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Report to the
Great Lakes Science Advisory Board

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**Report of the
Aquatic Ecosystem Objectives Committee**

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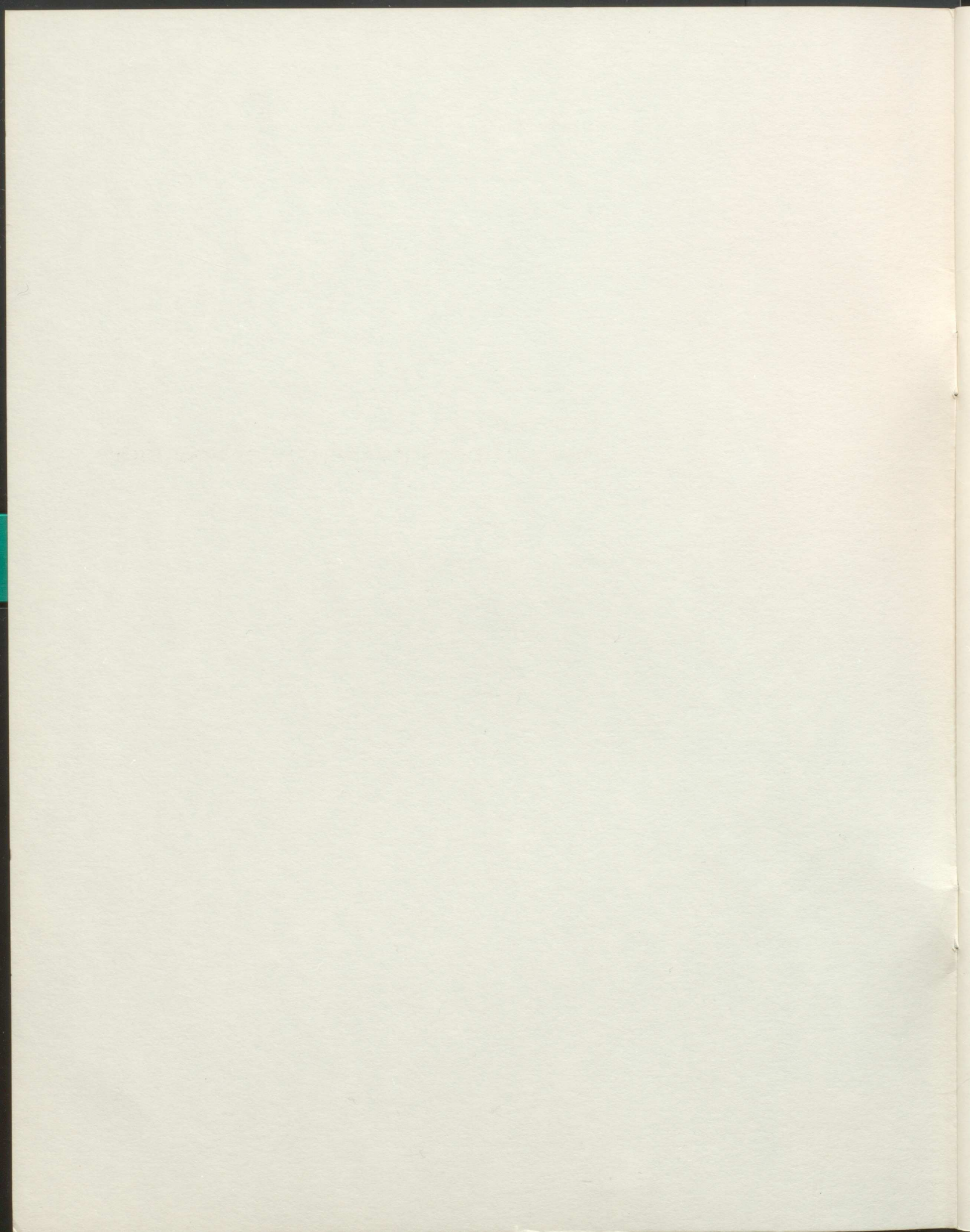


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**Report of the
Aquatic Ecosystem Objectives Committee**

November 1982
Windsor, Ontario

Order of this report are available from:
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Windsor, Ontario N9A 6T3

Report of the
Great Lakes Science Advisory Board

Report of the
Aquatic Resources Objectives Committee

Number 108
Windsor, Ontario

Copies of this report are available from:

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Summary Preface Recommendations

This report to the Science Advisory Board was prepared by the Aquatic Ecosystem Objectives Committee (AEOC). Though the Board has reviewed and approved this report for publication, some of the specific conclusions and recommendations may not be supported by the Board.

