Great Lakes Science Advisory Board

Report to the International Joint Commission

1980 Annual Report

A perspective on the problem of hazardous substances in the Great Lakes Basin Ecosystem

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Presented November 13, 1980
Toronto, Ontario

INTERNATIONAL JOINT COMMISSION

Great Lakes Science Advisory Board

November 13, 1980

International Joint Commission

Canada and United States

Commissioners:

The Great Lakes Science Advisory Board, in partial fulfillment of its responsibilities under the Great Lakes Water Quality Agreement of 1978, is submitting the following Annual Report on the activities of the Board and its working committees and task forces.

Respectfully submitted,

D I Mount

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Preface

Beginning about 1970 public concern became more pronounced about the occurrence of chemicals - some of which are hazardous substances - in air, soil, and water throughout the continent. Prior to this period the use of various pesticides, especially the chlorinated hydrocarbon insecticides, were the major concern. Several bans on pesticide use and seizures of food products occurred as a result of concentrations being discovered which exceeded administrative guidelines or were at levels thought to be unsafe. Rachel Carson's book Silent Spring did much to arouse public reaction.

Several events have occurred to increase the degree of this public concern. The use of chemicals in commerce increased drastically as the standard of living and economic conditions improved. The development of modern plastics and new adhesives, paints, coatings and synthetic materials contributed to the increased use of chemicals. In industries, such as agriculture, the use of chemicals increasingly replaced manual labor as more capital intensive technologies were adopted.

Analytical capabilities improved dramatically with the development of gas chromatography and mass spectroscopy. The positive identification of complex organic chemicals became easier, and detection limits were lowered making it possible to measure many chemicals at concentrations much lower than previously detectable in water and air. The public, aware of environmental contamination, was willing to support monitoring and control programs. During this same period, the role of chemicals as a possible cause of cancer was widely heralded; public concern was further heightened. Legislation followed that required more stringent testing before large-scale production of new chemicals and more controls on their release into commerce.

Some hazardous substances have become dispersed over large areas; PCBs and DDT have been dispersed globally. Others are found only near the point of release. In large lakes particularly, long periods of time may be required before the concentrations in the lake reach equilibrium with the loadings. Such lag times require new and innovative monitoring strategies.

Leaching from solid waste disposal sites has recently been recognized as a significant source of hazardous substances in the environment. This is especially true for many older sites which were improperly located or poorly designed and operated. Love Canal is a well known example of such a site.

This report is largely devoted to the problems of hazardous substances, their entry into, movement through, and effects upon the Great Lakes. Technology currently available to destroy or remove these substances from wastes is also described. The Great Lakes Science Advisory Board has tried to present the major considerations which must be addressed in successfully resolving these problems. The Appendix provides much of the detailed background information used in developing the report.

In this report the Board stresses several principles concerning the hazardous substances problem:

1) an approach that gives priority to the most hazardous substances;
2) use of only the minimum amounts of chemicals necessary;
3) beneficial reuse of wastes or destruction rather than removal; and
4) conversion to solid wastes, such as sludge, as a last resort.

The Board's report also reviews the activities of several task forces and committees on problems related to Great Lakes eutrophication. These activities include development of phosphorus management strategies, health effects of non-NTA detergent builders, ecological effects of non-phosphate detergent builders, and bioavailability of phosphorus. The Board's Aquatic Ecosystem Objectives Committee continued to develop new and revised water quality objectives. The Joint Science Advisory Board/Water Quality Board Health Aspects Committee has been evaluating human health hazards associated with viruses and chemicals in the Great Lakes basin ecosystem. These Board activities are discussed briefly in Part X of this report. The details are available in the relevant committee and task force reports.

The following reports have been completed and are available:*

Phosphorus Management for the Great Lakes - Final Report of the Phosphorus Management Strategies Task Force, Windsor, Ontario, July 1980.

Health Effects of Non-NTA Detergent Builders - Task Force on Human Health Effects of Non-Phosphate Detergent Builders, Windsor, Ontario, November 1980.

Ecological Effects on Non-Phosphate Detergent Builders - Final Report on Organic Builders other than NTA - Task Force on Ecological Effects of Non-Phosphate Detergent Builders, Windsor, Ontario, July 1980.

Report of the Aquatic Ecosystem Objectives Committee to the Science Advisory Board, Windsor, Ontario, November 1980.

1980 Annual Report of the Committee on the Assessment of Human Health Effects of Great Lakes Water Quality - Presented to the Great Lakes Water Quality and the Great Lakes Science Advisory Board, Windsor, Ontario, November 1980.

*Available from the IJC Great Lakes Regional Office, 100 Ouellette Avenue, Windsor, Ontario, Canada N9A 6T3.

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I The Hazardous Substances Issue

The Great Lakes basin ecosystem encompasses an area of nearly three-quarters of a million square kilometres (three hundred thousand square miles) It is inhabited by nearly forty million people with a high per capita use of technology and energy. Although the basin is of relatively recent origin in terms of glaciation, plants and animals inhabiting the basin are the product of several billion years of ecological and biospheric history.

Over the past century - particularly the past 40 years - synthetic industrial chemicals have been produced in and imported into this ecosystem in exponentially increasing amounts. Many of these chemicals are new to the biosphere. Others have been added at hitherto unknown rates. Some are highly resistant to destruction. They have spread throughout the basin ecosystem and in some cases have entered human food chains. Some of these substances may be toxic.

Toxicity, a property of hazardous polluting substances, is the ability to produce adverse effects in living organisms when they are exposed to the substances through ingestion, inhalation, contact, or injection. As yet there is no instrument that can measure toxicity; it can only be determined by the response of an organism. Therefore, the concerns about toxicity are strictly biological in origin.

The toxicity of a substance is not a discrete property but a relative one. High toxicity has meaning only when one substance is compared to another. All elements, chemicals, and mixtures of chemicals produce toxicity at some exposure and time. To compare toxicities one must fix either the amount of the toxicant or the period of exposure. For example, both table salt and arsenic are toxic. However, salt is considered less toxic than arsenic because more is needed for a fixed exposure time or exposure over a longer period of time is needed for a fixed amount to produce toxic effects.

For some substances there is a threshold dose or exposure below which no adverse effects occur, regardless of the length of exposure. Other chemicals are believed to have no safe threshold; no amount may be safe.

In the 1978 Great Lakes Water Quality Agreement, a toxic substance is defined as "a substance which can cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances." This definition includes many substances that are not generally considered toxic. Therefore lists of toxic substances developed by various individuals or agencies will not be identical. In this report, the term hazardous substances will refer to those substances that produce adverse effects from exposure to low concentrations or doses or in short periods of time and will include the common meaning of "toxic substances". No attempt has been made to provide a list of specific substances which would be considered as toxic.

Designing chemicals to achieve desired properties has advanced to a sophisticated science and has led to the formulation of many molecular configurations to which organisms have never been exposed and for which there are no metabolic pathways to process them through the body. DDT and other insecticides were among the first synthetic chemicals to be produced in large quantities and to be widely dispersed in the environment. Because these chemicals were designed to kill insects, their high toxicity to many other organisms is not surprising. DDT has a low toxicity to humans, but a relatively high toxicity to aquatic organisms. Ironically, DDT was the first chemical to cause concerns in the Great Lakes, not because of its toxic effects, but rather because residues of it found in fish and other organisms exceeded the administrative guidelines for human food. Other hazardous substances causing problems are dieldrin, PCBs, and mercury. As chemical usage increased to current levels and more sensitive analytical methods were developed for more compounds, occurrences of many other chemicals were determined.

Controlling hazardous substances is fundamentally different from controlling the more conventional pollutants, such as biochemical oxygen demand (BOD) or phosphorus, in one respect, there is a large number of hazardous substances and little knowledge of their locations, quantities, adverse impacts, or persistence.

This report discusses the problems of hazardous substances in the Great Lakes basin ecosystem in the context of their biological effects, human health effects, transport and fate, sources and control alternatives, and presents a plan for attacking the problems. The problem of PCBs in the Great Lakes is described in Appendix A, as a specific example of one hazardous substance.

II Biological Effects

The adverse impact of hazardous substances on fish or man is the driving force behind most pollution abatement programs. Although effects on human health are considered to be of much greater consequence when they occur, they are often not readily distinguishable and therefore receive little attention except in unusual instances. However, most of the "headline" pollutants of concern in the Great Lakes during the last 10 years have been the result of exceeding the residue guidelines for fish used as human food or animal feed and not as a result of demonstrated toxicity to aquatic life.

Past Board and Commission activities have emphasized the protection of aquatic life, especially with respect to establishing water quality objectives. Effects on aquatic life are not only more easily observed than effects on other water uses, but frequently occur at lower concentrations. Therefore they have received more attention.

The Science Advisory and Water Quality Boards have repeatedly emphasized the lack of sufficient information to determine the biological effects of hazardous substances in the Great Lakes. The Board does not expect any large increase in resources being made available in either country to determine biological effects. Therefore existing resources and knowledge must be used more wisely to accelerate progress in evaluating the large number of potentially hazardous substances.

Since residues, the unwanted accumulation of substances in biological tissues, have been in the forefront of problems caused by hazardous substances in the Great Lakes, it would be prudent to focus initially on those substances which form residues. Residue formation, or bioconcentration potential, can be predicted either by analytical measurements or by calculations from chemical structure. Neither is as accurate as direct measurements from either laboratory exposure or field monitoring, but both are worth considering as a first step given the current lack of information.

Investigators have found that the solubility in the solvent octanol is a very good estimator of the substance's bioconcentration potential and is easily measured. A reasonable estimate of octanol solubility can be made from knowledge of the molecular structure without actual measurement.

A substances' relative solubility in water and octanol is often expressed as a logarithmic term called the partition coefficient (pK). It is possible to predict the bioconcentration potential of a hazardous substance (how it will distribute itself in fish, or other organisms or in water) by knowing the pK. If a substance has a bioconcentration factor of 10,000, then a one pound trout would carry the same quantity of the substance as 5 tons (or about 20,000) glasses of water.

However, the bioconcentration potential, tissue concentration divided by water concentration, will not be especially useful unless a judgement can be made on the acceptable residue limits. This requires animal data for chronic exposure that can be extrapolated to human beings or epidemiological data.

The 1980 report of the WQB/SAB Committee on the Assessment of Human Health Effects of Great Lakes Water Quality states that of the 381 compounds listed in Appendix E of the 1978 Annual Report of the Water Quality Board(1), only 89 had sufficient acute or chronic toxicity data available to allow for meaningful toxicity evaluations. Of these, 18 were acutely toxic but had insufficient chronic toxicity data, and 38 were found to cause chronic effects in animals. Thirty-three were known to cause chronic effects in man. Much more information must be generated in order to establish exposure levels that are acceptable, and then to establish permissible residue limits for Great Lakes fish.

The data required for making decisions are of a routine nature and a mechanism is needed to develop them outside the research community. The Board is not aware of any such mechanism nor even that anyone has been assigned the responsiblity for meeting this need. Clearly, this routine data need should not be classified as "research". Research scientists should not be expected to develop these data, especially since they are generally unwilling to do so and their laboratories are not designed and operated to produce large amounts of routine data. Even if funds are forthcoming and a mechanism is created, a long time will elapse before sufficient data will emerge. Decisions cannot wait until these data are available.

Much expertise exists in federal, provincial, and state health and environmental agencies. Undoubtedly there are also data held by these agencies and the private sector, that have not been used or released. An effort should be mounted immediately to consolidate such expertise and data in order to establish permissible residues where the information is sufficient, and flag those substances for which data are most needed but unavailable. A cooperative effort between both countries including all governmental levels would be more complete and acceptable than if done individually. Such an effort might also reduce the problem of different limits being established by the various jurisdictions.

