A SHORT SUMMARY OF THE SOURCES AND DISTRIBUTION OF CONTAMINATED SEDIMENTS IN THE GREAT LAKES

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Sediment Associated Contaminants: *Sources and Distribution*

Sediment-associated contaminants are a legacy of the industrial development of the United States. Sediments provide repositories of persistent and highly sorptive contaminants that have found their way into our lakes, rivers, streams, estuaries and coastal oceans. These contaminated sediments have been found to have substantial effects on the ecosystem ranging from direct effects on benthic communities[1] to substantial contributions to contaminant loads and effects on upper trophic levels through food chain contamination for tree swallows[2], for Caspian terns[3], for mink. [4] These effects directly impact human health in that the

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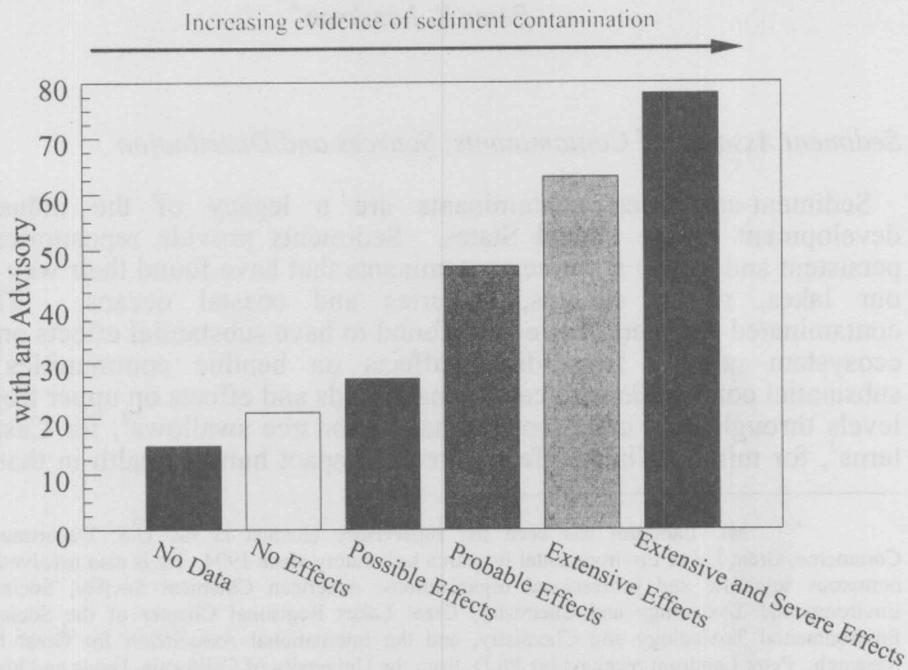
1. Timothy J. Canfield, Nile F. Kemble, William G. Brumbaugh, F. James Dwyer, Christopher G. Ingersoll, and James F. Fairchild, *Use of Bentheic Invertebrate Community Structure and the Sediment Quality Triad to Evaluate Metal Contamination Sediment in the Upper Clark Fork* River, Montana, *Environ. Toxicol.Chem. 13:1999-2102* (1994). *See also* Timothy J. Canfield, F. James Dwyer, James F. Fairchild, Pamela S. Haverland, Christopher G. Ingersoll, Nile E. Kemble, David R. Mount, Thomas W. La Point, G. Allen Burton, and Michael C. Swift, *Assessing Contamination in Great Lakes Sediments Suing Benthic Invertebrate Communities and the Sediment Quality Triad Approach., J. Great Lakes Research,* 22:565-583 (1996). *See also* Richard Swartz et al.., Faith A. Cole, Janet O. Lamberson, Steven P. Ferraro, Donald W. Schults, Waldemar A. DeBen, Henry Lee II, and Robert J. Ozretich, *Sediment Toxicity, Contamination and Amphipod Abundance at a DDT- and Dieldrin-Contaminated Site in San Francisco Bay*, *Environ. Toxicol. Chem.* 13:949-962 (1994).