1. NEW OBJECTIVES

Polychlorinated Styrenes

Examination of the existing data base for these substances established their substantial presence in the Great Lakes ecosystem particularly in the tissues of fish. Inadequate information exists on the effects of these chemicals, particularly those for chronic exposures. Further information is also required on the modes of distribution of these compounds in the system and a determination of the mechanism of their entry into the tissues of the Great Lakes.

2. Asbestos

Examination of recently developed data led to the conclusion that a specific objective was not scientifically defensible at this time. There is a continuing need to establish whether adverse effects result from the human ingestion of asbestos fibres and the AEOC recommends continuing activity in this area.

3. RE-EXAMINED OBJECTIVE

Silver

Information presented to AEOC in support of the development of the objective noted in the 1982 Report caused the committee to delay its formal recommendation to the Science Advisory Board. Evaluation of the data presented resulted in the conclusion to re-affirm the original recommendation of 0.1 ug total of year.

Preface

This report to the Science Advisory Board was prepared by the National Ecosystem Objectives Committee (NEOC). Though the Board has reviewed and approved this report for publication, some of the report's conclusions and recommendations may not be supported by the Board.

Summary of Recommendations

The Aquatic Ecosystem Objectives Committee (AEOC) makes the following recommendations to the Science Advisory Board (SAB) for consideration and forwarding to the International Joint Commission (IJC) and the Parties of the Great Lakes Water Quality Agreement (GLWQA).

1. NEW OBJECTIVES

Polychlorinated Styrenes

Examination of the existing data base for these substances established their substantial presence in the Great Lakes ecosystem particularly in the tissues of biota. Inadequate information exists on the effects of these chemicals, particularly those for aquatic organisms. Further information is also required on the extent of distribution of these contaminants in the system and a determination of the mechanism of their entry into the waters of the Great Lakes.

2. Asbestos

Examination of recently developed data led to the conclusion that a specific objective was not scientifically defensible at this time. There is a continuing need to establish whether adverse effects result from the human ingestion of asbestos fibres and the AEOC recommends continuing activity in this area.

3. RE-EXAMINED OBJECTIVE

Silver

Information presented to AEOC subsequent to the development of the objective noted in the 1980 Report caused the committee to delay its formal recommendation to the Science Advisory Board. Evaluation of the data presented resulted in the conclusion to re-affirm the original recommendation of 0.1 μg total silver/L.

Summary of Recommendations

The Aquatic Ecosystem Objectives Committee (AECC) makes the following recommendations to the Science Advisory Board (SAB), the Commission and the International Joint Commission (IJC) and the Parties of the Great Lakes Water Quality Agreement (GLWQA).

1. NEW OBJECTIVES

Polychlorinated Biphenyls

Examination of the existing data base for these substances revealed their substantial presence in the Great Lakes ecosystem particularly in the tissues of fish. Inadequate information exists on the effects of these chemicals, particularly those for aquatic organisms. Further information is also required on the extent of their input to these continents in the system and a determination of the mechanism of their entry into the waters of the Great Lakes.

2. Asbestos

Examination of recently obtained data led to the conclusion that a specific objective was not scientifically defensible at this time. There is a continuing need to establish whether adverse effects result from the human ingestion of asbestos fibers and the AECC recommends continuing activity in this area.

3. RE-EXAMINED OBJECTIVE

Silver

Information presented to AECC subsequent to the development of the objective noted in the 1980 Report caused the committee to delay its final recommendation to the Science Advisory Board. Evaluation of the data presented resulted in the conclusion to re-examine the original recommendation of 0.1 ug total silver/L.