Data for toxic effects on aquatic organisms are needed as well, and most of the above discussions on residues is applicable here too. Determination of effects appears to be more standardized for health evaluations than for non-health related considerations. Therefore, there is a need for agreement on the data sets required as well as to develop a data base and a mechanism for generating the data. Here, as for health effects, routine information is needed, be it laboratory or field data. Just as for residue data, the needs are routine and research budgets should not be expected to support such work. While necessary for regulation, the data per se are not an inherent part of regulatory actions; and so can be jointly produced and shared without interference with local authority. A hazard assessment framework based on current knowledge, needs to be adopted and routine data should be produced to provide a basis for wise regulation.

Because the organisms and communities to be protected are diverse and not well characterized in some instances, agreement is often slight when groups try to arrive at a hazard assessment plan. Such disagreement has a place in research where ideas must be tested and defended against peer review. Such debate, however, will thwart regulatory activity if the framework for hazard assessment depends on general agreement among the scientific community.

In order to move ahead on hazard assessment within the Great Lakes Water Quality Agreement activities, those responsible for the framework will have to accept incomplete knowledge and therefore deficiencies and errors. Any plan will need revision periodically as better techniques are devised. However, there is no reason to expect any quantum leaps in the field in the immediate future and, therefore, no reason to delay adopting an approach for current use.

Cooperative efforts among the jursidictions involving pooling of resources to generate data, use of a single data handling system, and common procedures for risk assessment will reduce costs and permit more complete information to be generally available in a shorter time. The Commission can play a vital role by promoting and fostering this international effort in a way that cannot be done by individual jurisdictions.

III Human Health Effects

While hazardous substances can affect all forms of life in the ecosystem, the effects on aquatic life, especially fish, often receives more attention from the media and the public than other biological effects. Man, too, is a part of the ecosystem and will be affected by events occurring in it. Since people move in and out of the Great Lakes basin and, more importantly, eat food and breathe air from outside the basin, detecting impacts of water quality in the Great Lakes on humans is difficult. Furthermore, epidemiological studies, which are the most important technique for determining such effects, have poor resolving power and are complicated by many factors. In addition, epidemiology depends on correlations that do not necessarily present cause and effect evidence. This science depends on a large number of observations and repeated studies. Sufficient data have not yet been collected to permit any conclusions to be drawn concerning human health effects from Great Lakes water quality.

In previous reports, the Board has pointed out the need for a better assessment of health effects from water quality conditions in the Great Lakes. Two of the principal routes for human exposure to hazardous substances in the Great Lakes are through drinking water and eating fish. A study completed by Dr. H.E.B. Humphrey of the Michigan Department of Public Health(2) examines the correlation between PCB residues in Lake Michigan fish and concentrations of PCBs in the blood of residents consuming such fish. This study does not provide data to show whether the intake of PCBs causes health effects. It does demonstrate that the higher blood levels found in those eating large quantities of fish, from four different populations, are highly correlated to the PCBs in Lake Michigan fish. Many other animal studies, for example Allen and Barsotti(3), show the ease of PCB uptake from food and leave little doubt that the correlations which Humphrey found are not due to chance.

The crucial question not addressed in Humphrey's study is: What adverse effects, if any, should be expected? This question is currently being investigated by ongoing studies, the results of which are not yet available. However, two conclusions can be made from Humphrey's study with a reasonable degree of confidence. First, hazardous substances that occur in the Great Lakes water and bioconcentrate in fish can be traced through food chains and found in humans consuming the fish. Second, consumption of sport fish can be a significant source of enhanced exposure for select populations, and is a source that may not be easily controlled by present regulatory efforts.

To the extent that the suggested permissible total cumulative dose of 200 mg of PCBs established by the U.S. Food and Drug Administration is valid, these select populations will obtain such a dose in a little over four years rather than in a lifetime thereby incurring an increased risk.

Swain(4) discusses yet another ramification of special high risk populations. He cites the data of Allen and Barsotti(3) as providing strong evidence that infant monkeys receive high doses of PCBs through mother's milk. There is no reason to assume humans are different. Several studies cited by Swain(4) report PCB levels in human mother's milk of .01 to .03 ppm with some values even higher. Unlike adults, consuming a small percentage of their total diet as PCB contaminated fish, nursing infants get almost 100% of their diet as milk!. Coupled with a probable greater sensitivity of infants and the pronounced tendency for PCBs to have a long residence time in the human body, this represents an enormously larger dose for nursing infants than for adults, even those who eat above average amounts of fish.

These observations and extrapolations suggest some questions that the Commission should resolve. First, these examples demonstrate that there are at least small populations exposed to higher than average risk that may not be adequately protected by nationally based limits (e.g. FDA action levels) because the source of exposure is not controlled by any regulatory agency or because consumption is well above the averages upon which the allowable food concentration is based. The Commission should advise the Governments to ensure that all jurisdictions have adequate regulations to protect such populations from higher than average exposure. This issue is completely separate from the question of whether the dose received is in fact harmful or not. It is separate because a sound argument can be made that small sub-populations within the Basin deserve the same degree of protection (or margin of safety) as is given to the average citizen. The Commission could play a more active role in assuring that everyone has sufficient information in an understandable form, to appreciate how his risk compares to that of the average person.

The results of the Humphrey(2) study also suggest that there are characteristics unique to the Great Lakes and associated socio-economic features that result in a risk to the region's inhabitants different from that of the average citizen in either country. For example, the most desirable groups of edible fishes in the Great Lakes, especially the upper lakes and Lake Michigan, are lake trout and salmon. These species also happen to be high in fat, and therefore usually have higher residues than other less fatty fish living in the same waters. In the case of sport fish consumption, in the Great Lakes basin, this intake could prove to be much more significant than in other geographic areas.

Another feature of the Great Lakes basin is the proximity of large populations to productive fishing waters. A large number of fishermen may catch and eat more sport fish than the average individual. Should current efforts succeed in improving water quality, achieving higher fish populations, and restoring the lakes to their original condition of large salmonid populations, fish consumption could be expected to increase for even larger sub-populations within the basin. Unless residue levels in fish are reduced, more people will receive a higher than average exposure to hazardous substances.

The foregoing discussion raises a basic question for the Commission, namely when should there be additional efforts to protect populations with higher than average exposure? Some jurisdictions make a concerted effort to ensure that sports fishermen are aware of the possible consequences of eating sport fish, for example the Ontario Ministries of Natural Resources and the Environment annually publish a "Guide to Eating Ontario Sport Fish". However, these efforts are not widespread nor consistent throughout the basin. The responsibility for protecting sub-populations at risk needs to be clearly delineated.

Another route for exposure to hazardous substances is drinking water taken from the Great Lakes. Both the United States and Canada have given added attention to this question in recent years. Most of the efforts have focused on pesticides and organic compounds formed as a result of chlorination such as chloroform and other haloforms, but the efforts have not been comprehensive for all major chemical groups.

Ontario issued a report in April 1977(5) which provides data on haloform concentrations in chlorinated drinking water taken from various sources, including the Great Lakes. Table 1 from the report shows that chlorinated drinking water from the various Great Lakes contained about 40% of the chloroform concentrations found in finished water taken from rivers, but had about 200% of the concentrations in finished water from groundwater sources. However, there was essentially no difference in the dichlorobromethane concentration among drinking waters taken from the three souces. Table 2 from the same report shows that chlorinated drinking water obtained from Lake Erie has distinctly higher concentrations of both chemicals than water from Lakes Superior, Huron or Ontario.

TABLE 1
AVERAGE TOTAL HALOFORM CONCENTRATIONS
IN CHLORINATED DRINKING WATER FROM VARIOUS SOURCES

Source	No. of Sites	$CHCl_3$ Concentration (µg/L)			$CHCl_2Br$ Concentration (µg/L)		
		Average	Low	High	Average	Low	High
Rivers	14	82	23	159	9	nd	22
Lakes*	2	79	42	116	55	4	7
Great Lakes	23	31	6	75	10	nd	19
Wells	7	17	nd	60	8.9	nd	41

* 2 locations in Sudbury

nd - not detected

Source: "Organics in Ontario Drinking Waters. Part II. A Survey of Selected Water Treatment Plants". Smillie, R.D. et al.(5)

TABLE 2

AVERAGE TOTAL HALOFORM CONCENTRATIONS
IN CHLORINATED DRINKING WATER FROM GREAT LAKES SOURCES

Great Lake	No. of Sites	$CHCl_3$ Average Concentration µg/L, (σ%)*	$CHCl_2Br$ Average Concentration µg/L, (σ%)*
Superior	2	22, (71)	3.5, (141)
Huron	8	36, (29)	10, (26)
Erie	4	51, (41)	15, (29)
Ontario	9	20, (51)	10, (39)

* Relative standard deviation

Source: "Organics in Ontario Drinking Waters. Part II. A Survey of Selected Water Treatment Plants". Smillie, R.D. et al.(5)

Symons, et al.(6) reported results of a U.S. National Organic Reconnaissance Survey for Halogenated Organics. The 80 water treatment plants studied included some using the Great Lakes as a water source. This study showed, as did Ontario's report, that haloform levels in Great Lakes drinking water are at relatively low concentrations when compared with other locations.

Both studies show that most of the haloforms, especially chloroform, are created as a result of chlorination rather than being present in the raw water used. Haloforms in the U.S. study were correlated with non-volatile total organic carbon while the Ontario report associates them with "organic loading". Maintaining a low organic content in water should reduce the amount of haloforms produced. Present efforts to reduce eutrophication of the Great Lakes should also reduce total organic carbon concentrations and therefore help curtail the production of haloforms in finished drinking water.

Finally, the Board wishes to point out the relative intake of hazardous substances from eating fish and drinking water. It is estimated that a 70 kilogram person consumes about 2000 grams of water per day. Average fish consumption in the U.S., and it can be assumed that Canadian consumption is comparable, varies between 10 and 20 grams per day. For compounds that do not bioconcentrate, the water intake is about 100 times greater than the fish intake. If a compound bioconcentrates 100 times, usually considered to represent a minimal value, the intake is equal. For compounds such as PCBs, that bioconcentrate 100,000 to 1,000,000 times, the intake from fish is 1,000 to 10,000 times larger than from water. In other words, one 150 gram (6 ounce) meal of fish provides as much exposure as three or more years of drinking water. This example illustrates why, in past reports, the Board has stressed the importance of focusing control efforts on those hazardous substances that have a high bioconcentration potential.

IV Transport and Fate

The impact of hazardous substances discharged into water bodies such as the Great Lakes, depends not only on their toxicity but also the ways in which they move through the lakes. Transport and fate pertains to how chemicals will move through the lakes, how they will degrade, where they will reside for short and long periods, and how they will be removed from the system.

Various chemicals exhibit different transport and fate characteristics as a result of their individual physical-chemical properties. These characteristics affect the surveillance approach needed to monitor the chemicals; the loadings that result in various concentrations in the water, sediment, and biota; the control programs that are required; and the cost/benefit ratios that can be expected from control efforts. Some of the more important fate and transport characteristics pertinent to the Great Lakes are discussed below.

Perhaps one of the most important properties of hazardous substances for large lakes is their persistency in the water, sediment, and biota. Persistence ranges from infinity for elements such as mercury, to a very transient existence for chemicals such as free chlorine. Based on persistence alone, a reasonable prediction can be made of how extensive the occurrence of a substance could be in the lakes. Many of the headline contaminants in the Great Lakes over the past fifteen years have been substances that are highly persistent. They enter the lakes from many sources, are found throughout the lakes, and are continuously present. Examples include DDT, dieldrin, mirex, PCBs, phthalates, and mercury. Such substances are usually found distributed throughout the ecosystem at different concentrations in sediment, water, and biota.

