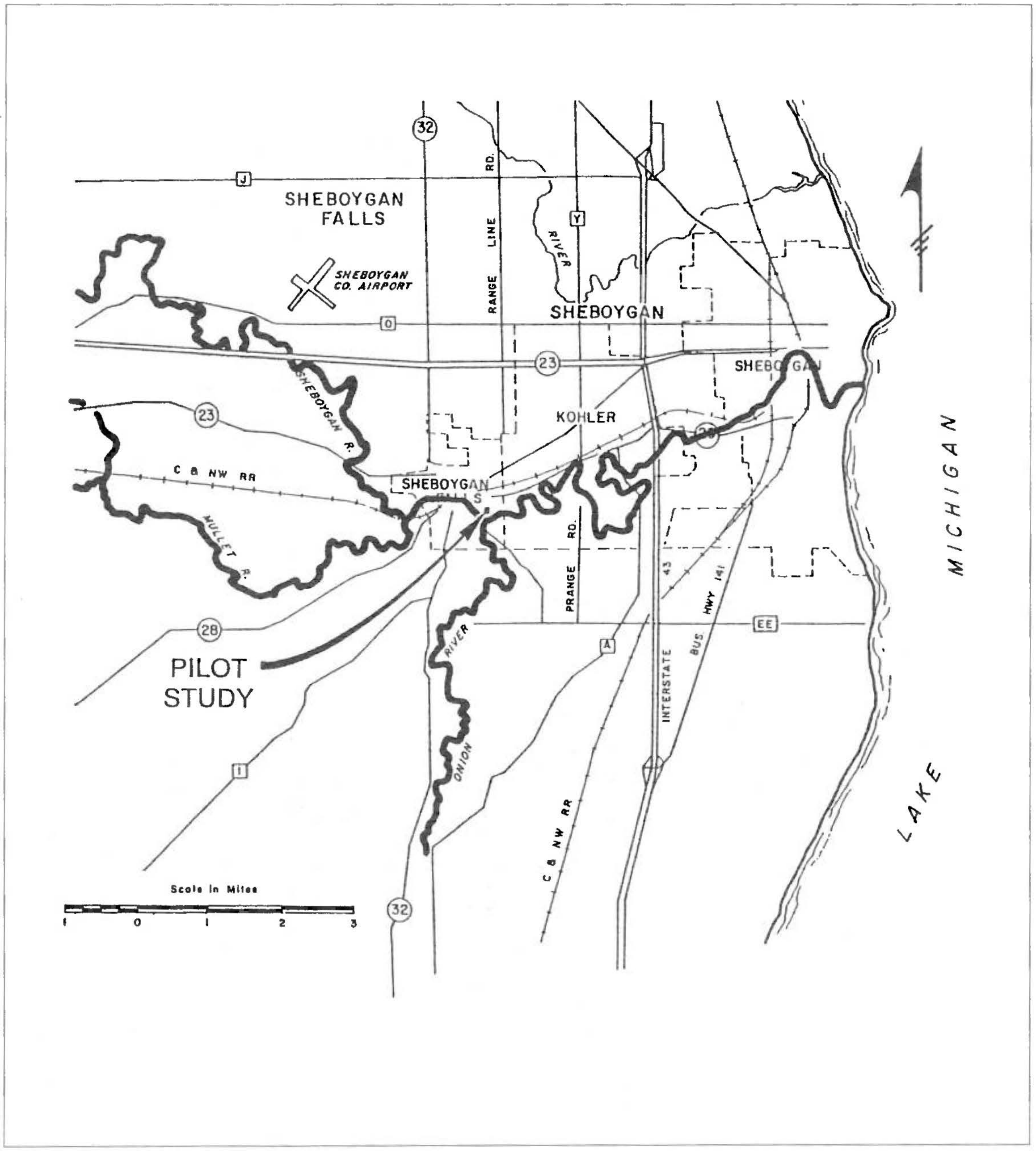
Openings were created within the armor to permit monitoring of the progress of anaerobic PCB dechlorination in the sediment below. *In-situ* anaerobic dechlorination has already detoxified the mixtures found in Sheboygan River sediment by more than 50 percent. In the year since the armor was installed, the armor has been covered with sediment and rooted aquatic plants have taken hold.

Both the dredging and sediment armoring were completed within a one-year period ending in October 1990. Under a separate EPA decision, a second phase of dredging, which began in June, 1991, will remove an additional 2500 cubic yards of sediment from the river.

Dr. Mark P Brown and Dawn S. Foster, P.E., are affiliated with Blasland & Bouck Engineers, P.C., in Syracuse, NY.

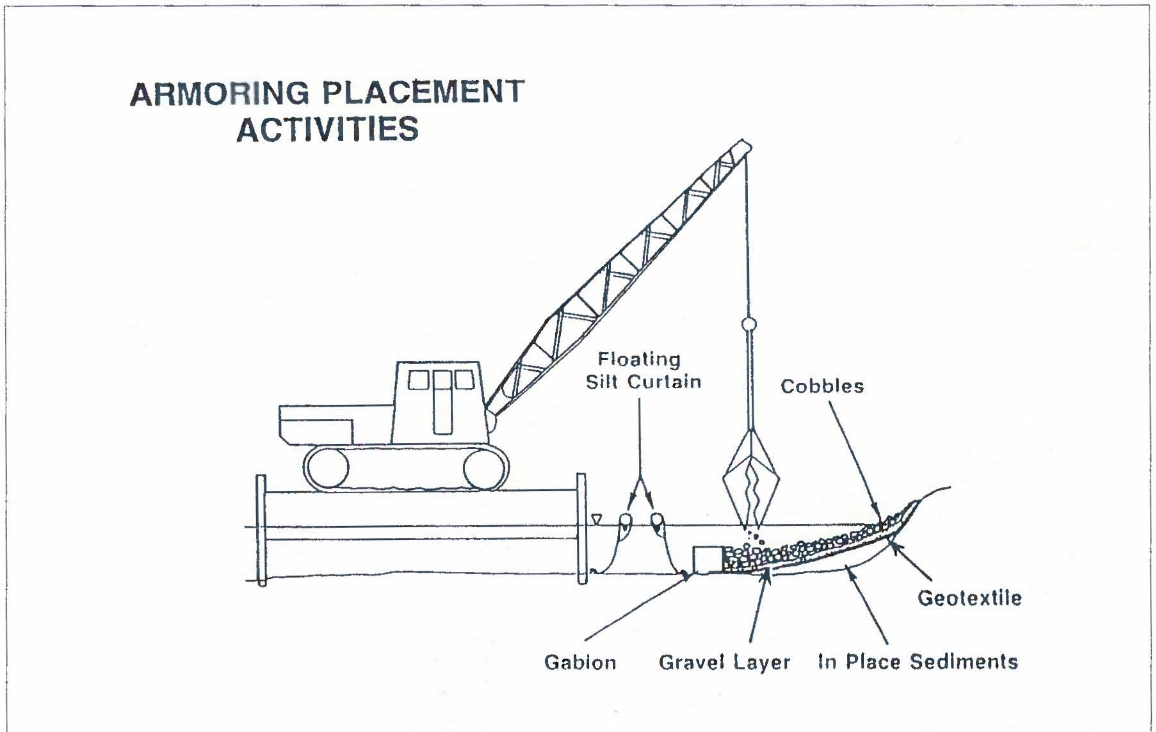
In conjunction with the pilot study of dredging and armoring, the first large-scale experiment to bioremediate PCB contaminated sediment is underway in the Sheboygan River and the CTF. The CTF, which sits on property adjacent to the river, is essentially an above-ground open-topped tank with exterior walls of interlocking sheetpiling and multiple plastic interior liners. The system has been subdivided into four cells which have independent plumbing for the delivery and management of solutes in the sediment pores. The CTF has a surface area of 14,000 square feet and contains four-to-seven feet of sediment. Ongoing bench-scale research at the University of Michigan is testing different formulations of amendments to enhance the current rate of anaerobic dechlorination in the CTF sediment. Baseline sampling of the CTF has been completed. The testing of the amendment delivery system will be completed this year with the large-scale experimental treatment to begin in late 1991 or early 1992. As with the sediment below the armor, anaerobic dechlorination has already substantially detoxified the mixture of PCBs in the CTF. The CTF demonstration of biotreatment will also be studied by EPA's Assessment and Remediation of Contaminated Sediments Program.