2 Bishop, C.A., Mahony, N.A., Trudeau, S., and Pettit, K.E. 1999. Reproductive success and biochemical effects of tree swallows (*Tachycineta bicolor*) exposed to chlorinated hydrocarbon contaminants in wetlands of the Great Lakes and St. Lawrence River Basin, USA and Canada, *Environ. Toxicol. Chem.* 18:263-271. *See also* McCarty, John P. and Anne L. *Secord Reproductive Ecology of Tree Swallows (Tachycineta bicolor) with High Levels of Polychlorinated Biphenyl Contamination. Environ. Toxicol. Chem.* 18:1433-1439 (1999).

3. Ludwig J.P., Auman H.J., Kurita H., Ludwig M.E., Campbell L.M., Giesy J.P., Tillitt D., Jones P., Yamashita N., Tanabe S., and Tatsukawa R.. 1993. *Caspian tern reproduction in the Saginaw bay ecosystem following a 100-year flood event. J. Great Lakes Res.* 96-108.

number of watersheds with fish consumption advisories is directly proportional to the extent of sediment contamination (Figure 1).[5]

Figure 1. Extent of Sediment Contamination as a :Link to Fish Consumption



The United States Environmental Protection Agency in 1997, provided a report to Congress describing the extent of contamination of the nations aquatic environment.[6] This survey examined all of the available data for watersheds and found that only about eleven percent had data that could describe the extent of contamination.[7] Thus, the true magnitude of contamination is unknown. Of the stations that had data to support evaluation of sediment contamination, twenty six percent of the stations were assessed as Tier 1 (sediment contamination great enough to cause probable effects) and forty nine percent were Tier 2 (sediment

4. Foley, R.E., Jackling, S.J., Sloan, R.J., and Brown, M.K. 1988. Organochlorine and mercury residues in wild mink and otter: Comparison with fish. *Environ. Toxicol. Chem.* 7:363-374.

5. Interview with James Keating, Environmental Scientist, US Environmental Protection Agency in Washington, DC, October 1996.

6. U. S. EPA, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*, Vols. 1-3. EPA 823-R-97-006, Washington, DC, (1997).

7. *Id.* at XX.

contamination great enough to cause possible effects).[8] That only leaves twenty five percent of the stations having sediment contamination below levels that are likely to cause effects. The extent of contamination among the various sites that had adequate data reflects the current monitoring program, which focuses on the areas of expected contamination. The contaminants that dominate the effects in the Tier 1 sediments in the Great Lakes are dominated by polychlorinated biphenyls (Figure 2).[9]