Persistent substances will eventually be widely dispersed in the lakes through various mechanisms; some of which are discussed in this section. Surveillance programs with lake-wide coverage will detect persistent substances. Sampling for less persistent substances must be done closer to the source since such substances will disappear sooner . There is no relation between persistence and toxicity. Persistency, increases the area affected but not necessarily the toxic effects with the area of occurrence.

There are no standardized or generally accepted tests for persistence that are specifically tailored for Great Lakes conditions. The development, validation, and acceptance of such methods is a matter of some importance and should be vigorously promoted. High persistence, such as that displayed by PCBs, is not characteristic of the majority of industrial chemicals. Measurements of environmental degradation rates, therefore, would aid in setting priorities on hazardous substances and in hazard assessment evaluations.

Another important property of some chemicals, in terms of their fate and transport in the lakes, is the tendency to adsorb or absorb (sorb) on suspended solids in the water such as silt, clay, algae, and bacteria, or on surfaces such as vegetation. Because of the large water volume and relatively small surface area of vascular plants, suspended solids are likely to be important in the Great Lakes. Through various coagulating mechanisms, nearly all suspended solids settle. If they did not, the lakes would be much more turbid because there is a large input of colloidal material from tributaries that would not settle without coagulation. The settling of suspended solids is an important transport mechanism for those substances that have high sorbtion characteristics because sedimentation carries the substances from the water column to the bottom sediments and depletes the water concentration. The principle is akin to the scavenging of pollutants from the air by rain. The rate of settling depends on the density and size of the particles and the depth of the water. Lake currents and wave action can resuspend sediments and transport substances into the water column again. Sorption onto suspended particles and subsequent settling explains why many substances are found in high concentrations in sediments.

Steen et al.(7) and Hassett et al.(8) have shown a strong correlation between the total organic carbon (TOC) content of suspended particles, including soil particles, and the sorption of organic chemicals on such particles. In the lower lakes, where the TOC of suspended material is generally greater than it is in the upper lakes, the particulate material is a more significant transport mechanism. A given loading of a hazardous substance per unit volume of water will distribute itself differently within the lake compartments depending upon the TOC content of the suspended material.

The affinity of chemicals for the particles changes the biological availability and therefore the biological effects. As an example, Ferguson et al.(9) have shown that endrin sorbed onto particles is less toxic than endrin in solution. In the Great Lakes where chemical/physical conditions can vary due to phenomenon such as stratification and deoxygenation, substances may desorb or be held less tightly and alter their biological and chemical behavior. Through such mechanisms, sediments may become sources rather than sinks for hazardous substances.

Whether suspended solids in water are beneficial or detrimental depends on many conditions. The public generally prefers clear water of high transparency. On the other hand, without suspended solids settling to the bottom and carrying with them many tons of sorbed substances, the water column is likely to contain a much larger proportion of the total input of hazardous substances, and these unsorbed substances are likely to cause more biological harm.

The disposal of contaminated dredged material in the open waters of the lakes may also be a significant source of hazardous substances. Once in the lakes, the particles function in much the same manner as other particulates, changing with time and conditions.

Solubility plays a major role in the sorbtion tendency. Substances, such as sodium chloride, which are highly water soluble are poorly sorbed. PCBs or DDT are very water insoluble and usually sorb readily. Solubility also plays an important role in a different mechanism, i.e. the accumulation of substances as residues in living tissue especially in lipid (fat). Some chemicals are hundreds or thousands of times more soluble in lipids than in water. In the case of a fish with high fat content the concentration of PCBs or DDT is strongly enhanced by the high fat solubility of these substances. However, the concentrations of PCBs and DDT in a fish also depends on its food habits, growth rate, and age. The increased concentration of chemicals in fish over that of the water is called the bioconcentration factor. In a mature lake trout or salmon this factor may reach a value as high as 1 million, i.e. the concentration of PCBs in fish may be 1 million times greater than that of the water.

Sorption and solubility result in a behavioral pattern of hazardous substance called compartmentalization. Compartmentalization refers to the relative amounts of the substances occurring in various parts of the lake, such as suspended solids, water, sediment, and aquatic organisms. Naturally, the manner in which proportioning of the substances among these compartments occurs, drastically changes the effects of a given loading. Water soluble substances added to the lake, will occur principally in the water while water insoluble substances will be principally in the suspended solids and sediment. The total quantity in the aquatic organism compartment is likely to be small because the biomass is far less than for sediment but the concentration may be quite high compared to that in the water. However, acceptable residue limits are expressed as tissue concentration and the impact on a small compartment, the edible fishes, may be large. Therefore, the distribution between compartments is very significant in determining the impact of a given lake loading.

A knowledge of compartmentalization is essential in order to assess the significance of a given loading on the lakes and their biota. Such knowledge is equally important in devising surveillance programs. The monitoring program currently being conducted on herring gulls is based on this compartmentalization. The pattern of compartmentalization is not fixed but changes as physical/chemical conditions change. It is necessary to know the rate at which changes occur as well as the equilibrium conditions.

The degradation or alteration of hazardous substances after their entrance into the lakes may also be significant. If hazardous substances are not persistent, they leave via evaporation, or degradation. Degradation usually proceeds to yield common substances such as carbon dioxide, water, and nitrate. Often, however, the degradation sequence produces intermediate substances, which, if the products are very toxic, may exist long enough to cause harm. Chemical degradation is important, but microbial degradation is frequently more significant for many organic compounds. The degradation pathway needs to be established to determine the nature and effects of intermediates.

Transformations of one substance to another have also been found to be important in the lakes. Examples are conversion of inorganic mercury to organic mercury compounds, heptachlor to heptachlor epoxide, and DDT to DDE, which has a more significant effect than DDT on egg shell thinning in birds exposed to it. In these examples, the transformation product is more toxic than the original one. Although chemists can usually predict such transformations, as in the case of methyl mercury, the role of microorganisms must not be overlooked.

In determining ways and means of reducing the production of those pollutants adversely affecting the aquatic ecosystem the "monitoring" function will have to be extended to cover the generation, uses, transportation, and disposal practices for such pollutants as well as their environmental diffusion and fate.

V Sources

Hazardous substances may gain access to the Great Lakes through emissions to the atmosphere, industrial and municipal wastewater discharges, urban and rural land runoff, and other sources such as spills and leaching from solid waste disposal sites. In order to develop control programs for any substances proven or suspected to cause problems, it is important to know the relative magnitude of the various sources.

In the past, the International Joint Commission and its Boards have been primarily concerned about wastewater discharges as sources of pollutants mainly because the Agreement focuses on Great Lakes water quality. Furthermore, regulatory authority for control of such discharges is well developed and could proceed immediately. However, information was available for only a very few of the many hazardous substances likely to be present and the regulators found themselves unsure about what course to pursue. Appendix D of this report provides recent information on the occurrence of 129 chemicals in municipal and industrial wastewaters and some treatment efficiencies for removing them, but much still remains to be learned about treatment technology. The information is used to provide some perspective on the relative loads of hazardous substances which may be introduced to the lakes from municipal and industrial point sources.

The Board would like to emphasize here its concerns about other sources of hazardous substances, which it believes are less understood. In the 1979 annual report(10), the Board highlighted the problem of atmospheric deposition in the Great Lakes and advised the Commission that such inputs should be viewed with substantial concern. Although it was not the Board's intention, those components causing acid precipitation received most attention and concern, probably because more was known about the sources and quantities and damage was already observable in various places. The Board emphasized then, and wishes again to impress even more emphatically upon the Commission, the need to assess, and control where necessary, atmospheric inputs of other hazardous substances. Currently the Commission has a minimal surveillance program to measure the loading to the basin or even to the lakes from the atmosphere. This situation continues even though evidence accummulates that airborne deposition is the significant source of some contaminants to the lakes. The Board expended some of its resources during the past year to accumulate existing information on present loadings from the atmosphere. Evidence is strong that the atmosphere is the major source of PCBs to Lake Superior. Airborne inputs of phosphorus have been recognized as substantial for some years. The global distribution of DDT in the Arctic ice sheet and other remote areas strongly suggests that atmospheric deposition is a major pathway for distributing some contaminants throughout the ecosystem. With both nations planning to generate more electrical power from burning coal, the Board believes that the Commission must take a more informed and aggressive role on atmospheric deposition if the Great Lakes are to be protected.

ATMOSPHERIC SOURCES

Only recently has an appreciation developed for the relative impact of atmospheric deposition on water quality. Air masses circling the globe become "polluted" by accumulating chemical components emitted from point (smoke stack) and nonpoint sources (sanitary landfills, urban areas). Most areas of the earth experience detectable degradation from atmospheric components. To emphasize the point, a recent National Academy of Sciences (NAS) report on PCBs in the environment(11) stated that the north Atlantic Ocean is the major global sink for PCBs. Nearly all reach the ocean as a result of atmospheric transport and deposition. A detailed discussion of the PCB problem in the Great Lakes is presented in Appendix A.

In order to assess of the extent of atmospheric deposition of contaminants to the Great Lakes, the Science Advisory Board funded two studies which are summarized below. Detailed information on airborne organic contaminants in the Great Lakes basin is included in Appendix A - "Assessment of Airborne Organic Contaminants in the Great Lakes Ecosystem" by S.J. Eisenreich, B.B. Looney and J.D. Thornton. Inorganic contaminants are described in Appendix B - "Assessment of Inorganic Contaminants in the Great Lakes" by H.E. Allen and M.A. Halley. These data are used to provide an estimate of the atmospheric inputs of hazardous substances.

Organic Substances

The estimate of atmospheric deposition of trace organic substances is hampered by: 1) an inadequate data base on their atmospheric concentrations; 2) inadequate knowledge about the distribution between vapour and particulate forms in the atmosphere; 3) a lack of understanding of the dry deposition process on a water surface; 4) inadequate micro- and macro- meteorological information over the lakes during dry and wet deposition; 5) a lack of appreciation for the episodic nature of atmospheric deposition of trace organic materials on water; and 6) an inadequate understanding of the temporal and spatial variations in atmospheric concentrations and deposition. It is possible, however, to use approximations of wet and dry deposition to estimate total deposition.

The range of concentrations of trace organic substances found in air and precipitation is reported in Appendix A. For each substance, one value was chosen as the best present estimate of median concentration for atmospheric deposition to the Great Lakes. Wet fluxes of airborne trace substances were also calculated for the Great Lakes basin, assuming a fixed concentration for each substance and an annual precipitation of 80 cm/yr.

The critical parameter in estimating dry deposition is the deposition velocity. In general, submicron particles exhibit deposition velocities of 0.1 to 0.6 cm/sec, therefore, a value of 0.3 cm/sec was selected for these calculations. The estimated dry fluxes were multiplied by the surface area of each lake to give total dry deposition, which is summed with wet deposition to give the estimates of total deposition shown in Table 3. These estimates are based on the small data base available, and are probably accurate to within a factor of 2 to 10.