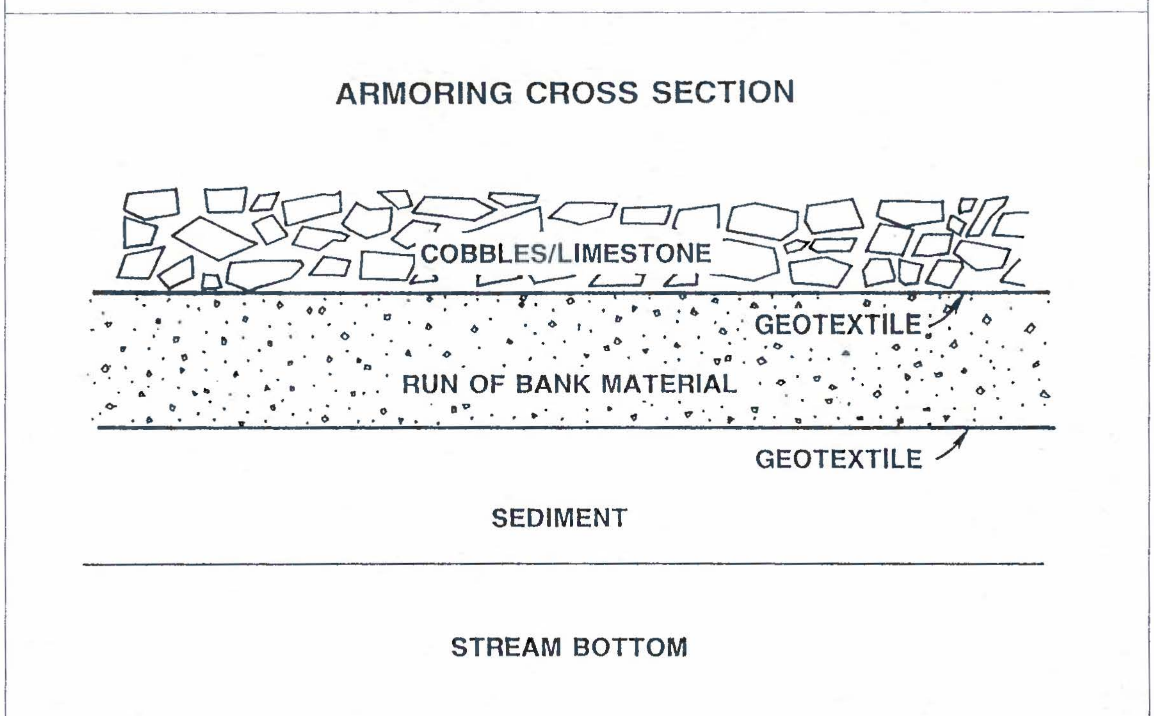
Work in the Sheboygan River has demonstrated that in certain situations practical approaches using conventional technology can be



highly effective in reducing the availability of sediment contaminants to the environment while minimizing the short-term risks of the technology. The experience has advanced knowledge of the costs, practicability, and effectiveness of contaminated sediment dredging and armoring. It can be shown that the estimated human health risks due to direct contact with nearshore sediments has been substantially reduced. However, the long-term effectiveness of the removal of these areas in reducing PCB levels in other exposure media, particularly fish, is yet unknown. Monitoring of PCB levels in caged fish is being used to examine the effectiveness of sediment removal and armoring.

Decisions to undertake larger-scale sediment remediation projects for the Sheboygan River and other sites will need to establish a greater level of confidence that remediation will significantly reduce contaminant transport and resulting effects over the long-term. In general, the current level of confidence does not seem to support the scale of investment requisite of large-scale sediment remediation projects.

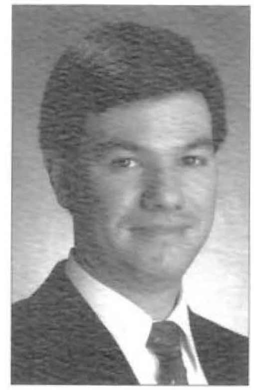




ARCS Program

Environmental Protection Agency Studies Contaminated Sediments In the Buffalo River

By Stewart W. Taylor



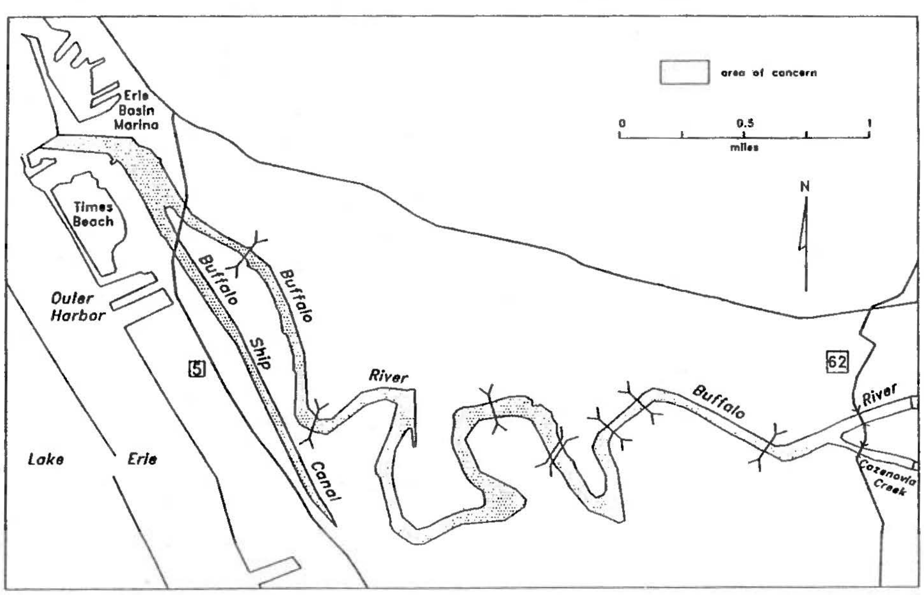
Stewart W. Taylor

The Buffalo River has been selected by the U.S. Environmental Protection Agency (EPA) as a pilot site for participation in the Assessment and Remediation of Contaminated Sediments (ARCS) program. The ARCS program is a five-year study and demonstration program established by the U.S. Clean Water Act relating to the control and removal of toxic pollutants in the Great Lakes, with emphasis on the removal of toxic pollutants from bottom sediments. This program is administered by the Great Lakes National Program office of the EPA, located in Chicago. Researchers at the University at Buffalo and the College at Buffalo are assisting in the ARCS Study of the Buffalo River by conducting field studies, analysis of samples and developing estimates of pollutant loadings to the river from point and non-point sources.

