Human Exposure to Toxic Materials

The New York–New Jersey Metropolitan Region

C. R. Krishna, Ph.D., R. C. Klein, M.S., Keith W. Jones, Ph.D., N. L. Clesceri, Ph.D., and E. A. Stern

People living in the New York–New Jersey metropolitan region around New York City are exposed to toxic chemicals or elements that occur naturally or are produced as a result of human activity. Radon is an example of a naturally occurring toxic element produced by the radioactive decay of naturally occurring elements. Polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) are examples of toxic chemicals historically produced and used in industry. Air pollution by particulates, such as SO_x and NO_x and other petroleum combustion products, is produced by the operation of internal combustion engines, home heating furnaces, industrial and utility combustion systems, and many other devices.

Human exposure to these materials comes about through the air we breathe, the water we drink, and the food we eat. As an example, consider some of the routes for exposure to lead. Lead has been used in many industrial activities for years and is widely distributed in urban regions. Operation of facilities for manufacture of lead-acid batteries directly exposes workers to airborne particles and has often brought about substantial pollution of the surrounding land. Run-off carrying lead from the site then pollutes streams, rivers, and estuaries and enters the food chain through agricultural produce or fish and shellfish taken from affected waters. The general population is at risk from inhalation of lead contained in particles of lead-containing paint. The urban water supply can be affected by lead contained in components of the water system and by different types of bacteria.

The consequences to human health from these exposures are substantial. Environmental exposures have been linked to cardiovascular, pulmonary, reproductive, and neural dysfunction, immune system disorders, cancer, and developmental problems. It is obviously important to emphasize improved medical treatment of conditions which may be wholly or partially the result of environmental exposures. It is equally important to work to reduce the levels of exposure of the population by improved environmental regulations, making changes in the materials and methods used in manufacturing, and the ways in which homes and offices are operated.

The actual implementation of change is difficult because of the complex nature of the urban system. Changes which reduce a contaminant can bring about deleterious effects elsewhere which negate the benefits gained from the original action. Environmental, health, and economic needs must be considered in an integrated way if overall progress is to be made. Creation of new organizational teams bringing together all the skills and interests that represent the various interests are needed. The participation of environmental and occupational physicians and epidemiologists as part of this grouping is important.

Problems related to contamination of sediments in the Port of New York–New Jersey are a current illustration of situations and conflicts that arise in attempts to ameliorate environmental degradation that ultimately relates to clinical practices in environmental and occupational medicine. An outline of the problem is given be-

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Address reprint requests to Keith W. Jones, Brookhaven Rensselaer Environmental Partnership, Brookhaven National Laboratory, Building 901, Upton, NY 11973-5000.

low. The intent is to show the complexity of the problem and to touch on potential health-related concerns.

Contaminants

Airborne. Airborne contaminants are a major pathway for human exposure in urban areas. The magnitude of the problem in the New York–New Jersey region is shown in the estimates of emissions from point and area sources (**Table 1**) (1). Airborne emissions are directly related to problems of contaminated sediments. First, pollutants can be transferred from air to water in the port region and thence to the sediments. Second, decontamination of dredged material (and sewage sludge) using several different methods can result in air emissions of contaminants that contribute to the overall air quality problem in the region. Problems that stem from use of incinerators have been considered in a joint study (2) of the United States Environmental Protection Agency (USEPA), the New Jersey Department of Environmental Protection and Energy (NJDEPE), and the New York State Department of Environmental Conservation (NYSDEC).

A recent study (3) from the Harvard School of Public Health highlights the health consequences of fine particulates (defined as particles with aerodynamic diameters less than 2.5 μm) that are present in metropolitan area atmospheres. The fine particles are derived chiefly from fossil fuel combustion sources and their size range contributes to their deep penetration into the lung. They can also act as carriers for potentially harmful chemicals.

In Soil. Soil contamination is highly variable and it is not possible to give an overall view of concentrations of particular chemicals or compounds that are representative of the region as a whole. Two examples can be cited. In the Jersey City region, the plating industry was a heavy user of chromium, which brought about contamination of soils and ground water (4). Chemical manufacturing in Newark on the Passaic River resulted in contamination of soils and sediments with high levels of dioxins. Surface runoff and contamination of ground water ultimately leads to transfer of the contaminants from soils to the harbor environment, including water and sediments.

In Sediment. Contaminants in the sediments are the result of contributions from many sources (5), including runoff from farms and lawns in rural, suburban, and urban areas. Discharges from factories to the atmosphere, water, or soils ultimately are contributors. Sewage processing facilities must deal with large volume discharges of both solids and liquids. Atmospheric contributions are responsible for a substantial part of the input to the harbor.