The available data suggest that dry deposition of trace organic substances is significantly greater than their wet deposition. Table 3 also suggests that total deposition to each lake is proportional to that lake's surface area. The upper Lakes Superior, Huron, and Michigan consequently receive more deposition. The magnitude of the atmospheric loadings of compounds such as

TABLE 3

TOTAL DEPOSITION OF AIRBORNE TRACE ORGANIC SUBSTANCES
TO THE GREAT LAKES
(metric tons per year)

SUBSTANCE	LAKE				
	Superior	Michigan	Huron	Erie	Ontario
TOTAL PCB	9.8	6.9	7.2	3.1	2.3
TOTAL DDT	.58	.40	.43	.19	.14
α-BHC	3.3	2.3	2.4	1.1	.77
γ-BHC	15.9	11.2	11.6	5.0	3.7
DIELDRIN	.54	.38	.55	.17	.13
HCB	1.7	1.2	1.2	.53	.39
p,p'-METHOXYCHLOR	8.3	5.9	6.1	2.6	1.9
α-ENDOSULFAN	7.9	5.6	5.8	2.5	1.8
β-ENDOSULFAN	8.0	5.6	5.8	2.5	1.9
TOTAL PAH	163	114	118	51	38
ANTHRACENE	4.8	3.4	3.5	1.5	1.1
PHENANTHRENE	4.8	3.4	3.5	1.5	1.1
PYRENE	8.3	5.9	6.1	2.6	1.9
BENZO(a)ANTHRACENE	4.1	2.9	3.0	1.5	1.1
PERYLENE	4.8	3.3	3.4	1.5	1.1
BENZO(a)PYRENE	7.9	5.6	5.8	2.5	1.8
DBP	16	11	12	5.0	3.7
DEHP	16	11	12	5.0	3.7
TOTAL ORGANIC CARBON	$2x10^5$	$1.4x10^5$	$1.5x10^5$	$6.6x10^4$	$4.6x10^4$

Source: Appendix A - "Assessment of Organic Airborne Organic Contaminants in the Great Lakes Ecosystem" - S.J. Eisenreich, B.B. Looney, and J.D. Thornton.

PCBs and DDT which are no longer being used is cause for concern and supports the need for increased monitoring. For example, it is estimated that only about 30% of the approximately 585,000 metric tons of PCBs produced or imported in North America between 1930 and 1975 have been destroyed or released to the environment (Appendix A). The remaining 60% is still in use or storage and will eventually require effective disposal or it will be released to the environment.

Inorganic Substances

Although the estimates of atmospheric deposition of some inorganic substances fall into rather narrow bands, the range for others is broad, extending over one order of magnitude (Appendix B). In particular, reported values for atmospheric loading of cadmium, calcium, copper, iron, and sulfate appear to be inconsistent. The lack of better agreement among the values may have several causes. Iron and calcium may be soil-derived. Thus, variation in their loading may be seasonal and related to soil characteristics and land use practice. Variation in sulfate loading is a consequence of long range transport patterns associated with acid deposition.

Table 4 provides preliminary loading estimates for the major trace metals as derived from the literature. Estimates of loadings of nutrients and some other major elements are also provided in Appendix B. Unlike the organic materials, the nutrient and major element loadings are generally elevated in the lower lakes as compared to the upper lakes, suggesting that location might be more important than surface area, or that nutrients and major elements are less volatile or ubiquitous than the trace organic substances. Trace metals data, on the other hand, do not display any geographical distribution on a lake by lake basis. This lack of obvious gradients may be due to sampling and analytical differences.

In view of the limited urban and industrial development in the upper lakes basin, the atmospheric inputs of toxic metals such as zinc and lead, noted in Table 4, are likely the most significant source of these contaminants to those basins.

TABLE 4

TOTAL DEPOSITION OF AIRBORNE TRACE METALS TO THE GREAT LAKES
(metric tons per year)

METAL	LAKE				
	Superior	Michigan	Huron	Erie	Ontario
Zn	8,210	#	#	#	948
Pb	1,230	1,730	596	754	379
Cu	821	575	298	151	95
Cd	82	58	60	75	28
Ni	328	575	89	75	76
Fe	8,210	#	4,770	3,270	1,520
Al	14,000	28,800	#	#	#
Mn	1,640	1,150	#	#	#

Estimate not possible from available data.

Source: Appendix B - "Assessment of Airborne Inorganic Contaminants in the Great Lakes" - H.E. Allen and M.A. Halley.

INDUSTRIAL SOURCES

Industries producing or using hazardous substances are likely to discharge some of these substances in their wastewater effluents. In addition, small quantities of substances may be discharged from many different industries. The problem of assessing the relative importance of the various possible industrial sources is enormous.

In a June 1976 settlement of a law suit with the Natural Resources Defense Council (NRDC), the U.S. Environmental Protection Agency agreed to devote more attention to potentially toxic substances in industrial wastewater. The resulting NRDC Consent Decree required EPA to promulgate regulations for the control of 65 classes of toxic pollutants associated with 34 different industrial categories. The 65 classes of pollutants include 129 specific substances referred to as "consent decree priority pollutants" or simply "priority pollutants".

In order to develop regulations to control these toxic substances and set effluent limits under the National Pollutant Discharge Elimination System (NPDES), the U.S. EPA's Effluent Guidelines Division undertook a comprehensive program to accumulate and summarize data on the occurrence of priority pollutants in industrial waste discharges. The voluminous and diverse occurrence and treatability data have been assembled into a comprehensive Treatability Manual(12) by EPA's Office of Research and Development. The manual is to be used in developing NPDES permit limitations for facilities which, at the time of permit issuance, were not covered by industry-specific effluent guidelines authorized under the Clean Water Act.

Initial screening surveys have been completed for 21 classes of industries. The quality of these data varies. The initial screening data gathered prior to August 1979 is not supported by quality assurance. The verification data (post August 1979) is supported by quality control, such as that described by Kleopfer et al.(14). As a result, the overall quality of the data base has not been fully defined and is not uniform. Since the data were developed by standard inorganic and gas chromatography/mass spectroscopy procedures(15), the identification of the specific chemicals should be reasonably definitive, but the quantitative data are uncertain.

In Canada, the Environmental Protection Service of the Department of the Environment is preparing dossiers on a variety of industries producing or using hazardous substances. Concurrently, field studies by both the Ontario Ministry of the Environment and the Federal Department of the Environment are in progress. Hazardous substances source identification is the major objective of these studies being conducted at chemical and petrochemical plants in Cornwall, Sarnia, and Elmira and Algoma Steel in Sault Ste. Marie, Ontario.

Generalized data on the occurrence of various hazardous substances in the industrial waste effluents and a knowledge of the amount of wastewater discharged by specific industrial groups in the Great Lakes basin will permit an estimate to be made of the potential loadings from these sources. The Water Quality Board's inventory of industrial point source discharges(13) provides an estimate of the flow; the data being generated for the Treatability Manual(12) provides a preliminary estimate of the concentrations of various hazardous substances which may be present in these effluents.

As typical examples, estimated cadmium and benzo(a)anthracene loadings to the lakes are presented in Tables 5 and 6, based on the occurrence data and the wastewater flows from each industry category discharging in each lake basin. It should be noted that these preliminary estimates do not include data for a possibly significant source of cadmium loadings, the electroplating industry. Also, the wide variation in the industrial plants within an industrial class may significantly alter the loadings for the specific water basin. This type of information provides an estimate of the possible magnitude of the loads and provides direction for monitoring programs. For example, the potentially significant input of cadmium and benzo(a)anthracene to Lake Michigan from the iron and steel industry, warrants further investigation. Sample information on priority pollutant data and its use in estimating industrial loadings in the Great Lakes is included in Appendix D.

MUNICIPAL SOURCES

Another possible pathway for hazardous substances to gain access to the lakes is via municipal wastewater discharges. The problem of trying to monitor all municipal wastewater discharges for the large number of potentially hazardous substances which may be present is obvious.

The general occurrence of hazardous substances in municipal wastewater treatment plant discharges is being developed in major surveys in both the United States and in Canada. The U.S. EPA's Office of Water Planning and Standards is surveying 40 U.S. cities for hazardous substances in plant influents, effluents and sludge discharges using basic EPA analytical methods(15)(16). The EPA's Municipal Environmental Research Laboratory is surveying 25 cities using the more extensive methodology of DeWalle and Chian(17). A second study by the Office of Water Planning and Standards is also underway on six cities to determine the sources (industrial, commercial, and domestic) of the hazardous substances entering the municipal system and

TABLE 5

PRELIMINARY ESTIMATES OF LOADINGS OF CADMIUM TO THE GREAT LAKES FROM TREATED INDUSTRIAL WASTEWATERS

INDUSTRY	TREATED WASTEWATER							
	Concentration[a] (μg/L)			Lake Loading[c] (t/yr)				
	Minimum	Maximum	Mean	Superior	Michigan	Huron	Erie	Ontario
Coal mining	2	4	2	0	0	0	0	0
Textile mills	NA[b]	13	6[d]	0	0	0.003	0.006	0.002
Timber products processing	BDL[b]	7	1[d]	0	0	0	0	0
Petroleum refining	<1	20	<2[d]	0.002	0.4	0.09	0.5	0.3
Paint and ink formulation	BDL	200	24	0	0	0	0	0
Gum and wood chemicals	NA	NA	NA	0	0	0	0	0
Rubber processing	NA	1,500	760	0	10	0	190	0
Auto and other laundries	<1.0	31	11	0	0	0	0	0
Porcelain enameling	ND[b]	2,000	650	0	0	0	0	0
Pharmaceutical manufacturing	ND	ND	ND	ND	ND	ND	ND	ND
Ore mining and dressing	0.002	16	<0.03	0.001	0.0006	0	0	0
Foundries	10	840	120	0	0.4	8.2	7.9	0.4
Iron and steel manufacturing	NA	770	270	5.8	860	72	520	210
Nonferrous metals manufacturing	ND	3,000	780	2.3	0	35	6.7	0.3

[a]Information on concentration was obtained from Volume I of the U.S. EPA "Treatability Manual"(12): Data are incomplete

[b]NA - not available; ND - not detected; BDL - below detection limit.

[c]Lake loadings determined by multiplying mean pollutant concentration by industry wastewater discharges as reported in the "Inventory of Major Municipal and Industrial Point Source Dischargers in the Great Lakes Basin"(13)

[d]Median, not average.

TABLE 6

PRELIMINARY ESTIMATES OF LOADINGS OF BENZO(a)ANTHRACENE TO THE GREAT LAKES FROM TREATED INDUSTRIAL WASTEWATERS

INDUSTRY	TREATED WASTEWATER							
	Concentration[a] (μg/L)			Lake Loading[c] (t/yr)				
	Minimum	Maximum	Mean	Superior	Michigan	Huron	Erie	Ontario
Coal mining	ND[b]	<3.3	<0.2[d]	0	0	0	0	0
Timber products processing	BDL[b]	3,400	9[e]	0	0	0	0	0
Auto and other laundries	NA[b]	ND	ND	0	0	0	0	0
Foundries	<20	7,300	1,200	0	4.0	82	79	4.4
Iron and steel manufacturing	NA	470,000	34	0.7	108	9.0	65	27
Nonferrous metals manufacturing	ND	6.0	0.7	0.002	0	0.03	0.006	0.0002

[a]Information on concentration was obtained from Volume I of the U.S. EPA "Treatability Manual"(12).

[b]NA - not available; ND - not detected; BDL - below detection limit.

[c]Lake loadings determined by multiplying mean pollutant concentration by industry wastewater discharges as reported in "Inventory of Major Municipal and Industrial Point Source Discharges in the Great Lakes Basin"(13) where mean is not available, one-half the reported maximum was utilized.

[d]Analytical method did not distinguish between benzo(a)anthracene and chrysene.

[e]Median, not average.

their fates in the municipal treatment plant. These surveys include quality control for estimation of the precision and accuracy of the data. In addition, the EPA is conducting research on the occurrence and removal of hazardous substances in typical municipal waste treatment systems.