Environmental Significance

Contaminated sediments are ubiquitous in the industrialized waterways of the Great Lakes. Officially, there are 42 so-called "areas of concern" within the Great Lakes basin, as designated by the International Joint Commission. The Buffalo River area of concern is shown in the accompanying figure and photograph. Sediments in these waterways have been contaminated by a variety of pollutants released in industrial wastestreams or by accidental spills over a period spanning several decades. Much of this contamination occurred prior to the 1970s when industrial activity was high in the Buffalo area. With the present regulation of pollutant discharges to the environment, the rate at which sediments are being contaminated has been significantly reduced. However, potential sources such as industrial wastewater discharges, combined sewer outfalls, and seepage of contaminated groundwater from inactive hazardous waste sites continue to pollute the Buffalo River. {see schematic}.

Sediments in most "areas of concern", including those of the Buffalo River, are contaminated with chemicals which adsorb strongly to the sediments and have little affinity for water. In other words, if one were to measure the distribution of these pollutants in a water-sediment mixture, the pollutant concentration in the sediment would be many times greater than the concentra-



Buffalo River Area of Concern

Dr. Stewart W. Taylor is an assistant professor in the Department of Civil Engineering at State University of New York at Buffalo.

tion in the water. Pollutants commonly found in sediments include polychlorinated biphenyls (PCBs), pesticides, petroleum-derived products, and heavy metals such as lead. In the Buffalo River sediments, a group of organic chemicals called polycyclic aromatic hydrocarbons (PAHs) are the major pollutants. Many of these pollutants are considered to be carcinogens in both fish and humans.

Contaminated sediments are of environmental interest because the pollutants tend to bio-accumulate and propagate through the food chain. These pollutants are known to bio-accumulate in aquatic insect species which burrow in and feed upon the sediments. Bottom-dwelling fish, such as brown bullhead and carp, consume these insects by sifting through the sediments, further concentrating the pollutants in their tissues. Human consumption of these fish is an important exposure pathway.

The ARCS Program and the Buffalo River

The primary objectives of the ARCS program are to evaluate and demonstrate methods for assessing the extent of sediment contamination and technologies for remediation of contaminated sediments. Although this program is being applied at five demonstration sites, one being the Buffalo River, the findings will transfer to other "areas of concern" and locations in the Great Lakes.

For the Buffalo River, the assessment of contaminated sediments is on-going and is a two-step process. First, the nature and extent of sediment contamination is being assessed by extensive environmental sampling. Cores of bottom sediments and samples of river water have been taken from the area of concern and analyzed to map pollutant levels along this river reach. Results of this sampling provide a "snapshot" in time of the distribution of pollutants in the river sediments and the locations of high concentrations, "hot spots."

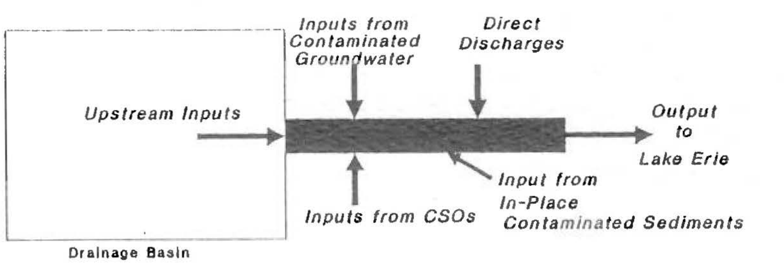
Second, computer models of the Buffalo River, which simulate the transport and fate of pollutants in the sediments and river water, are being used to predict how pollutant levels might change in the future. With these models, "what if" management questions can be addressed. For example, will pollutant levels in fish be reduced if pollutant "hot spots" are dredged, or will "hot spots" be buried with incoming clean sediments and no longer pose an exposure problem? Results from this step of the study will be used to guide the development of a comprehensive Remedial Action Plan for the Buffalo River.

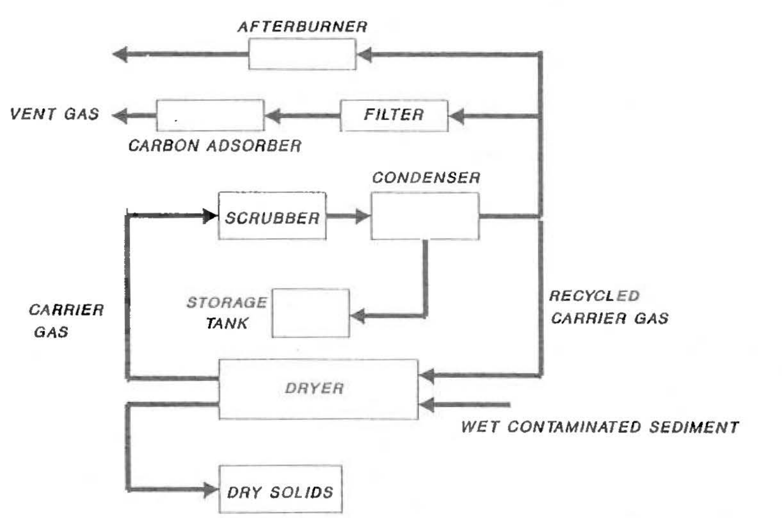
Once the nature and extent of the contaminated sediments have been determined, ARCS will demonstrate clean-up technology for a selected portion of the river sediments. Based on the nature of the PAHs (the primary contaminants of concern in the Buffalo River), a thermal extraction process has been selected for pilot-scale demonstration.

A small portion of sediments will be dredged from the river, dewatered, and then treated by this process, selected for demonstration because of the propensity for PAHs to volatilize (or evaporate). Moderately elevated temperatures increase the rate of evaporation, transferring the contaminants from the sediment to a carrier gas stream (see accompanying flow chart). In this way, sediments are cleaned and the volume of contaminated residuals has been greatly reduced.