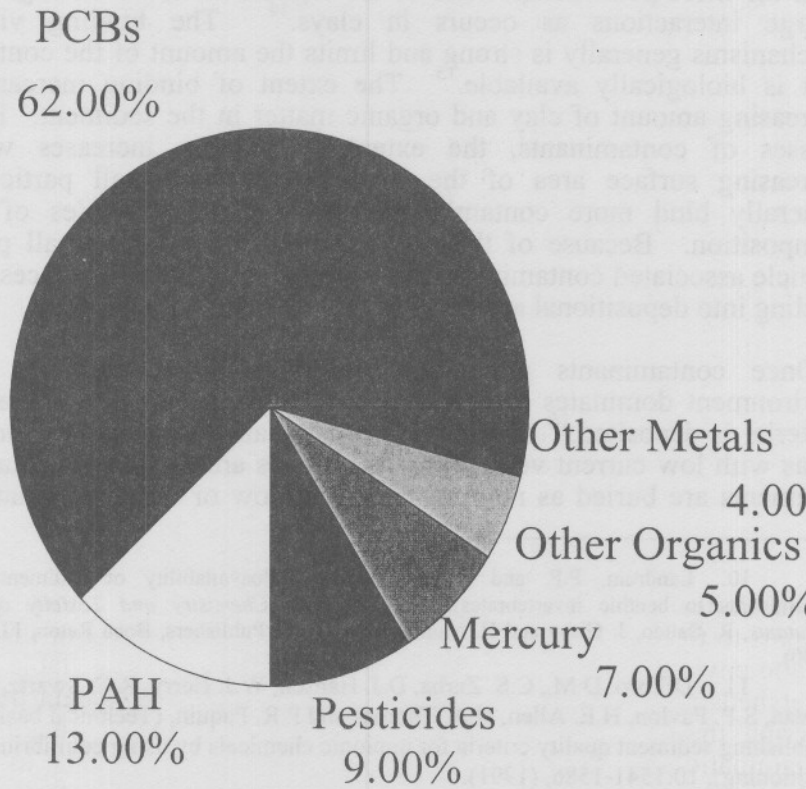


Figure 2. Distribution of Contaminants Contributing to the Tier 1 Impacts in the Great Lakes

The characteristics of the represented contaminants include persistence in the environment and strong particle sorption characteristics. Persistent contaminants are those that cannot be readily destroyed by biological or

8. *Id.* at 2-2.
9. *Id.* at 3-48.

by chemical degradation. The particle sorption occurs because the contaminants are either very hydrophobic or are strongly reactive with the components of settling particles.[10] The hydrophobic contaminants are organic contaminants and they tend to bind to the organic portion of sediments.[11] Thus, the capacity of sediments for these contaminants increases as the extent of organic matter in sediment increases.[12] Increasing the amount of organic matter in sediment generally decreases the bioavailability of the contaminants to biota.[13] For inorganic contaminants, the binding with sediments is through ligand binding often with the more polar components of the organic matter or through charge-charge interactions as occurs in clays.[14] The binding via these mechanisms generally is strong and limits the amount of the contaminant that is biologically available.[15] The extent of binding increases with increasing amount of clay and organic matter in the sediment. For both classes of contaminants, the extent of binding increases with the increasing surface area of the particles. Thus, small particles will generally bind more contaminants than a larger particles of similar composition. Because of the high binding capacity of small particles, particle associated contaminants can be transported long distances prior to settling into depositional areas.

Once contaminants are bound to particles, the physics of the environment dominates the processes, dictating where the contaminated material is deposited.[16] Therefore, contaminants are usually deposited in areas with low current velocities. As sources are removed, contaminated sediments are buried as new material with low or no contamination that

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10. Landrum, P.F. and J. A. Robbins, (Bioavailability of sediment-associated contaminants to benthic invertebrates), *In*: *Sediments: Chemistry and Toxicity of In-Place Pollutants*, R. Baudo, J. Giesy and H. Muntau, eds. Lewis Publishers, Boca Raton, FL, 337-263, (1990).

11. DiToro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas and P.R. Paquin, (Technical basis for establishing sediment quality criteria for nonionic chemicals by using equilibrium partitioning), 10:1541-1586, (1991).

11. DiToro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas and P.R. Paquin, (Technical basis for establishing sediment quality criteria for nonionic chemicals by using equilibrium partitioning), 10:1541-1586, (1991).

12. *Id.* at 1533.

13. *Id.* at 1565.

14. Förstner, U. *Inorganic Sediment Chemistry and Elemental Speciation*: *In Sediments: Chemistry and Toxicity of In-Place Pollutants*, R. Baudo, J. Giesy and H. Muntau, Lewis Publishers, Boca Raton, FL, pp 61-105, (1990).

15. Newman, Michael C. and Charles H. Jagoe. *Ligands and the bioavailability of metals in aquatic environments*, *In Bioavailability: Physical, Chemical and Biological Interactions*, Jerry L. Hamelink, Peter F. Landrum, Harold L. Bergman and William H. Benson, Lewis Publishers, Boca Raton, FL, pp 39-61 (1994).