The Ontario Ministry of the Environment has just completed a survey of 10 municipal plants in an attempt to identify and quantify hazardous substances in plant influents and effluents. Environment Canada's Environmental Protection Service is conducting a similar screening study on a limited number of different types of waste treatment plants across Canada.

Preliminary information on hazardous substances occurrence from the 25 cities surveyed in the U.S. are included in Appendix D for the Renton Wastewater Treatment Plant in Seattle, Washington, the Oakland Plant in California, and the Clayton Plant in Atlanta, Georgia.

The analyses of wastewaters from these three plants found 87 priority pollutants of the 127 on the list; asbestos and dioxin were not analyzed. There is a wide variation among plants for both compounds identified and concentrations found. Similarly, removals for specific compounds varied from zero to almost 100%. Despite these variations, some observations can be made. Of the 87 compounds found, 24 organic substances and 13 metals were found in all the plants. Chlorination for disinfection generally increased the concentration of certain compounds. Most compounds were detected at increased concentrations in the sludge; the phthalate esters and the polynuclear compounds tended to accumulate in the sludge to much greater concentrations than other compounds.

The order of magnitude of some of the pollutants detected in wastewater treatment plant effluents are shown in Table 7. Trends will become more apparent as the data from the remaining plants become available. Table 8 presents the relative annual loadings to the lakes from municipal point sources which would result from pollutants occurring in the wastewater discharges at the various concentrations shown. These data and their use in estimating loadings of hazardous substances to the Great Lakes via municipal wastewater are discussed in more detail in Appendix D.

TABLE 7

ORDER OF MAGNITUDE OF POLLUTANT CONCENTRATIONS IN MUNICIPAL WASTEWATER TREATMENT PLANT EFFLUENTS (SECONDARY TREATMENT)

COMPOUND	CONCENTRATION (μg/L)
Trichloromethane	10
Phenol	15
Phthalates	< 5
Pesticides	0.1
Cadmium	5
Lead	20

Adapted from: "Presence of Priority Organics in Sewage and their Removal in Sewage Treatment Plants." F. DeWalle and E. Chian(17)

TABLE 8

ANNUAL POLLUTANT LOADS FROM MUNICIPAL POINT SOURCES FOR VARIOUS EFFLUENT CONCENTRATIONS (metric tons per year)

LAKE BASIN	POLLUTANT CONCENTRATIONS (μg/L)					
	0.1	1	5	10	15	20
Superior	0.009	0.09	0.4	0.9	1.3	1.8
Michigan	0.1	1.1	5.7	11.4	17.2	22.9
Huron	0.03	0.3	1.3	2.7	4.0	5.3
Erie	0.3	2.5	12.7	25.4	38.0	50.7
Ontario	0.2	1.6	8.1	16.3	24.4	32.5

Based on flow from municipal discharges as reported in "Inventory of Major Municipal and Industrial Point Source Discharges in the Great Lakes Basin" (13).

URBAN AND RURAL RUNOFF

The U.S. EPA is assessing the occurrence of hazardous substances in urban runoff through its Municipal Environmental Research Laboratory and its National Urban Runoff Program in the Office of Water Program Operations. The data currently available are chiefly for toxic metals. It is not adequate to allow a comparison of the metals in combined sewer overflows and urban runoff with those in municipal wastewater treatment plant effluents. The Canada Centre for Inland Waters also has on-going monitoring programs in urban catchments in Cornwall and Burlington, Ontario to identify hazardous substances in urban runoff. These data are being developed to provide a basis for extrapolating lake loadings and evaluating the effectiveness of control programs. Completion of the planned studies should provide the required perspective on hazardous substances in urban runoff.

The final report(18) and many technical reports(19) of the Pollution from Land Use Activities Reference Group study have covered urban and rural nonpoint source runoff loadings. The Board notes that most of the available data are for some pesticides and fertilizer constituents. There are insufficient data to permit any reasonable assessment of the contribution of other hazardous organic substances and metals from agricultural, silvicultural, and other land runoff. The absence of these data should be a stimulus for action.

OTHER SOURCES

The Commission is familiar with the extensive efforts and resources that have been devoted to removing pollutants, including hazardous substances, by means of wastewater treatment plants. The Board draws attention to the fact that most treatment technology removes but does not convert such chemicals to the elemental forms or common natural compounds. For those chemicals that are persistent, removal means concentrating and disposing of them elsewhere. The disposal site is often a solid waste disposal area where chemicals are by no means excluded from leaching into the lakes or causing injury to man and other terrestrial organisms. The Board has not been able to assess the significance of such loadings to the lakes. The data are not available. The importance of chemical loadings to the Great Lakes from solid waste disposal sites urgently needs to be determined.

More importantly, chemicals leaching from abandoned industrial hazardous waste disposal sites such as Love Canal can result in very high concentrations of hazardous substances in the aqueous environment. The extent to which such pollutants may be transmitted to the lakes by groundwater needs to be determined.

Finally, spills which occur during the transportation and handling of hazardous substances are yet sources which may be contributing unknown quantities of many substances to the ecosystem. The Board is aware that the Commission has taken action in regard to this problem. Additional action is recommended to better assess the significance of these sources.

RELATIVE IMPORTANCE OF VARIOUS SOURCES

There are several obstacles to an adequate assessment of the relative importance of the various pathways for hazardous substances entering the Great Lakes: atmospheric, tributaries, and industrial and municipal point source discharges. Which of the many thousands of chemicals produced or used in the basin should be considered? Which source emissions are most significant? Which should be given priority status? Are there adequate concentration data for the various sources in the basin upon which an assessment can be made?

Preliminary estimates of inputs of cadmium and benzo(a)anthracene into the Great Lakes from atmospheric sources and municipal and industrial point dischargers are summarized in Tables 9 and 10. Other potential sources of loadings not shown include tributaries and shoreline erosion. Although the atmospheric loadings are a major source, more factors need to be considered before a definite evaluation can be made of the relative significance of the various inputs. Much of the input from point sources, tributaries, and erosion consists of larger particles or pollutants sorbed onto particles. Once in the lake, sedimentation of the larger sized particles occurs rapidly. Atmospheric deposition covers the entire lake surface, and the fraction of material in soluble form is greater and is generally more reactive. Thus, less settling occurs and a greater proportion of the input is available to harm a larger number of aquatic biota.

It should be emphasized that estimates of hazardous substances loadings using general or national data bases and extrapolating to the Great Lakes basin are at best only first approximations. They can indicate the need and direction for specific monitoring to confirm loadings to provide a basis for regulatory or control programs.

TABLE 9

PRELIMINARY ESTIMATES OF CADMIUM LOADINGS TO THE GREAT LAKES
(metric tons per year)

LAKE	SOURCES		
	Atmospheric	Municipal	Industrial *
Superior	82	0.4	8.1
Michigan	58	5.7	870
Huron	60	1.3	115
Erie	75	12.7	725
Ontario	28	8.1	211

* Data are incomplete

TABLE 10

PRELIMINARY ESTIMATES OF BENZO(a)ANTHRACENE
LOADINGS TO THE GREAT LAKES
(metric tons per year)

LAKE	SOURCES		
	Atmospheric	Municipal	Industrial
Superior	4.1	ND	0.7
Michigan	2.9	ND	112
Huron	3.0	ND	91
Erie	1.3	ND	144
Ontario	0.94	ND	31

ND - Not Detected

VI Control Alternatives

Control alternatives can be grouped into five major options: wise use, reuse, bans, treatment technology, and use of assimilative capacity. Too frequently, regulatory approaches are limited to treatment technology, perhaps because historically pollution abatement began with the successful development and use of domestic sewage treatment plants. These were good solutions in part because the pollutants in the water to be treated were largely degradable and the end products were ordinary innocuous compounds. Treatment technology applied to today's mix of complex chemicals, especially those that are not readily degradable, is accompanied by a set of new problems.

WISE USE, REUSE, AND BANS

More can be done to reduce the amounts of potentially hazardous substances disbursed throughout the ecosystem by the application of wise-use strategies. Some of our problems, such as those of DDT and other persistent pesticides, have been exacerbated by excessive use. In the early days of these chlorinated hydrocarbon pesticides, applications to cropland were not restricted to the minimum quantity necessary. As a result problems arose. More emphasis on wise use will benefit society in many ways; from cost reduction to resource saving and less environmental contamination. The institutional/legal mechanisms for implementing wise-use practices are less well understood and practiced than those for treatment requirements. Attention should be given to mechanisms to reduce waste volume.

The reuse of waste components or products of waste treatment also benefits society. Products will be reused when it is financially advantageous to do so. Much remains to be done to increase the awareness of such advantages and to hasten reuse. Industries, like agencies, are compartmentalized and may lack the internal coordination necessary to take advantage of reuse options. The Commission might perform a vital role by pointing out the benefits of reuse. Certainly the energy saving alone would warrant such an effort.

Bans that prohibit the utilization of certain chemicals have been used. These bans are limited to those problems where substitutes are available, where use is not essential, or where society is willing to make the sacrifice. Bans will have to be reserved for a few selected problem substances, but they can be effective under some circumstances.

AIR POLLUTION CONTROL TECHNOLOGY

The largest anthropogenic source of emissions of organic substances into the atmosphere is the discharge from the fuel used in the transportation industry (Appendix C). This includes the private vehicles, buses, trucks, trains, and aeroplanes. Of these, only the light duty vehicles are subject to strict regulations. The catalytic converters attack the more reactive types of hydrocarbons and there is some evidence that they also lower the discharge of the aromatic group of hydrocarbons.

The second largest source of manmade hydrocarbon emissions is incineration. Well-designed incinerators will consume virtually all of the organic materials; however, burning dumps and grass, brush, and forest fires can develop a significant local concentration of polycyclic (polynuclear) aromatic hydrocarbons (PAHs). Since numerous fires in these categories are started by man, some of them intentionally, the current educational programs are especially important.

Many industrial processes and some paints use organic solvents as carriers. These solvents subsequently evaporate and are generally lost to the atmosphere. Process changes and/or materials changes offer diverse control options for abating air pollution. Such changes are generally specific for each use or process and may not eliminate the need for emission control systems.

Other principal sources of manmade hydrocarbon emissions include petroleum refining, oil/gas production and distribution, industrial processes, waste handling and treatment, and stationary fuel combustion, especially home heating with coal or wood. Control technology for the large sources can be conveniently divided into three segments for control of: particulates (solid or droplet), ducted vapours, and fugitive emissions.

The major sources of fugitive hydrocarbon emissions are handling and breathing losses from storage vessels. Storage and breathing losses are increasingly contained by the use of floating roof storage tanks, which eliminate the displacement of vapour-saturated air from above the volatile liquid contents.

One possible attack on continuous fugitive losses from stationary fuel burning sources is through increased maintenance. Nowhere is this more apparent than on coke ovens, a major source of PAHs, where leaks from the discharge doors have long presented problems. Redesigning the door seals and cleaning with extra care have reduced smoke emissions by 80-90%.

Containment of vapour losses from ducted sources during the last ten years has seen little in the way of new concepts. At the same time it has required considerable extension of the various technologies, and an understanding of the processes and development of basic data to enable effective technical designs to be made. The development of improved adsorbents such as resins and activated carbons together with extensive research into their capacities for adsorbing and releasing organic compounds has made the design of effective systems possible. In some instances, recovery of reusable materials is possible; in others the adsorbed organics may be discarded.