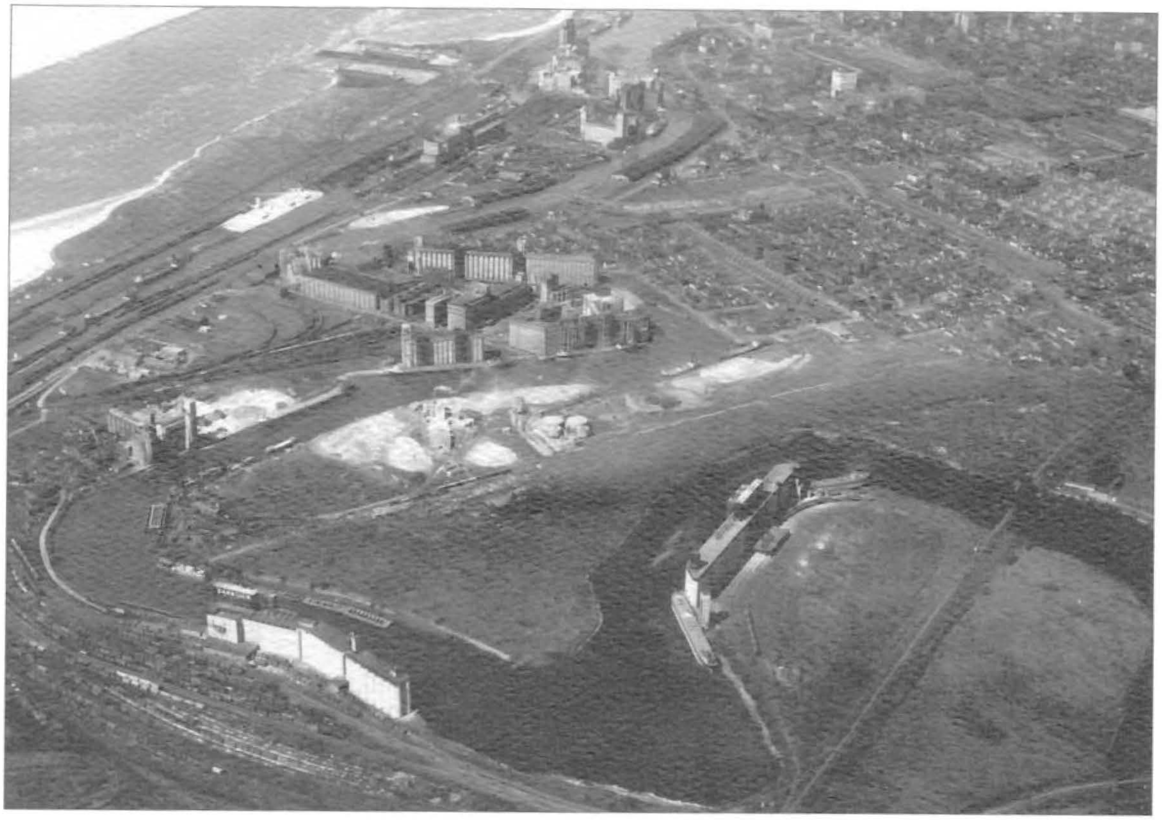
The ARCS study in the Buffalo River and at four other selected sites will provide an extensive data-base, including evaluation of potential remediation technologies, that will guide management decisions at other "areas of concern" within the Great Lakes region.

Buffalo River Schematic
AREA OF CONCERN





THERMAL EXTRACTION PROCESS



Aerial view of the Buffalo River, left, c. 1975. Photograph courtesy of The Lower Lakes Marine Historical Society.

NYS Center for Hazardous Waste Management Offers Research and Development Reports

The New York State Center for Hazardous Waste Management announces the availability of several recently printed reports that summarize the research findings from Center-funded projects. These 10-page summaries, designed to communicate briefly and effectively the objectives, methods, findings and significance of each research project, deal with projects undertaken at NYU Medical Center, Rensselaer Polytechnic Institute, SUNY College of Environmental Science and Forestry, SUNY at Stony Brook and Corning, Inc.

The newly-printed reports are:

Alexander, M.G., (Corning Inc.), "**Vitrification of Ash from Waste-to-Energy Incinerators**"

The goal of this project is to demonstrate that fly ash from waste-to-energy incinerators can be vitrified, as a method of immobilizing toxic metals. Ash samples from WTE incinerators were subjected to chemical analyses, leach testing of the pristine ash, and melting experiments. Vitrification parameters and glass compositions were determined. Glassy materials produced were subjected to leaching tests. Experiments continue using cold-crown vertical melting furnaces, with special attention to gas evolution, condensation in the "blanket" cover, and segregation of components.

Young, L., (NYU Medical Center), "**Bioremediation Strategies for Benzenes and Napthalenes under Anaerobic Conditions**"

This project focused on the demonstration of biodegradative activity under anaerobic conditions of benzene, toluene, xylene {BTX} and polynuclear aromatic hydrocarbons, chemicals commonly associated with contaminated soils at former manufactured gas plant sites. Enrichment cultures on BTX were initiated and resulted in the mineralization of toluene and m-xylene and the toluene-dependent transformation of o-xylene. Carbon balances demonstrated that greater than 50% of the toluene and m-xylene carbon was oxidized to carbon dioxide with the remainder assimilated into cellular carbon. Denitrifying enrichment cultures on coal tar were also initiated, with a focus on the biodegradation of PAH. No biodegradation was observed of PAH nor of BTX; but, upon dilution of the coal tar, an increase of denitrification activity was observed, indicating that biodegradation may have been inhibited by toxicity of the coal tar.

Wiberley, S., (Rensselaer Polytechnic Institute), "**Evaluation of Productive Uses of Hazardous Solid Waste Generated by General Electric Silicone Products Division at Waterford, NY**"

This report describes procedures used to characterize a listed solid hazardous waste from silicone manufacture and the investigation of possible industrial applications for the waste. Analytical testing revealed that amorphous silica, calcium carbonate and copper were present in significant amounts. Possible industrial applications investigated were copper recovery by bioleaching, the production of glass, and partial replacement of cement in mortar or concrete. Further large-scale tests are underway using the solid waste as an additive to cement in concrete.

Tanenbaum, S., (SUNY College of Environmental Science and Forestry), **"Anaerobic Respiration for the Biodegradation of PCBs"**

This research program aimed to isolate and identify microbial consortia that might utilize nitrate as electron acceptor for PCB dissimilations. Three environmental isolates were obtained by conventional enrichment techniques which exhibited significant degradation capabilities for Aroclor 1242. All three cultures demonstrated a preference for congeners with "open", 2,3 sites, indicative of a critical role for 2,3-dioxygenase activity. These new isolates may be of use in future bioremediation processes which involve an initial anaerobic dechlorination of the more heavily substituted chlorobiphenyl components within the various commercial PCBs.

Swanson, R.L., (SUNY Stony Brook), **"Stabilized Incineration Residue in Shore Protection Device"**

The goal of this research was to stabilize potentially toxic incineration residue rendering it harmless and to then use the stabilized material for the purposes of constructing energy deflecting or absorbing structures to reduce shore erosion. The secondary material produced may have other applications in marine construction. Sample ash was collected at an operational mass burn facility and characterized physically and chemically. The ash, following removal of ferrous metal, had a grain size distribution similar to light weight aggregate; moisture and specific gravity were within the range of acceptable values; and the absorption and percentage of friable particles was higher than observed for natural aggregates. Using Portland cement and chemical admixture, samples of concrete were fabricated using the processed ash and tests for unconfined compressive strength were in excess of 3000 psi. This research is continuing with a focus on the evaluation of the performance of marine structures using concrete with ash aggregate.