I. Introduction

During the period of the 1972 Great Lakes Water Quality Agreement, two Committees (Water Quality Objectives Subcommittee -- WQOS and Scientific Basis for Water Quality Criteria -- SBWQC) were responsible for formulating new or modifying existing water quality objectives. Their collective efforts resulted in Annex 1 of the 1978 Great Lakes Water Quality Agreement. Since the signing of that Agreement, it has been the responsibility of the Aquatic Ecosystem Objectives Committee (AEOC) to ensure that Annex 1 is kept current. In 1980, AEOC recommended to the Science Advisory Board the adoption of two new objectives (pentachlorophenol and polychlorinated dibenzodioxins), the revision of two existing objectives (lead and microbiology) and the adoption of four objectives previously proposed by WQOS/SBWQC (silver, chlorine, temperature and nutrients). In 1981, AEOC's recommendations included the revision of the selenium objective, the confirmation of the mirex objective and the development of a mechanism to define Limited Use Zones. The Science Advisory Board has concurred with these objectives and the International Joint Commission has recommended them to the Parties, with caveats for chlorine and temperature.

The framework¹ for developing objectives was developed by WQOS/SBWQC and is reprinted here for the sake of clarity.

1. In developing specific water quality objectives the philosophy of protecting the most sensitive use is employed.
2. The objectives serve as a minimum target wherever water quality objectives currently are being met.
3. For jurisdictionally-designated areas which have outstanding natural resource value and existing water quality better than the objectives, the existing water quality should be maintained or enhanced.
4. Specific water quality objectives are to be met at the periphery of mixing zones. This assumes that water quality conditions better than the objectives will result beyond the mixing zones. The objectives should be implemented in concert with limitations on the extent of mixing zones or zones of influence and localized areas as designated by the regulatory agencies.
5. In recommending objectives to protect raw drinking water supplies, it has been assumed that a minimum level of treatment is provided before distribution to the public for consumption.

¹International Joint Commission. New and Revised Great Lakes Water Quality Objectives, Volume II. Washington, D.C. and Ottawa, October 1977. pp. 3-7.

6. Adoption of objectives does not preclude the need for further study of the effects of pollutants on the aquatic environment.
7. Since infinite combinations of water quality characteristics may occur, the objectives often are unable to take into account antagonistic, synergistic and additive effects; because of lack of data.
8. Since new data may lead to modified recommendations, the objectives are subject to continual review.
9. No adequate scientific data base exists for establishing scientifically justifiable numerical objectives for unspecified non-persistent toxic substances and complex wastes. Therefore, criteria for developing an operationally defined objective for local situations have been recommended.

The AEOC endorses this framework with the caveat that objectives do not consider socio-economic factors. The Committee agrees with previous recommendations (Water Quality Board 1980)² that socio-economic impact assessment is the responsibility of the jurisdictions and should be done at the time of setting of regulations or standards. Objectives should not be construed as regulations or standards but should be considered as goals to be achieved and as a minimum basis for developing regulations or standards by the jurisdictions.

In the course of their development, the objectives have been subject to iterative reviews within the Committee and by scientists with relevant expertise. The Committee, however, welcomes any comments or additional scientific evidence relevant to any of the objectives and consistent with the above philosophy.

²Alternatives for Managing Chlorine Residuals: A Social and Economic Assessment. Final Report of the Chlorine Objectives Task Force to the Great Lakes Water Quality Board. Windsor, Ontario, April 1980.

2. Objectives

2.1 POLYCHLORINATED STYRENES

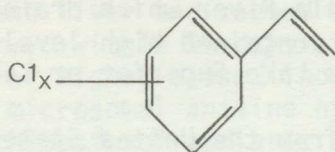
Recommendation:

Inadequate information exists on the effects on organisms and on the environmental distribution of these compounds in the Great Lakes ecosystem. Consequently, no scientifically defensible objective can be recommended at this time.

Rationale:

1. General

Polychlorinated styrenes (PCSs) are compounds with the generic formula $C_8H_8-xCl_x$ where x varies from 1-8 and the chlorine atoms can be located on the side chain as well as on the aromatic ring.



They are not produced commercially (Kuehl, 1981) although some of them have been proposed as development monomers for use in plastics with desirable thermal properties (Coulter, et al., 1969). There are 110 possible congeners, excluding stereoisomers, about the vinyl bond. The lower chlorinated congeners are high boiling liquids while higher chlorination produces solids. Water solubility for the octachloro isomer (OCS) has been reported as 7.1 $\mu\text{g/L}$ (Veith, et al., 1979) and 2.5 $\mu\text{g/L}$ (Haver in Bjerk and Brevik, 1980).