TABLE 1
Summary of Atmospheric Emissions in New York and New Jersey (metric tons/year)

	Point Sources		Area Sources	
Substance	NY	NJ	NY	NJ
SO2	760,082	233,574	99,994	69,202
SO4	23,645	6,520	17,767	12,855
NO	279,527	127,777		
NO2	8,372	4,623		
NOX			407,276	258,647
Pb	16	0	1,140	640
CO	113,978	83,692	4,213,753	2,005,206
HCL	9,200	2,442	63	112
HF	1,875	302	5	24
NH3	3	12	12,663	62
TSP	245,892	98,206	505,141	275,792
Ca	1,367	37		
MG	1,144	24		
NA	548	11		
K	310	6		
VOC	90,149	104,827	971,333	536,991
THC	141,636	119,935	1,020,955	571,389

VOC, volatile organic compounds; TSP, total solid particulates; THC, total hydrocarbons.
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The types of contaminants found in sediments include the full spectrum of metals and chemical compounds used in the daily activities of an industrial society. Typical values (6) are available (**Tables 2, 3**) for sediments taken from four different sections of the Harbor: the Gowanus Canal and Newtown Creek in New York, the Arthur Kill lying between New York and New Jersey, and upper Newark Bay in New Jersey. An overall evaluation of existing data for the Harbor has been presented by Squibb et al. (7)

A specific evaluation of potential hazards from high levels of mercury (Hg) contamination in the region of Arthur Kill, Newark Bay, and the Passaic River has been carried out by Gillis et al. (8). They list a number of sources for the Hg contamination, including "metallurgy facilities, smelters, scrap metal yards, agricultural and urban storm water runoff, power plants, pulp and paper mills, textile manufacturers, petroleum refineries, municipal waste disposal facilities, combined sewer outfalls and stormwater bypasses." Results found for Hg concentrations in sediment samples taken in the area show a maximum 9.8 mg/kg (dry weight). They reported evidence for effects on health of fish, even though the concen-

TABLE 2
Metal Concentration in Sediments from the Gowanus Canal and Three Locations in the Port of New York–New Jersey: Upper Newark Bay, Arthur Kill, and Newtown Creek

	Concentration (mg/kg dry weight))*			
Metal	Newark Bay	Arthur Kill	Newtown Creek	Gowanus Canal
Antimony	NA	NA	NA	<21
Arsenic	9–17	17–25	5–33	10
Beryllium	NA	NA	NA	1
Cadmium	1–2	1.5–3	1–20	11
Chromium	175	161	305	151
Copper	105–131	178–304	61–770	630
Lead	109–136	111–261	68–554	1,343
Mercury	2–3	2–4	1–3	3
Total				
Nickel	33–40	20–60	12–140	88
Selenium	NA	NA	NA	2
Silver	2–4	2–5	2–3	21
Thallium	Na	NA	NA	<42
Zinc	188–244	230–403	104–1,260	1,130

NA, not available.
* The metal concentrations for Newark Bay, Arthur Kill, and Newtown Creek were obtained from the U.S. Environmental Protection Agency (private communication from Audrey Massa, 1994) and, for the Gowanus Canal, from Hazen and Sawyer, Inc. (private communication from Robert Smith).
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tration levels were below 1 ppm. They suggest that the mercury concentrations may be high enough to pose a threat to human health and that additional sampling and better understanding of the chemistry and transport of Hg are needed before final conclusions can be drawn.

Dredging

Economic Necessity in the Port of NY–NJ. Dredging of the Port of New York–New Jersey is necessary to maintain adequate depths in shipping channels. The need is accentuated by the slow shift to use of vessels with increasing drafts, requiring deepening of the channels beyond their historic depths. At the same time, restrictions on ocean disposal of dredged materials have been increased by more stringent regulations based on bioaccumulation and biotoxicity tests.

The port is now in danger of becoming economically uncompetitive in comparison with other ports along the Atlantic coast. Reduction of commerce handled through the port will have a severe impact on the economy of the bistate region. There is a direct impact on revenues and jobs based directly in the port. It is estimated (9) that the total economic activity generated is $20 billion per year and that this is responsible for more than 180,000 jobs.

Reduction of the port activity implies that other means will be needed to transport needed materials to the region. Offloading cargoes from larger to smaller ships, either at a port location or elsewhere, will raise shipping costs. If traffic is diverted to other locations and moved to New York–New Jersey by rail or truck, considering that the cargo of one ship is claimed (9) to represent the capacity of 1000 rail cars or 2000 trucks, it is plausible to believe that large strains would be placed on the regional infrastructure. There would clearly be both economic and environmental consequences that would have a strong impact on the region.