To order the reports, write or call: New York State Center for Hazardous Waste Management, SUNY Buffalo, 207 Jarvis Hall, Buffalo, NY 14260, (716) 636-3446. Make checks payable to The University at Buffalo Foundation. Reports are $5 (five dollars) per copy.

Booklet Available

Boyer, Barry B., **"No Place to Hide: Great Lakes Pollution and Your Health."** Published by the Baldy Center for Law and Social Policy in conjunction with the Great Lakes Program, SUNY at Buffalo, ISBN 0-9630415-0-9, 1991, 40 pp.

This booklet provides an excellent overview of the origins, types, and effects of pollutants in the Great Lakes and includes discussion of what is being done to remedy potential problems. The author asks six major questions and gives balanced, well-researched answers in easily-understood language. The booklet offers an interdisciplinary perspective not commonly available. The booklet is $5, payable to the University at Buffalo Foundation. To order, write the Great Lakes Program at SUNY Buffalo, 207 Jarvis Hall, Buffalo, NY 14260 or call (716) 636-2088.

Hot, Dry Weather Contributed To Lowered Sediment Oxygen In the New York Bight

The Waste Management Institute at Stony Brook participated in three cruises this summer with the New York City Department of Environmental Protection aboard the agency's research vessel OSPREY. The purpose of these cruises was to examine the levels of bottom dissolved oxygen in the New York Bight area, particularly along the northern New Jersey coast.

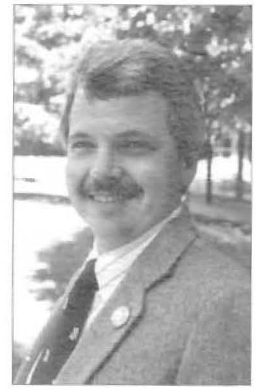
Low precipitation, and resulting low fresh water discharge from the Hudson River, and excessive atmospheric heating during the year caused surface salinity and temperature values to be higher for the summer of 1991 than for other years. Early atmospheric heating increased water column stratification and isolation of the bottom layers. This, in turn, caused an earlier onset of bottom dissolved oxygen depletion without replenishment from saturated surface waters, as compared to other years.

The average bottom oxygen concentration in August was as low as it has been since 1976, the year Bight waters experienced extensive anoxic conditions. The average was, however, within the variance of past observations. By early September, following Hurricane Bob and some atmospheric cooling, there appeared to be signs of water column destratification and a slight increase in the mean value of dissolved oxygen.

Dredging Contaminated Sediments

Good Operating Procedures Lead to Reduced Dispersion

By Henry Bokuniewicz



Henry Bokuniewicz

When dredging contaminated sediment, whether as part of a project to improve navigation or a clean-up operation, avoiding uncontrolled dispersion of the contamination is a principal concern. The most serious contamination problems occur in fine-grained sediments. The resuspension of sediment can be controlled, however, by customized procedures and specialized equipment. The technology is well developed and, once the required level of control is decided, the principal problems are ones of cost and availability.

In 1989, the National Research Council undertook an investigation of contaminated sediments (Kamlet, et al., 1989). Included in this assessment were reviews of the technology for environmental dredging done by Cullinane, et al (1989) and Herbich (1989). This article is a review of the options based largely on this previous work.

> *. . . avoiding uncontrolled dispersion of contaminated sediments during a dredging operation is a principal concern . . .*

It may not be necessary to dredge at all. If the source of contamination has been eliminated, or, if sedimentation patterns have changed, uncontaminated sediment may be accumulating over the contaminated material. In time, therefore, the contamination may be contained by the layer of clean sediment and isolated from disturbances due to storms or flood and beyond the reach of burrowing organisms. If the natural accumulation of uncontaminated sediment is not happening rapidly enough, it may be possible to cover the contaminated sediment in place artificially, as long as the contaminated sediment has a strength sufficient to support the cap. Contaminated sediment that exists as fluid mud cannot be covered. In other situations, burial is not an option. Navigable waters may not be allowed to shoal, for example, or the contamination may be such that, a cap of clean sediment would not be a barrier to the release of contaminants. This would be the case if the contaminated sediments are flushed with groundwater with the potential for remobilizing some species of the contamination. (Even in this case, however, it may be possible to isolate the contaminated sediment with an impermeable cap, sort of upside-down liner, although there is no documentation of any places where such a technique has been used.)

If dredging is unavoidable, good operating procedure is required. The location and depth of dredging should be well known and monitored. Problems, such as leaky pipelines, broken barge doors, even, perhaps, exceptional weather, should require the operation to shut down while repairs or adjustment are made. The control of anchors or other mooring equipment and boat traffic associated with the dredge can also be helpful in reducing resuspension.

It may be that adverse impacts can be further minimized while using standard equipment by instituting special controls on the procedure. If dredged sediment is being transferred into a barge or hopper, filling of the barge compartments or the hopper can be limited to prevent the overflow of turbid water. A quantitative study of barge overflow found that about 1 percent of the dredged material overflowed during loading and most of that settled back to the sea floor in the immediate vicinity (Tavolaro, undated). There is a price to pay for applying this restriction to dredging operations. Prohibiting overflow reduces the load each barge can receive so more barges must be filled at a cost of time and, perhaps, additional equipment. A barge or hopper loaded without overflow also has a high water content. This could pose turbidity problems at the disposal site. Restrictions might also be imposed on the dredging schedule to avoid resuspending materials under conditions which would allow it to be widely dispersed. In this way, the resuspended sediment could be ex-

Dr. Henry Bokuniewicz is a professor at the Marine Sciences Research Center, State University of New York at Stony Brook.

pected to resettle in the same area. Avoiding operation during times of maximum tidal current, of high river flow, or of strong winds may all help to reduce the amount of uncontrolled dispersion, but could greatly add to the time and cost of the project.

The next level of protection would probably involve the installation of barriers to inhibit the spread of resuspended sediment from the site. Installing, barriers may prove to be more economic than placing restrictions on the dredging itself. Silk curtains are flexible, impervious barriers suspended from surface floats. Properly used, they can be effective in quiescent environments but are not generally reliable in open ocean conditions or where current speeds exceed 50 cm/sec. (Herbich and Brahme, 1983). In addition, since they are designed to contain dilute suspension, they should not be intended as a barrier to fluid mud which can exert pressure on the sheets and flow under the curtain. Curtains can also cause their own problems since anchors and mooring lines may drag on the bottom and resuspend sediment. If water levels recede, excess curtain material may drag on the bottom. A more costly alternative to curtains would be to install special barriers, such as a dike or sheet-piling of conventional sort. These must be constructed and dismantled with minimal disturbance of the bottom sediments and properly maintained, but all these measures can be taken using standard dredging equipment.