Direct incineration and catalytic incineration, in a few instances when the condensed materials are sufficiently volatile, are also applicable to the control of condensed and particulate organics. In many instances, the cost of incineration is excessive and other technologies are used to remove these materials. Electrostatic precipitators, baghouses, and scrubbers have all been used.

The principle of charging particles and mists to enhance scrubber capabilities through use of electrostatic forces is in the developmental stages. In other instances, the water droplets have been charged and the organic particulates left uncharged. It is in the use of the so called phoretic effects - electrophoresis, diffusiophoresis and thermophoresis - that the development of scrubber technologies has the most promise.

The organic mists and particulates are mostly produced by the condensation of vapours; therefore, they have small diameters, less than a micrometre. The efficiency of scrubbers which historically have been dependent on impaction of the particulate on surfaces or droplets of water, is generally low for particles of less than a micrometre in diameter. The cost of collecting particles of less than three micrometres also increases dramatically since impaction efficiency is related to gas and liquid relative velocities and hence to the energy input.

Since the major portion of industrial emissions are from petroleum refining and processing and the combustion of fuels and industrial wastes, the effects of process changes have not been great. These industries have always sought to contain raw materials and products and to utilize raw materials. Thus, the largest gains have been in the reduction of handling losses.

Fine particles have a greater surface to volume ratio than large particles. This property enhances the tendency of volatiles to condense on small particles in flue gases. Substances such as the PAHs which are produced during fossil fuel combustion, have been shown to predominate in fine particles in ambient air. Other potentially hazardous substances behave similarly with respect to concentration on the surface of fine particles.

Organic matter adsorbed on or occluded within airborne particulate matter will also be transported and transformed in an air mass. Larger particles are removed by control equipment, rapidly settled from the atmosphere, and more readily removed by the nasal hair and mucous membranes of the human protective system. Furthermore, even when they do reach the lung, they are less inclined to enter the airways and are more frequently expelled. Very fine particles (those having a mean aerodynamic diameter less than one micrometre) carry a greater proportion by weight of condensed organics. They can stay suspended in the atmosphere for many days, leading to a large potential exposure. Particles of this size range can be inhaled into the small airways (alveoli) of the human lungs, where they may cause a toxic effect, especially if adsorbed toxic materials are desorbed into the lung. These particles are also in the size range which is least efficiently collected by currently available control equipment.

The chemistry of the generation of organic compounds during and after burning has been unravelled and incinerators can be designed with temperatures, contact times and available oxygen to reduce the formation of by-products and prevent the passage of unburned organic substances. Some of this information has come from European sources and is therefore based on a different raw materials mix and practice. Only time and trial will dictate the viability of these solutions; it may not be feasible to apply all of them to existing installations.

Incineration of sludges and industrial wastes must be carefully evaluated to ensure that pollutants are destroyed and not converted to atmospheric contaminants. Application of this technology is suggested as one of the more desirable disposal methods for dealing with the large amounts of PCBs still in use or storage(20). If degradation is not practical, then adequately designed and operated disposal sites must be developed if long term loss to the environment is to be prevented and future problems minimized. The Commission is well aware of public reaction against solid waste land disposal sites and should press for degradation rather than removal as a prime feature of future waste treatment technology choices, especially for the hazardous wastes.

WASTEWATER TREATMENT TECHNOLOGY

Most wastewater treatment technologies depend on either microbial degradation or physical removal, often with chemical combination to enhance removal. Bacteria are remarkable organisms, capable of evolving to degrade many chemical structures. Many industrial chemicals are not readily metabolized by bacteria and therefore not well taken care of in biological treatment. Recent examples are PCBs, dieldrin and DDT. An important distinction is the differences between removal and treatment or degradation. Substantial removal for such chemicals as DDT are achieved in biological treatment, but this may be a result of sorbtion on the suspended solids. In such cases, the chemical is merely transferred to the sludge where it may create a disposal problem. In a similar fashion, many chemical treatments remove, but do not degrade the pollutants, and disposal is still unresolved. Treatment technologies should be based on degradation rather than removal unless the pollutant is more easily degraded in sludge than in wastewater.

Pretreatment requirements can significantly reduce the concentration of specific pollutants in the municipal wastewater and sludges produced at the treatment plants. Industrial waste by-laws and pretreatment requirements have been designed to control high strength conventional pollutants and high concentrations of hazardous substances to prevent treatment plant upsets. This approach needs to be extended to reduce the discharges of contaminants which are not effectively removed by conventional municipal treatment systems.

As described in Appendix D, a great deal of research is being directed at the fate of hazardous substances in conventional treatment systems and the efficiency with which these materials are removed from the waste stream. Preliminary data suggest that conventional processes effectively remove many trace organic substances and heavy metals.

A demonstration project involving the wet oxidation process for the destruction of complex hazardous substances at a chemical manufacturing plant in Ontario has received approval. The objective is to evaluate the effectiveness of the process as a pretreatment step to conventional treatment.

Pilot scale process development studies involving fixed film and suspended growth systems for the treatment of coking plant effluents are in progress at Environment Canada's Wastewater Technology Center in Burlington.

A wide range of treatment processes or systems is available for industrial wastewater treatment. The ability to remove hazardous substances by means of these systems have been extensively summarized in the Treatability Manual(12). The more important treatment processes or systems in the manual include: gravity oil separation, clarification/sedimentation,gas flotation, filtration and ultra-filtration, activated sludge, trickling filters, activated carbon adsorption, stripping (air and steam), chemical oxidation, reverse osmosis, disinfection (chlorination), and anaerobic treatment. The removability data available in the Treatability Manual should provide a satisfactory means for selecting treatment systems to control hazardous substances discharges in specific industrial wastewaters.

If hazardous pollutants are concentrated in chemical or biological sludges, disposal requires careful attention. Special precautions in land fills are required to prevent the escape into groundwater or surface water. Atmospheric loss from such disposal sites may result in atmospheric transport to the lakes. Other treatment technologies such as land application need to prevent the entry of industrial chemicals into the ground or surface water. More information on removal versus degradation is needed in such systems.

USE OF ASSIMILATIVE CAPACITY

The ability of water bodies such as the Great Lakes to dilute or degrade wastes is referred to as their assimilative capacity. Since the late 1960's, the use of assimilative capacity has been abhorred. This feeling developed because the ability to accept waste had been so abused, that abstinence seemed the only recourse. In practice, nearly all pollution abatement programs in both countries recognize and permit less than 100% removal of pollutants. Such permissiveness acknowledges the use of assimilative capacity to dispose of wastes not removed by treatment.

Large lakes, such as the Great Lakes, develop concentrations of discharged pollutants slowly and lose them slowly if the pollutants are persistent. Uncertainties about the impact of various concentrations make it difficult to select a safe concentration. Because of the lag time in larger systems and the magnitude of impact if an error is made, the policy of not using assimilative capacity has prevailed. The hazard is less if pollutants are not persistent.

From the point of view of a larger ecosystem, the use of assimilative capacity is sometimes wise. As treatment removal efficiency approaches 100%, the resource consumption in the form of chemicals, concrete, steel and energy increases dramatically. In some technologies, the amount of chemical residue resulting from treatment exceeds the amount of pollutant being removed. What is not often recognized is that the damage to the environment might only be shifted from the Great Lakes in this case to another site - - where the coal is mined, the chemicals are manufactured, or the sludge is dumped. When the benefit to the lakes expected from the application of treatment technology is less than the harm it may produce in other parts of the ecosystem, the assimilative capacity with an appropriate safety factor, should be used. Societal decisions must be made to protect one part of the ecosystem to the detriment of another, or forfeit the benefits of the waste generating commodity, or seek an alternative means of production which are less harmful to the environment.

There is no current framework for such ecosystem decision making, nor is the need even recognized by many regulators. Bureaucratic compartmentalization strongly impedes such decision making, and often the necessary authority is not vested in the right place or does not exist at all. For the public to understand the gamut of issues upon which decisions are based, would require an awesome educational effort. The difficulty of reaching such decisions does not negate the truth of the ecosystem approach nor the consequences of a wrong decision!

SOCIETAL BASIS FOR CONTROL ALTERNATIVES

Both the 1978 Great Lakes Water Quality Agreement and the U.S. Toxic Substances Control Act state that some substances are so dangerous to the ecosystem that their production and use should be banned. Other substances are to be managed from "cradle to grave" under programs such as the Resource Conservation and Recovery Act (RCRA) in such a manner as to keep them out of the air, water, and soil. A management option for many hazardous substances is to reduce the amount or the variety produced. Process changes or other options for the reduction of volume at the production source have been used in Japan and to a lesser extent in the United States and Canada. Waste exchange or the reuse of waste products in other processes are beginning to be more widely used. The wise-use option can be interpreted to mean implementation of strategies which require education and training. It includes options which depend either upon proving that a hazardous substance is essential for achieving social goals or protecting human health.

Each control alternative implies a distribution of burden among parts of the consuming and taxpaying public. It is easy to support management control actions if the consequences of them are undertaken by others. Effective public choice requires understanding the distribution of associated costs.

Both the United States and Canada have recognized the need to protect all ecosystems from intrusion by hazardous chemicals. The development of rules, regulations, and codes of practice under the Toxic Substances Control Act and the Environmental Contaminants Act has begun. The responsibility still exists to establish priorities for hazardous substances control and management and to use scarce public dollars wisely. Priorities must be set for the particular substances to be controlled and perhaps on areas where net benefit of control will be the greatest. The 1978 Great Lakes Water Quality Agreement set a priority to protect the unique freshwater resources of the Great Lakes with respect to hazardous substances. There are means - the use of regulatory structures, planning, and environmental impact assessment - through which the site specific impacts of hazardous substances or wastes can be determined at least for the near term.

No control strategy is capable of solving all problems. Present social policy states that the "bad actor" substances must be identified and kept out of the ecosystem. Sophisticated hardware and technology will not solve all the problems. Other management options should be considered and used and the political will to make decisions benefitting future generations must be strengthened.

The judgement of an acceptably safe concentration of a hazardous substance is frequently cast as scientific but is, in fact, more societal. The questions are then who decides for whom, and how well informed are those affected by the choices. Most people seem to tolerate more personal risk in their daily lives if they choose the risks. On the other hand, people oppose risks which are placed on them indiscriminately by others. This working principle is reflected in the laws of both countries.

This principle also applies to the more complex risks of modern living, including those from hazardous substances. The whole regulatory structure reflected by food and drug laws, pollution control standards, and occupational health and safety regulations reflect the view that restrictions have to be placed on those activities that increase public risk. Legitimate differences occur between those who generate risks and those who are exposed to them as to what constitutes a reasonable balance among the interests involved.

The key here is the quality and reliability of the risk data and information which is provided to those exposed to the risks. The Board believes it has an important role to play in ensuring that the Commission has the best information available with regard to hazardous substances in the Great Lakes basin ecosystem. The Commission should then be in a better position to make recommendations to the Governments of Canada and the United States pertaining to these substances in the overall context of the provisions of the 1978 Great Lakes Water Quality Agreement.

VII Attacking Hazardous Substances in the Great Lakes

Selecting a practical plan to deal with the most important hazardous substances is essential but difficult. Wise use or elimination should be urged where practical.

Judgements must be made to focus effort on the most hazardous of substances. The list of potential problem substances can be reduced because:

1) some are not used or produced in the Great Lakes basin;
2) some are produced in such small quantities that they can be ignored initially; and,
3) some will quickly degrade to innocuous materials and will not cause problems initially.

The first step in a hazardous substances control strategy, therefore, is to list the substances which may be present and then relegate a lower priority to those that have any of the above characteristics.