16. Manahan, S.E.. *Environmental Chemistry*, Lewis Publishers, Boca Raton, FL, 583, (1991).

settles on top of the contaminated material.[17] The reworking of the sediments by the benthic organisms slows this burial.[18] This reworking of sediments takes place where organisms feed on sediment particles at depth and deposit the fecal material on the surface.[19] Further, the contaminants can be moved back to the surface by storm scouring or by anthropogenic activities such as dredging.[20] In the Great Lakes, the contamination is highest in bays and harbors.[21]

> Polluted sediments are the largest major source of contaminants to the Great Lakes food chain, and over 97% (8,325 km) of the shoreline is considered impaired. The Region V sediment inventory contains 346 contaminated sediment sites. Fish consumption advisories remain in place throughout the Great Lakes and many inland lakes. Contaminated sediments also cause restriction and delays in the dredging of navigable waterways, which in turn can negatively affect local and regional economies. Contaminated sediments must be cleaned up before they move downstream or into open waters, which makes them inaccessible and cleanup impossible [22]

The high contamination areas are represented by the "Areas of Concern" as listed by the International Joint Commission.[23] In all but one of the 42 Areas of Concern, there are contaminated sediments substantially contributing to the use impact of these Areas of Concern.[24] The contaminants that are most often found at sites include PCBs, heavy metals, mercury, PAH, pesticides such as DDT, chlordane, and mirex, and dioxins.[25] Other contaminants occur in specific sites but they are usually more site specific.[26] These contaminants come from a wide variety of sources (Table 1).[27] Some of the sources are more historical than current. For instance, since the pesticide category focuses on the chlorinated pesticides, which are now banned from use, the sources from croplands, urban sources, and industrial discharges are essentially historical in

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17. Robbins, J.A. 1982. Stratigraphic and dynamic effects of sediment reworking by Great Lakes zoobenthos. *Hydrobiologia* 92:611-622, (1982).
18. *Id.* at 621.
19 Robbins, J.A. A model for particle-selective transport of tracers with conveyor belt deposit feeders. *J. Geophys. Res.* 91:8542-8558, (1986).
20. Burton, G.A. Plankton, macrophyte, fish, and amphibian toxicity testing of freshwater sediments. In *Sediment Toxicity Assessment*, G. A. Burton, ed. Pp.167-182, (1992).
21. International Joint Commission, 8, (1999).
22. *Id.* at 4.
23. *Id.*
24. *Id.*
25. U.S. EPA, *Great Lakes Areas of Concern*, <http//www.epa.gov/glnpo/aoc>.
26. *Id.*
27. U.S. EPA *supra* note 6, at 4-4.

nature.[28] Likewise, the discharge of PCB from industrial sources is largely historical. However, essentially all of the other sources can be considered active and contributing to current contaminant loads.[29]

Table 1: Correlations of Sources to Chemical Classes of Sediment Associated Contaminants[30]

Source/Chemical Class	Mercury	PCB	PAH	Metals	Pesticides	Other Organics
Harvested Croplands					•	
Inactive and Abandoned Mine Sites	•			•		
Atmospheric Deposition	•	•	•	•	•	•
Urban Sources	•		•	•	•	•
Industrial Discharges	•	•	•	•	•	•
Municipal Discharges	•	•		•	•	•

Remediation has taken place in the Great Lakes and the cumulative number of projects by 1998 was 38 with an expenditure of nearly $600 million dollars.[31] As a result of these projects nearly 2,500,000 m3 of contaminated sediment was removed.[32] These activities have demonstrated clear improvements where activities have been completed.

While most of the focus on sediment contamination is on these very persistent and historically recognized contaminants, there are a wide range of contaminants that have not been monitored routinely, such as pharmaceuticals and their metabolites. The true extent of sediment contamination is largely unknown and the impact of sediment-associated contaminants may not be fully appreciated until better monitoring of

28. *Id.*
29. *Id.*
30. *Id.*
31. IJC *supra* note 21, at 24.
32. *Id.*

contaminants and investigations of their impacts take place.