> *. . . we have not yet been compelled to take advantage of much of this (foreign) dredging technology. . .*

Specialized equipment can also be used. Modifications of the dredging plant can be made to prevent the generation of turbidity and to contain or capture excess suspended material during dredging. Such technology is available but the choice of a particular method must be tailored to the sediment conditions and may be limited by either expense or availability of the equipment. Nearly all of the more sophisticated plants are European or Japanese and not generally available in the United States.

A clamshell dredge is used routinely to remove cohesive sediment. It has the advantage of extracting relatively large volumes of material undisturbed but turbidity is generated with each bite and as the bucket is raised to the surface. Tavolaro (undated) estimated that 1 percent of the dredged sediment was dispersed in the water column in this way and local turbidity levels can reach nearly 200 mg/l (Herbich, 1989). In shallow, quiescent waters most of this material will resettle to the bottom in the immediate vicinity or could be contained by barriers. There is a closed bucket available to reduce turbidity during the process. A closed bucket has a series of flaps around the jaws and a cover that seals when the bucket is closed. This system can reduce turbidity in the water column by 30 to 70 percent (Herbich and Brahme, 1983).

Contaminated, cohesive sediment can also be removed with a hydraulic dredge using a cutterhead. The sediment is mechanically disaggregated by a rotating cutting device on the sea floor. The loosened material usually is pumped through a pipeline directly to a disposal area. This type of dredging can generate high levels of turbidity and produce a spoil with a very high water content. Turbidity levels are highest near the cutting head at the bottom. Suspended solid concentrations of several hundred milligrams per liter can be found within a meter of the head (Herbich and Brahme, 1983), but turbidity levels are much less above a few meters from the bottom and about 100 m downstream.

By controlling the pumping rate and cutting depth and speed, turbidity at the sea floor can be managed essentially by capturing the resuspended sediment in the pipeline. Hydraulic suction dredges without mechanical cutters can also be used if the sediment has little cohesive strength, such as cohesionless sands, which very rarely are contaminated. Suitable contaminated sediments would likely be fluid muds. Turbidity around suction dredges can be substantially reduced by installing a shield over the cutterhead and/or intake pipe in which the high level of suspended sediment in the immediate vicinity of the cut is contained and pumped from the area through the pipeline. One such shielded dredgehead, called a matchbox dredge, has been designed by the Dutch. The "matchbox" covering the top of the dredgehead prevents the escape of excess resuspended sediment as well as gases liberated by the dredging. It also is intended to reduce the amount of water that is mixed with the dredged sediment (McLellan, et al., 1987).

Another shielded hydraulic dredge called the Clean-up System has been developed and used in Japan for dredging highly contaminated sediment. The sediment is loosened by an auger that is completely shielded. The shield has adjustable flaps that are designed to remain in contact with the bottom and special shrouds for collecting escaped gas. The Refresher Dredge, the Water-less Dredge and the Wide-Sweeper Dredge are all Japanese designed equipment that operate on similar principals. The Wide-Sweeper Dredge does not have a mechanical cutter.

As with any dredging project, proper, well-controlled operation is essential. The position and depth of the cut, the rate of dredging and movement of the cutting head or suctionhead must be carefully monitored. Special-equipment dredges are equipped with acoustic sensors, turbidity meters and even submerged television cameras to keep the operator constantly appraised of the condition of the dredgehead. All of the special purpose dredges maintain very low levels of turbidity. Herbich (1989) reports that turbidity levels were between 1 and 7 mg/l above the suction of the Clean-up System and 4 to 25 mg/l at a distance of 3 m from the head of the Refresher Dredge. The Clean-up System, Refresher Dredge and Wide-Sweeper have been used extensively in Japan, removing as much as one-half million cubic meters of contaminated sediment in a single project.

. . . modification of dredging plants can prevent generation of excess turbidity levels. . .

Pneumatic dredges consist essentially of low pressure chambers. When these chambers are vented to the sediment, sediment is driven into the chamber and removed from the site. Herbich (1989) discusses two models of pneumatic dredges--the Pneuma Pump and the Oozer Dredge. These have been used extensively in Europe and Japan and are especially suited for removing contaminated sediments of high water content with little excess turbidity. Tests on both show turbidity values typically near background levels within 3 to 8 meters of the intake (Herbich and Brahme, 1983).

The Pneuma Pump, Dozer Dredge, and the array of other special equipment and techniques discussed above, compose a technology that should enable the safe removal of any subaqueous contaminated sediment. If there is an engineering problem yet to be solved, it would be providing this capability at lower cost. In the U.S., however, we have not yet been compelled to take advantage of much of this technology. There is little or no experience here in using the more sophisticated equipment and little incentive for the development of a U.S. industry to provide special purpose dredges. Since access to foreign dredges would be difficult due to cabotage laws (Kamlet et al., 1989), the ability to safely excavate contaminated sites is not limited by the technology as much as by the practical matters of obtaining special-purpose dredges.

References

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*Kamlet, K.S., E.J. Adams, A.K. Ahmed, H.J. Bokuniewicz, T.A. Grigalunas, J.B. Herbich, R.J. Huggett, H.L. Sanders, and J.M. Thornton, 1989. Contaminated Marine Sediments - Assessment and Remediation, National Academy Press, Washington, DC, 493 pp.

McLellan, T.N., C.L. Tuitt, and M.R. Palermo, 1987. Evaluation of the Matchbox Dredgehed and submerged diffuser. Proceedings of the 19th Dredging seminar, Department of Civil Engineering, Texas A&M University: 138-146.

*"Survey of Materials-Handling Technologies Used at Hazardous Waste Sites", 1991. Office of Research and Development, U.S. EPA/540/2- 91/010. Washington, DC. 214 pp.

Tavolaro, J. (undated) Sediment Budget Study for Clamshell Dredging and Disposal Activity. Report of the New York District, U.S. Army Corps of Engineers, 27 pp.

* Suggested Additional Reading

Recycling Expo Set in Buffalo

The Lower Great Lakes Waste and Recycling Expo will be 11 a.m. to 7 p.m. Nov. 13 and and 10 a.m. to 5 p.m. Nov. 14 in the Buffalo Convention Center, Buffalo, NY. The Lower Great Lakes area includes parts of New York, Ohio, Pennsylvania, and Ontario and is defined by Lakes Ontario and Erie.

Food Web Plays Critical Role in The Mobilization Of Contaminants From Sediments

By James W. Gillett

James W. Gillett

Dr. James W. Gillett is professor of ecotoxicology in the Department of Natural Resources and director of the Institute for Comparative and Environmental Toxicology at Cornell University.

Any attempt to manage wastes requires knowledge of the long-term chemodynamics of highly persistent chemicals and their consequences within ecosystems. The fate, transport and effects of the highly persistent chlorinated hydrocarbon compounds—DDT, cyclodiene insecticides (e.g., dieldrin, chlordane, kepone), polychlorinated biphenyls (PCBs), and polychlorinated dibenzodioxins and dibenzofurans—have been a major concern in the Great Lakes and Hudson River basins. Irrespective of the initial mode of contamination, be it overflow of a waste treatment lagoon on the St. Lawrence, dry fall as pesticide-contaminated clay swept by thunderstorms from Texas, effluent from a truck tire plant in Ontario, or runoff from the streets of Albany, this galaxy of chemicals has ended up in the sediment of the Great Lakes and St. Lawrence and Hudson Rivers. These sediments thus serve as a continuing source of exposure of not only the aquatic species, but also their land-dwelling consumers, including both people and a large number of valuable, vulnerable and endangered species.