Of the remaining substances, we must know what amount might be released in the Basin, where, the possible biological effects, the degree of persistence, and how they will compartmentalize in the lakes as discussed in Part IV. In the United States, information on production volumes is contained in the Toxics Substances Inventory. However, for some of the compounds the manufacturer has declared the information confidential, and access to it is restricted. Data on the production, use, and location of specific chemicals may be obtained by Environment Canada under the Environmental Contaminants Act. Although Canadian companies are required to provide the information, they may claim confidentiality.

Whether a given company discharges its wastewater to a municipal sewer system or directly into a watercourse may alter the location of its effects. In the United States, a check of NPDES discharge permits would indicate direct discharges from manufacturers. In Canada, reference to Ontario Ministry of the Environment files or direct contact with the industry or municipality would be required in order to determine where wastewaters are discharged. This could drastically affect discharge locations; in some cases, such as at Chicago, resulting in discharge to another basin.

Two of the more important properties of hazardous substances in terms of possible biological effects are their toxicity to aquatic organisms and their bioconcentration potential. Toxicity data for many chemicals, especially chronic effects data, are not available and toxicity for aquatic organisms is difficult to predict. Therefore, the absence of such data should trigger an effort to acquire it. Bioconcentration data for many chemicals are not available either, but such properties can be reasonably well predicted either by measurement or from studies using the high pressure liquid chromatograph. Even estimates based on chemical structure can provide a fair indication of whether or not a compound will bioconcentrate.

Data on persistence are also scarce. Persistence can be reasonably well measured for many conditions that might occur in the lakes, but not for all. By scrutinizing chemical structure, experienced chemists can make reasonable estimates of the compound's persistence. Similarly, compartmentalization can be estimated reasonably well by chemists using water solubility data, vapor pressure, and other characteristics available in the literature.

Once these data are assembled an attempt can be made at placing the potential problem chemicals in priority order. This placement will reflect the most important considerations and the knowledge of locations of highest probability for finding such substances. This information can be used to direct surveillance efforts to the most important locations, thereby reducing costs and increasing the usefulness of the data.

Persistent hazardous substances discharged in small quantities and non-persistent hazardous substances will be measured only in certain locations. Surveillance depends on the success of the scheme outlined above.

The above approach will involve thousands of data points which must be stored for easy and rapid retrieval. This is one purpose of the ISHOW (Information System for Hazardous Organics in Water) data system which now exists and receives Commission support. This approach has not been used historically nor has it been needed for other pollutant problems such as phosphorus or municipal sludge. For those pollutants the sources were known; the need was to control them. The identity and importance of the many potentially hazardous substances are not known; establishing such data must precede a control program.

If each jurisdiction builds and organizes its own data sets there will be duplication, excessive costs and poorer quality than if the work is done jointly through an organization such as the International Joint Commission. Since the availability of production data varies in Canada and the United States, the Commission should encourage the two Parties to cooperate. The approach requires various agency inputs that will be difficult for the states, the province, and the two federal governments to obtain. Success depends on a comprehensive effort throughout the basin.

The above approach requires much data specific to the Great Lakes basin. The Great Lakes Water Quality Agreement needs its own data handling plan to incorporate the site specific data; it cannot rely on an existing or planned data handling systems to serve its needs. The system itself is not expensive to set-up or operate; it is the cost of obtaining the input data that is high. Existing systems are being used to provide input so that ISHOW does not duplicate other efforts.

The International Joint Commission must declare its intent and commit its resources if this approach is to be useful and timely. Progress is slow, and sometimes undetectable, in part because the Commission has not instructed the Parties regarding a hazardous substances strategy for the Agreement. It is time for the Commission to do so.

The Board has outlined a rational, practical plan that is partially developed and already functional. It must be made binational and as comprehensive for Canada as it is for the United States. While more needs to be accomplished in the United States as well, we have enough information now to move rapidly towards control action.

A list will soon be available of substances produced in the United States which have a high probability of bioconcentrating . The sites where they are produced will also be identified. The International Joint Commission and the U.S. Environmental Protection Agency, Region V have provided funding for this work. A similar effort should be expected from Canada. Such an effort would be a step forward toward solving the hazardous substances problem. Firm support and direction must emanate from the International Joint Commission to complete this phase.

The Science Advisory Board feels confident that the time has come to adopt a strategy based on present knowledge. It is now time to move forward aggressively.

VIII Recommendations

Based on its assessment of the problem of hazardous substances in the Great Lakes Basin Ecosystem, the Science Advisory Board recommends that:

I *THE INTERNATIONAL JOINT COMMISSION SHOULD URGE THAT JURISDICTIONS INSTITUTE PROGRAMS TO QUANTIFY THE ATMOSPHERIC LOADINGS OF HAZARDOUS SUBSTANCES TO THE GREAT LAKES.*

Atmospheric transport to the Great Lakes is an important source for some metals and organic chemicals. Data are inadequate to identify all chemicals for which atmospheric loading is important. In 1977 the Science Advisory Board recommended to the Commission that loading data for each lake be developed and that exchange among air, water, sediment, and biota be determined. In its 1976 Annual Report the Water Quality Board recommended that all jurisdictions establish close coordination between air, water, and solid waste programs to assess the total input of chemicals. The atmospheric inputs are still largely unknown, but such data are essential to meet the goals of the 1978 Great Lakes Water Quality Agreement. Much binational attention is being given to "acid rain", but insufficient attention is being given to other atmospheric pollutants that may have significant impact. More vigorous pressure from the Commission is needed to accelerate the collection of surveillance data required to identify the most important problems.

II *THE COMMISSION SHOULD URGE JURISDICTIONS TO RECOVER HAZARDOUS SUBSTANCES FOR REUSE AND EMPLOY TREATMENT TECHNOLOGIES THAT DESTROY, RATHER THAN MERELY REMOVE, CONTAMINANTS FROM WASTE DISCHARGES.*

Treatment of water and air discharges does not ensure that substances of concern will not harm the ecosystem, unless they are destroyed during treatment. In many technologies for air and water treatment, the substances being removed are concentrated in sludges which then may be disposed of as solid waste. The Water Quality Board in its 1978 Annual Report advised the Commission that waste treatment techniques which destroy chemicals rather than concentrate them in sludges will substantially reduce solid waste generation. Similarly, treatment technologies which do not produce large volumes of chemical sludge are highly desirable. Some substances such as heavy metals will remain intact and should be reused if possible, but will usually require careful disposal probably as solid waste. Every effort should be made to keep such substances to a minimum in all discharges.

III *THE COMMISSION SHOULD ENCOURAGE DISCHARGERS TO SEEK WAYS TO REDUCE THE USE OR LOSS OF HAZARDOUS SUBSTANCES THAT MAY FIND THEIR WAY INTO AIR OR WATER EFFLUENTS.*

While the economic benefits of wise chemical use will probably be recognized eventually by the industrial sector, pressure from regulatory agencies could speed such recognition. To the extent that better use can lessen the amount of treatment needed, society will benefit. Although preventing hazardous substances from occurring in waste seems obvious, the past losses of mercury from chlor-alkali facilities illustrates the need for closer scrutiny in all industrial processes.

IV *THE COMMISSION SHOULD URGE THE JURISDICTIONS TO IDENTIFY AND INFORM POPULATIONS IN THE BASIN WHICH MAY HAVE HIGHER THAN AVERAGE EXPOSURE TO HAZARDOUS SUBSTANCES AS A RESULT OF THEIR DIETARY HABITS OR LIVING CONDITIONS, AND THAT THE JURISDICTIONS EXPAND THEIR EFFORTS TO IDENTIFY ANY CAUSE AND EFFECT HUMAN HEALTH RELATIONSHIPS ASSOCIATED WITH THE CONSUMPTION OF GREAT LAKES FISH AND WILDLIFE.*

Because various small groups in the Great Lakes population eat quantities of fish in amounts well above average, because residues in sport fish are less well monitored, and because many desired sport fish have high lipid contents, the exposure of these populations is above average. Therefore, acceptable residue concentrations based on average consumption may not be sufficiently protective. Residues in sport fish are currently regulated differently in various jurisdictions and usually only by public advisories, which are not mandatory. While the consequences of such increased exposure are not known, these populations should be informed of their high exposure. Monitoring of the residues they consume should be at least as intensive as they are for the average population. The Water Quality Board has recommended that common risk assessment procedures be developed by the jurisdictions. Initial effort concentrated on an identifiable sub-population would be easier than considering the entire population of the Basin because these groups are smaller. Such efforts will be especially significant for protecting high exposure groups.

V *THE COMMISSION REQUEST THAT APPROPRIATE AGENCIES IN CANADA AND THE UNITED STATES REVIEW THE HUMAN HEALTH TOXICITY INFORMATION ON THOSE HAZARDOUS SUBSTANCES WHICH FORM RESIDUES IN GREAT LAKES FISH AND WILDLIFE, AND ESTABLISH TOLERANCE LEVELS FOR THOSE SUBSTANCES AS THEY ARE IDENTIFIED.*

Substances that are not food additives or pesticides are not uniformly measured or controlled. Acceptable residue limits for such substances in fish do not currently exist. Through a binational effort and pooling of agency resources, interim levels could be established and used for regulatory actions. These actions would provide a basis to judge the importance of residues found in fish used for food and would aid in establishing estimated risks to residents of the basin. Both the Water Quality Board and the Science Advisory Board in previous reports, have emphasized the need for knowing the significance of chemical residues on human health. Resources to accomplish this goal have not been forthcoming. An alternative is to use existing data and expertise to make best judgements of acceptable intakes. The Commission should urge that a sound regulatory basis be developed that will enable defensible and valid limits to be set for the protection of the Great Lakes basin ecosystem.

VI *THE COMMISSION SHOULD STRONGLY URGE GOVERNMENTS TO ESTABLISH PROGRAMS TO DEVELOP ROUTINE FATE AND EFFECTS INFORMATION NEEDED FOR PREDICTIVE HAZARD ASSESSMENT.*

In 1973 the Water Quality Board advised the Commission that there was a need for data on the level and effects of various contaminants, with special emphasis on the environmental significance of PCB levels in the biota, in order to evaluate the human health implications. In addition, both the Science Advisory and Water Quality Boards in previous reports have stressed to the Commission the importance of developing fate and effects information. However, very little additional work has been initiated. The generation of such data is routine work and should not be done by research organizations, which are not efficient in routine data production. They should use their resources to develop better methods for data production and a better knowledge of what data are most needed. Routine data generation is not the responsibility of any agency. This fact may explain why little has been done. Because such data are so important to regulations, funding outside existing research budgets should be requested to develop the required data.

VII *THE COMMISSION SHOULD CENTRALIZE AN INFORMATION SYSTEM TO COLLECT, STORE, SORT, AND DISPENSE DATA NEEDED BY THE JURISDICTIONS FOR CONTROL OF HAZARDOUS SUBSTANCES.*

Much of the data needed for the control of hazardous substances, such as toxicity, persistence, and bioconcentration potential must be generated or gathered from diverse sources. Each jurisdiction will need such data as a basis for its control actions. Furthermore, each jurisdiction will be concerned with a number of substances. A single organized assembly of this data at a central location will be far more cost effective than many individual efforts. The Science Advisory Board in its 1978 Annual Report recommended a centralized system. The Water Quality Board has repeatedly stressed the need for information of this nature. Little progress has been made in developing a common data bank accessible to all. The Commission should take a more aggressive role in assisting the jurisdictions to gain access to this data.