Management of Dredged Material. The traditional method for disposal of dredged materials has been ocean dumping, which has become increasingly restricted in use because of the difficulties in obtaining the necessary permits. An alternative method is urgently needed for disposal of that fraction of dredged materials not suitable for ocean dumping. Several possible methods have been mentioned (10). They include the use of "borrow pits," subaqueous pits filled with contaminated dredged material and capped with clean material to prevent the dispersal of the contaminants. A more sophisticated approach is to use containment islands which are designed with impermeable barriers to prevent fluid flow between the dredged materials and the surrounding waters. Finally, application of decontamination technologies that remove the contaminants from

TABLE 3
Concentrations of Volatiles, PCBs, and Other Properties of Sediments from the Gowanus Canal and Three Locations in the Port of New York–New Jersey: Upper Newark Bay, Arthur Kill, and Newtown Creek.

	Concentration (mg/kg dry weight)*			
Contaminant	Newark Bay	Artur Kill	Newtown Creek	Gowanus Canal
Benzene	NA	NA	NA	8
Toluene	NA	NA	NA	20
Chlorobenzene	NA	NA	NA	9
Ethylbenzene	NA	NA	NA	79
Total xylene (o,m,p)	NA	NA	NA	54
Total PAHs	NA	NA	NA	24742
Corrosivity (ph)	7.06–7.61	7.08–7.47	7.38–7.76	9
Ignitability (C)	NA	NA	NA	>100
Total available cyanide	NA	NA	NA	<.3
Total available sulfide	683	1820	4850	475

NA, not available; PAHs, polynuclear aromatic hydrocarbons.
* Concentrations for Newark Bay, Arthur Kill, and Newtown Creek were obtained from the U.S. Environmental Protection Agency (Audrey Massa, private communication 1994) and, for the Gowamus Canal, from Hazen and Sawyer, Inc. (Robert Smith, private communication, 1994).
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the dredged materials may be able to clean those dredged materials so that they can be disposed of in the ocean, landfill, or through some beneficial reuse. The challenge, regardless of the approach chosen, is to find a method or methods that can be applied to solve the problem of disposal of dredged materials at an economically feasible cost.

No matter what method is chosen for disposal, efforts to reduce emissions and discharges which pollute waters, soils, and atmosphere with toxic materials are very important. In the long term, the quantity of contaminated sediments will decrease, and the problem of disposal will steadily decrease.

Methods for Decontamination. Methods for decontamination of dredged materials are varied. Each can be evaluated for effectiveness in contamination reduction. In addition, each represents a large-scale industrial process with its own inherent potential for emissions unsatisfactory from an environmental standpoint, and for other hazards important from an occupational safety standpoint.

A simple example would be the use of mechanical separation of large and small particle types. The rationale for this is the higher concentration of contaminants generally found in the fine particles (clays) than in larger ones (sands and gravels). From an environmental standpoint, there could be emissions of fine particles into the atmosphere and the need to control odors. Workers will be exposed, and proper industrial hygiene measures must be taken to protect them during the operation.

More complex treatment methods are also used. For example, the application of high temperatures to these materials can convert them into a glasslike matrix which can effectively bind toxic metals. At the same time, the temperatures are high enough to bring about the destruction of organic materials. Again, it is necessary to consider all discharges to the environment which could in the end be harmful and to take the necessary operational precautions. Other decontamination technologies include stabilization of the materials in a cementlike matrix, washing with chemicals to remove surface contaminants, use of bacteria to destroy organics or to concentrate metals.

It can be seen that none of these methods is a panacea. All are moderately large scale manufacturing processes that must be operated carefully so as not to damage the environment or to cause a hazard to human health, either in the general population or in occupationally exposed workers.

Implications for Environmental and Occupational Health

Work on dredged materials is important since it affects the economic viability of the Port of NY–NJ and can have implications for the health of the environment and for the health of humans. The clinical physician should be aware of the complexity of the environmental problems posed by conditions in NY–NJ and how they relate to human health. Some of the general problems have been mentioned above. Physicians dealing with patients from a group which does subsistence fishing might consider the possibility of illness related to high levels of toxic chemicals or metals in the fish. In addition, if a new industry develops in handling and treatment of contaminated dredged materials (or soils), it would be good to be informed about the concentrations of contaminants and possible health problems relating to exposures.

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