To begin to cope with this problem requires that we do so on larger temporal and spatial scales than heretofore deemed feasible for direct analysis at least at the level of a region or landscape and for periods of years or decades. Two fascinating features of this complex and ill-understood set of phenomena arise as we attempt to apply the information we have in computer models simulating chemical exposure. The first is that, even though we lack much information on species, etc., and even though the natural variation in environmental processes make outcomes seem almost chaotic in the possibilities, *the uncertainty about predictions can be accurately simulated using computer technology.* The second is that *the specific structure of the food web within an ecosystem may require different management approaches in different places,* for the same type of problem in apparently similar systems, since the outcomes implicate different processes of greater or lesser importance.

That the processes of bioconcentration, bioaccumulation, and biomagnification are central to food web mobilization of chemicals is now widely accepted, but not necessarily well understood by all who would employ them in explication of the chemodynamics of persistent compounds. *Bioconcentration* implies the direct uptake from the medium around a plant or animal, but has come to be restricted to that phenomenon in aquatic organisms. *Bioaccumulation* is the uptake and retention of chemicals by all routes, including dietary absorption. *Biomagnification* is a special form of bioaccumulation in which the transfer between trophic levels results in higher concentrations of the pollutant in the consumer species. Each of these phenomena are dependent on a variety of factors regarding both the organisms and the characteristics of the chemical. The higher the lipophilicity ("fat-loving" nature) of a neutral organic chemical, as represented by its octanol-water partition coefficient (K_{ow}) or the inverse of its water solubility, the more likely it is to bioconcentrate or bioaccumulate. However, this propensity (the fraction of maximum bioaccumulation actually achieved at a point in time) can be modified by species-specific degradation and excretion rates, percent lipid composition, gill architecture, and the nutritional, genetic, and chemical history and physiologic status of each individual in a wild population. It should therefore not be surprising that chemical residues in individual fish may vary widely for the same chemical in the same species (by a factor of up to 10^3) and between species (by up to 10^5). The work of Thomann and others has shown that the accumulation process can be represented by a one-compartment model:

$$C_b = [k_1 * C_w + F * A * (p_i C_i)] * [1 - \exp(-k_2 t)] / k_2,$$

where C_b, C_w and C_i are the concentrations of the chemical in whole organism, water, and i^{th} prey species, respectively; k_1 is the uptake rate from water, F is the feeding rate, A is the fraction of ingested chemical absorbed, p is the fraction of the i^{th} organism in the diet, k_2 is the summary rate of excretion, metabolism or other loss, and t is time.

Ram and Gillett recently have developed a PCB food web model of aquatic and terrestrial ecosystems in the St. Lawrence/Lake Ontario-Erie bioregion and a parallel system for the Lake Ontario deepwater food web. The models themselves link one-compartment models representing a "guild" of food web organisms (one or more species consuming the same prey organisms as measured or estimated from consumption rates of prey). These food webs start with contaminated sediments and ultimately lead to the highest aquatic and terrestrial consumers, which are frequently species of concern for their economic or aesthetic value. They may be endangered or already extirpated from the region, but the model can make predictions using estimated physiologic parameters. The ability to predict contamination in species used as food by humans and other species sharing these resources clearly has substantial value.

The Ram food web guild model is unique in the breadth of species for which residues are predicted: 269 species were consolidated into 119 guilds, for which the residues could be compared to measured values in 46 species collected near the General Motor-Akwesasne superfund site by the Akwesasne Environmental Division and New York State Department of Environmental Conservation. The vertebrate guilds were grouped into major food webs in both aquatic and terrestrial environments (fish, reptiles and amphibians, aquatic birds, terrestrial birds, raptors and owls, and mammals). Linkages between major ecosystems occur for four of these six groups. The model employed species-specific values of uptake, excretion and metabolism, prey consumption rate, and seasonality of residence, then used the range of values for each parameter within a guild to represent the model. By use of a Monte Carlo simulation technique (random sampling of all values in many iterations), the model yielded the range of residues (as a lognormal distribution). The 95% confidence intervals of predictions included all measured values for 92% of the species for which 3 or more values were available.

The outputs thus illustrate the uncertainties (and indeed the realities) of the log-normally distributed residues found in nature. Even when a species is no longer effectively present (e.g., mink), the model clearly explains why. Predicted values for mink blanket the range that results in either mortality or significantly reduced reproduction. One can conclude that unless PCB contamination in sediment can be reduced by at least a factor of 20, mink cannot be restored to this region.

A comparison of the St. Lawrence bioregion and the Lake Ontario deepwater models illustrates a further point. Although the species composition of the deepwater lake and the river seem comparable, the actual trophic dynamics and rates differ, such that the outcomes in the former are almost strictly food web-dependent (dominated by alewife), while the latter are almost as much or more influenced by bioconcentration from water directly (as opposed to sediment transfer). The implications for water and sediment management have not yet been thoroughly examined, but obviously need to be, using a form of critical pathway analysis.

All of this labor-intensive model development (literally thousands of values taken from or estimated by techniques from the literature) rests on extensive laboratory and natural history studies performed by many scientists; some data extend back to the early decades of this century. That work is often no longer of much note to scientific journals and Ph.D. thesis committees, so that the enormous ecological changes wrought by such undertakings as the St. Lawrence Seaway have not yet been evaluated in terms of their influence on the model's assumptions and output. The model also suffers from not being able to predict outcomes in terms of species numbers or biomass available for the food web. Changes in species distribution and prey selection brought about by sediment contamination require this type of information.

Simplifications of the food web guild model are likely to be sufficient and useful for many management purposes, and some of the assumptions about linear food chains (and conclusions therefrom) probably are not far off the mark. However, incorporation of all available information is necessary in order to represent adequately the uncertainties in outcome, so that residues are expressed as the range and mode of lognormal distributions, rather than point estimates or means. Renewed or continued study of the natural history of species at all levels of aquatic and terrestrial ecosystems are needed, in order to understand the biological basis by which contaminants in sediments are made available to biota.

Selected Site-Specific Data and Model Projections

Guild (Species)	**PCBs (ppm) Model**	**PCBs (ppm) Site**
MG1 (Meadow vole)	<0.01-0.24	<0.01-0.17 (25)
MG5 (Pygmy shrew) (Masked Shrew)	0.37-26.9	<0.1-23 (19) 0.1-15 (23)
ABG15 (Mallard)	0.43-25.2	0.4-5.9 (5)
RAG2 (Leopard frog)	0.05-7.8	<0.1-7.8 (10)
FG5 (Pumpkinseed)	0.05-22.5	0.11-0.19 (12)
FG17 (Sm. mouth bass) (Pike) (Muskellunge)	0.12-31.3	0.19-4.42 (25) 0.1-5.12 (28) 0.15-1.08 (3)
FG18 (Yellow perch) (Rock bass) (Rainbow trout)	0.1-19.9	0.11-12.3 (28) <.15-4.02 (5) 0.86, 0.94 (2)

Model = 95 % confidence interval of lognormal distribution

Site = Range of values (number in parentheses) at Akwesasne

Notes and Announcements

Stony Brook Offers Publications

Copies of the following publications are available from the Waste Management Institute, Marine Sciences Research Center, State University of New York at Stony Brook, Stony Brook, NY 11794-5000, (516) 632-8704.