VIII *THE COMMISSION SHOULD RECOMMEND RESEARCH FOR DEVELOPING METHODS TO DETERMINE NET BENEFIT AS A NECESSARY CONSIDERATION IN FUTURE DECISION MAKING IN THE GREAT LAKES BASIN ECOSYSTEM.*

Many pollution abatement procedures, such as chemical precipitation of phosphorus and operation of air scrubbers, require the use of chemicals and fossil fuels. The extraction and conversion of fossil fuels produces impacts on various parts of the ecosystem. Likewise, the production of chemicals and the disposal of sludge after treatment can cause adverse impacts. Often these secondary effects occur in locations outside the Great Lakes basin ecosystem. When these impacts exceed the benefit of the abatement steps, the net environmental result is negative and the abatement probably should not be implemented. Careful environmental assessments are needed to identify when this point is reached. The ecosystem approach adopted by the Commission requires that all control programs within the basin result in net environmental benefit. At present there are no methods available to determine net environmental benefit, but they are needed to guide decision making.

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X Board Activities

Under the 1978 Great Lakes Water Quality Agreement, the Science Advisory Board is a scientific advisor to the International Joint Commission and the Commission's Great Lakes Water Quality Board. The Science Advisory Board is responsible for developing recommendations on research and developing statements on the state of scientific knowledge pertinent to the identification, evaluation, and resolution of current and anticipated water quality problems in the Great Lakes.

To meet its responsibility as the scientific advisor to the Commission and the Water Quality Board, the Board draws upon the knowledge of its members who are experts in scientific, engineering, and societal fields within governmental, industrial, university, and private sectors. Further, the Board appoints committees and task forces, from time to time, and holds workshops and conferences to assist in developing information and to provide scientific advice.

This year the Board concentrated on an assessment of the problem of hazardous substances in the Great Lakes basin ecosystem. The committees have contributed greatly toward the Board's perception of this issue. They and the various task forces have also developed essential information and reports over this past year which address other issues of importance to restoring and enhancing Great Lakes water quality.

COMMITTEES

The Board has three Expert Committees to provide continuing independent advice and synthesis of scientific opinion on new and continuing Great Lakes problems. These three committees also identify oversights, weaknesses, and opportunities for international cooperation in Great Lakes research activities in Canada and the United States. Two other committees deal with more specific issues. The following is a summary of the scope of the committees and their activities since July 1979.

Expert Committee on Engineering and Technological Aspects of Great Lakes Water Quality

This Committee's activities encompass in part the technological procedures and treatment of man's effects on receiving waters. The Committee includes members with expertise in industrial and municipal waste treatment. The membership was recently expanded to include expertise in air pollution control.

A recommendation by the Committee led to establishment of the Phosphorus Management Strategy Task Force which reported to the Science Advisory and Water Quality Boards and the Commission in July 1980.

A subcommittee was formed which met with several experts to discuss measurement and assessment techniques for determining biologically available forms of phosphorus and sources, and their relative input to lakes. This work led to a state of the art report on "Biological Availability of Phosphorus" which was submitted in April 1980 and is under review by the Board.

The Committee developed the technical information for the Board's response to a Commission request for an assessment of the contribution of low temperature incineration of waste to water quality impairment in the Great Lakes.

Since the Board plans to focus its 1981 Annual Report on the possible environmental consequences that alternative scenarios for energy production may have on the Great Lakes basin ecosystem, the Committee is assessing the adequacy of present technology to control the release of hazardous substances from nuclear fuels, petroleum, coal, and synthetic fuels.

Expert Committee on Ecological and Geochemical Aspects of Great Lakes Water Quality

This Committee's responsibility includes issues relating to ecological and geochemical effects of man's activities.

The major activity of this Committee during the past year has been to investigate the extent of atmospheric deposition of hazardous substances in the Great Lakes and to acquaint the Board with information on the subject. Much of the information in this report on hazardous substances incorporates the findings supplied by the committee (Appendices A and B).

The Committee has received the Board's support to convene a symposium to synthesize current knowledge on atmospheric inputs to lakes as they relate to surface-film chemistry and physics in the eventual partitioning and food-chain fluxes. The results of the symposium will be published in an appropriate scientific journal.

Expert Committee on Societal Aspects of Great Lakes Water Quality

The jurisdictional, political, institutional, legal, educational, and other non-physical measures influencing the effects of man's activities on receiving waters are considered by this Committee. The Committee includes expertise representative of economics, energy issues, planning, citizen/public interest, political science, human behavior, legal aspects, and regulatory activities.

The Expert Committee held a workshop on anticipatory planning in early March 1979. Proceedings of the workshop, Anticipatory Planning for the Great Lakes Volume I, Summary, 1979, and Workshop Report Anticipatory Planning for the Great Lakes, Volume II, 1980, have been published and distributed to the Boards and the Commission. They provide a broad perspective on Great Lakes problems not being adequately addressed and problems likely to emerge within the next five to ten years.

The committee is continuing to explore means whereby it can assist the Board and the Commission to develop an adequate anticipatory planning capability.

Aquatic Ecosystem Objectives Committee

The Aquatic Ecosystem Objectives Committee (AEOC) has been provided with a broad mandate to develop aquatic ecosystem objectives to protect the various uses of the Great Lakes, including the most sensitive use. AEOC's activities to date fall into four interrelated areas:

1. AEOC identifies substances for which new specific objectives are required and determines whether the existing data base is adequate for their development.

2. On a continuing basis, AEOC regularly reviews the scientific literature to determine if the objectives as given in the 1978 Great Lakes Water Quality Agreement are still protective of the most sensitive use, and proposes revisions to these objectives if warranted.

3. Objectives developed to date have generally considered only the aqueous component of the ecosystem. AEOC has adopted the philosophy that objectives should be holistic, that is, consider all aspects of the ecosystem and the movement of substances among the various compartments. AEOC has begun development of such broad-based objectives where the data base exists.

4. An aquatic ecosystem objective is envisaged as a desired state of the system and integrating all aspects of the ecosystem. AEOC has embarked on the task of developing such indicators of ecosystem health.

AEOC's 1980 report recommends and substantiates to the Science Advisory Board four new or revised objectives for the 1978 Agreement:

1. Pentachlorophenol
2. Polychlorinated dibenzodioxins
3. Microbiological indicator - to supplement the present objective
4. Lead - to broaden the existing objective.

AEOC also recommends that five objectives, previously proposed, be incorporated into the 1978 Agreement:

1. Chlorine
2. Silver
3. Cyanide
4. Temperature
5. Nutrients

In its report, AEOC presents a list of sixteen substances for which the present objectives are under active review or for which consideration is being given for the development of new objectives. A tentative mixtures objective is presented, and public comment is solicited. Other potentially fruitful future directions for the development of objectives are also outlined.

AEOC's report also summarizes the philosophy and the importance of objectives, the procedure for their development, and their relationship to jurisdictional standards. AEOC also reports on progress for development of an example of an aquatic ecosystem objective, which will be the subject of a future report to the Science Advisory Board.

Joint Science Advisory Board/Water Quality Board Committee on the Assessment of Human Health Effects of Great Lakes Water Quality

This joint committee of the two Boards was formed in early 1978. Its activities include:

- assessment of health risks posed by contaminants in the Great Lakes;
- review of action levels and guidelines for selected substances;
- interpretation and consultation on health matters; and
- maintaining an awareness of current advances in knowledge regarding health effects of water constituents.

The major activities undertaken by this committee in the past year include the health hazard evaluation of the chemicals identified in the Great Lakes ecosystem, an investigation of the problem of viruses in the Great Lakes, the development of compatible cancer registries within the Great Lakes basin, and a review of levels of contaminants in fish. A summary of findings is included in the Committee's 1980 report to the Boards.

TASK FORCES

The Board establishes task forces to deal with specific issues which require intensive interdisciplinary investigations. Such task forces gather and examine information on the specific issues and recommend a course of action, a policy, or an investigative direction to reach a solution. The task forces may be established as a result of discussions within the Science Advisory Board, recommendations of the Expert Committees, referrals from the IJC or its groups, and referrals from the scientific community or citizen groups. The task forces are disbanded upon acceptance of final reports by the Board.

Ecological Effects of Non-Phosphate Detergent Builders

This task force was formed in 1976 to provide information to the Board on potential ecological effects of phosphorus substitutes in detergents. Task force members were selected for the respective expertise in the fields of biochemistry, waste treatment, environmental modelling, aquatic toxicology, water chemistry and metal transport, and eutrophication. Initial activities of the task force were directed towards an ecological assessment of nitrilotriacetic acid (NTA). The task force report entitled: Ecological Effects of Non-Phosphate Detergent Builders: Final Report on NTA was published in December 1978.

The task force has also completed a review of three other important organic detergent builders: citrate, carboxymethyloxysuccinate (CMOS) and carboxymethyltartronate (CMT). This review is reported in the task force's report Ecological Effects of Non-Phosphate Detergent Builders - Final Report on Organic Builders Other than NTA, July 1980.

The task force is continuing its work with an assessment of inorganic detergent builders which are currently used or proposed for use.

Health Effects of Non-NTA Detergent Builders

The task force was formed in 1977 to evaluate the potential health effects of detergent builders other than NTA. The task force has studied carbonates, carboxymethyloxysuccinate (CMOS), carboxymethyltartronate (CMT), citrates, phosphates, soluble silicates, and Type A Zeolite (a synthetic aluminosilicate). The report on these detergent builders was submitted to the Board in September 1980.

Phosphorus Management Strategies

Upon the recommendation of the Board's Expert Committee on Engineering and Technological Aspects, a task force on phosphorus management strategies was formed and subsequently expanded to a joint task force of the Science Advisory and Water Quality Boards.

The task force was instructed to:

- Review and evaluate the adequacy of existing data, factors affecting phosphorus loads, analysis and technologies pertinent to the development of alternative phosphorus management strategies. Items of concern were to include: the assumptions and rationale underlying the phosphorus loads recommended in the 1978 Water Quality Agreement; the availability and practicality of technology and the costs for control of point and nonpoint sources; the reduction of phosphorus content in detergents and associated costs; consideration of the biological availability of phosphorus in the assessment of alternative phosphorus management strategies; and the applicability of systems approaches for determining control strategies.

- Evaluate and test alternative phosphorus management strategies specifically as they impact on ecology, waste treatment, sludge disposal, energy consideration, and economics.

- Incorporate, as time allows, the findings of the associated task forces and committees on health effects, environmental impacts, societal aspects, and nutrient objectives.

- Identify specific subject areas where additional information is needed.

The final report of the task force entitled Phosphorus Management for the Great Lakes was submitted to the Board and the Commission in July 1980 and released publicly. The Science Advisory and Water Quality Boards are expected to provide their comments to the Commission with respect to the recommendations of the task force at the Annual Meeting on the Great Lakes Water Quality Agreement, November 1980.

XI Appendix - Background Reports

The following reports were prepared for the Board as background information for use in developing its report on hazardous substances:

A. Assessment of Airborne Organic Contaminants in the Great Lakes Ecosystem - S. J. Eisenreich, B.B. Looney, and J.D. Thornton, Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, Minnesota.

B. Assessment of Airborne Inorganic Contaminants in the Great Lakes - H. E. Allen and M.A. Halley, Pritzker Department of Environmental Engineering, Illinois Institute of Technology, Chicago, Illinois.

C. Sources and Control of Organic Air Pollutants - R.B. Caton and E.T. Barrow, Air Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario.

D. Toxics in Municipal and Industrial Wastewaters - D.F. Bishop, Municipal Environmental Research Laboratories, U.S. Environmental Protection Agency, Cincinnati, Ohio.

These reports are bound in a separate volume and copies are available from the IJC Great Lakes Regional Office, 100 Ouellette Avenue, Windsor, Ontario, Canada, N9A 6T3.

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