Valle-Levinson, A. and Swanson, R.L.,1991. **Wind induced scattering of medically-related and sewage-related floatables**. *Marine Technology and Society*. Vol. 25, No. 2, pp 49-56.

Swanson, R. L., Bell, T. M., Kahn, J. and J. Olha. 1991. **Use impairments of the New York Bight**. *Chemistry and Ecology*. Vol. 5, pp 99-127.

Swanson, R. L. and A. Valle-Levinson. 1990-91. **Meterological conditions that kept the beaches of Long Island and New Jersey free of floatables during the summer of 1989**. *Journal of Environmental Systems*. Vol. 20, No. 1, 53-69

Call for Papers

The West Virginia University Department of Civil Engineering will host the 1992 Mid-Atlantic Industrial Waste Conference July 15-17 at the Lakeview Resort and Conference Center, Morgantown, WV. Dr. W. Wesley Eckenfelder, Jr. will be keynote speaker.The conference will focus on the technical aspects of process wastewater treatment, sludge treatment and disposal, waste minimization and reuse, site remediation, and the managerial aspects of regulatory implementation and compliance. Prospective authors should submit seven copies of a 500-word abstract by Jan. 10, 1992, to Dr. Brian E. Reed, West Virginia University, Department of Civil Engineering, Morgantown, WV 26506-6101. Consultants, environmental managers, regulators, and academicians interested in attending the conference may write to the same address or call (304) 293-3031, extension 613.

Cornell Researcher On Fulbright Program Project In India

Dr. Daryl Ditz, Senior Extension Associate at the Cornell Waste Management Institute, will conduct research on hazardous waste management in India. This project, under the auspices of the Fulbright Program, will run from September 1991 to April 1992.

While in India Ditz will hold a joint affilitaion with Jawaharlal Nehru University and the Indian Institute of Technology in Delhi. On the staff of the Cornell Waste Management Institute since 1988, he has worked on environmental, regulatory and planning issues with other researchers, state officials, communities, and others.

Cornell Tests Biomonitoring Near MSW Incinerator

Researchers at the Cornell Waste Management Institute and the Boyce Thompson Institute for Plant Research are collaborating in a unique application of biomonitoring around a waste-to-energy facility.

The project, directed by Dr. Daryl Ditz and Dr. Len Weinstein, is designed to measure the accumulation of selected metal and organic pollutants by specially prepared plant receptors at 17 sites around the Warren County Resource Recovery Facility in Oxford, New Jersey.

Anthony Carpi, a graduate student in Environmental Toxicology at Cornell, manages the preparation, deployment, collection and processing of several hundred samples gathered over a 12-week period. The project complements on-going ambient air monitoring at the site by researchers at Rutgers University, the Robert Wood Johnson Medical School, and the New Jersey Department of Environmental Protection. Results, which will help in quantifying human exposure to emissions from the facility, are expected by the summer of 1992.

Ditz Article to Examine EPA Recycling Rule

In December 1989, the U.S. Environmental Protection Agency (EPA) proposed that 25 percent of solid waste headed for new or existing incinerators should be separated for recycling.

EPA supported this requirement through the comment period and up to the eleventh hour. Then, under heavy pressure from the White House, EPA removed the "materials separation" provision.

In the spring 1992, Vol. 7, No. 1 edition of *FORUM for Applied Research and Public Policy*, a journal for energy, environmental and economic policy, Cornell Waste Management Institute staff member Daryl Ditz will examine the rationale for the 25 percent requirement and its deletion. Reprints will be available through The University of Tennessee, Energy Environment and Resource Center, Knoxville, TN 37996-0710.

Home-study Course Describes Composting Of Municipal Waste

"Municipal Compost Management," a home-study course published by the Cornell Waste Management Institute, offers an answer to the problem of municipal solid waste. The course provides a comprehensive overview of municipal composting issues, useful for those who want information about the environmental benefits and potential economic savings which make composting a waste-handling option with immediate public appeal.

The Institute also produced a 35 minute video "tour" of municipal composting projects, "Recycling Yard Waste: A Tour of Community Programs." The video is designed to help local officials and others learn how to implement a variety of management systems, including mixed material composting. It also has a companion study guide entitled "Yard Waste Management — A Planning Guide."

Guest Comment

Contaminated Sediments A Long-Existing Problem

By Nelson Thomas

Nelson Thomas

Toxic chemicals and conventional pollutants have steadily accumulated in the sediments of coastal, estuarine, and freshwater ecosystems over the past century. The degradation of benthic ecosystems by poor sediment quality has become so severe in certain areas that the normal biota have been replaced by a depauperate assemblage of stress-tolerant species. The natural diversity of invertebrates that support pelagic food chains is no longer present. Demersal fishes in many urbanized embayments are plagued by diseases such as fin erosion and epidermal and hepatic lesions. Commercial and recreational fisheries have been closed because of a sediment-related contamination. In the past, sediment has provided a convenient "sink" for a variety of anthropogenic wastes. More recently, as sediment problems have become the focus of regulatory programs, it has become evident that the "sink" may have become the "source" of continuing damage to both the benthos and pelagic biota.

Investigation of sediment contamination and its biological consequences is a relatively new research area. The articles contained in this issue are an example of some of the new areas of research in in the field of contaminated sediments. The goal of the sediment research should be to create a comprehensive program on sediment quality to develop approaches for both preventing further deterioration of sediment quality, and mitigating present problems. This program would greatly improve the scientific foundation for sediment assessments currently required by regulations concerning ocean dumping, NEPA review, Superfund, and estuarine protection. Sediment research is needed in five areas:

- ❑ Sediment Quality Criteria
- ❑ Fate of Sediment Contaminants
- ❑ Toxicological and Chemical Assessment Methods for Marine and Freshwater Sediments
- ❑ Mitigation/Prevention of Sediment Quality Problems
- ❑ Field Validation of Sediment Assessment Methods

Much of the research will be conducted at universities. Regulatory agencies will develop control programs that rely on sediment quality criteria, toxicological and biological assessments techniques. Without engineering studies on mitigation and innovative treatment techniques, many of the cleanup programs would be too expensive.

By using more precise assessment techniques and more cost effective treatment and disposal technologies, problems of contaminated sediments can be minimized.

Nelson Thomas is the Senior Advisor for National Programs at the Environmental Research Laboratory in Duluth, MN.

Waste Management Research

Report

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Aerial view of North Campus,
State University of New York at Buffalo

Photograph by F. Luterek