PCSs have been observed as by-products in the magnesium processing industry (Lunde and Bjorseth, 1977) and implicated in chlorine-carbon electrode processes (Kuehl, et al., 1981; Kuehl, 1981; Veith, et al., 1979) as employed in chlorine production. PCSs have also been identified during the combustion (Ahling, et al., 1978) and photochemical degradation (Weir and Milkie, 1979) of polyvinyl chloride. In the case of combustion, emissions as high as 2.3 mg OCS/kg PVC were observed, a level which could be of concern given the high volume usage of this plastic and the likelihood of its disposal by incineration.

2. Environmental Exposure

Polychlorinated styrenes, mainly the octachloro isomer, OCS, have been reported in a number of situations. In the first of these reports, Koeman, et

al., 1969, noted OCS in duck (*Somateria mollissima*) and stern (*Sterna sandvicensis*) tissues from the Netherlands. Subsequently, OCS was found in fish, seals and birds from the same sampling areas and additionally, the probable identification of two heptachlorostyrene (HCS) isomers was noted (ten Noever de Brauw and Koeman, 1972). In Norway, a series of reports (Lunde and Ofstad, 1976; Ofstad, et al., 1978, Ofstad, et al., 1979; Bjerk and Brevik, 1980) identified OCS and HCS in fishes, sediments and surface films near a magnesium electrolysis plant.

In North America, PCSs have been reported mainly for fishes in the Great Lakes Region (Veith, et al., 1979a; Kuehl, et al., 1981; Kuehl, et al., 1980; IJC, 1977). In most cases, only a few samples were collected in any one area and consequently, the extent to which the analyses are representative of the region, or even a locale, is unknown. Nevertheless, OCS and HCS were found in the majority of samples examined and hence form a basis for concern over these substances.

The most comprehensive of the Great Lakes reports is that by Kuehl, et al., (1981) on levels of OCS, HCS and other chemicals in seventeen fish samples, some of which were composites of different species. Concentrations of OCS plus HCSs from Lake Ontario were 394 and 224 $\mu\text{g}/\text{kg}$ in 1977 and 1979; levels in the same species from Saginaw Bay, Lake Huron, were 2 and 111 $\mu\text{g}/\text{kg}$, respectively. Highest levels of OCS plus HCSs (911 $\mu\text{g}/\text{kg}$) were found in northern pike samples from the Ashtabula River which drains into Lake Erie; other species from the same area also contained high levels. No PCS contamination was found in fishes from Lake Superior or Lake Michigan.

In a study of 1,500 bird samples from the United States, Reichel, et al., (1977) reported levels of OCS and the presence of HCS, only for Great Blue Herons (*Ardea Herodias*) found in the Lake St. Clair area. Carcasses contained up to 0.43 $\mu\text{g}/\text{g}$ (mean 0.27) and eggs up to 0.23 $\mu\text{g}/\text{g}$ (mean 0.08) of OCS. Presumably these levels reflect eating habits which are primarily piscivorous and local in nature (Hoffman, 1978) although they do migrate.

Veith, et al., (1979b) have determined a bioconcentration factor for OCS (partition coefficient between fathead minnows, *Pimephales promelas*, and water) to be 33,000. This figure was similar to those observed for PCBs, HCB and DDT - all of which are well-established contaminants. An n-octanol-water partition coefficient of 1.9×10^6 is also given which can be used, according to Karickhoff, et al., (1979), to obtain a sediment/soil sorption constant of 25-49 000 for material of 2-4 percent organic carbon content. Since neither water nor sediment concentrations have been determined for the Great Lakes, these estimations have not yet been checked against field data. However, using Veith, et al.'s bioconcentration factor, the Karickhoff sorption constant and an OCS field level for lake trout of 300 mg/kg, a water concentration of 0.01 $\mu\text{g}/\text{L}$ and sediment levels of 3-500 $\mu\text{g}/\text{kg}$ would be predicted. These are potentially measurable with present day technology.

A brief notation in Chu, et al., (1982) states that "...OCS is resistant to metabolic degradation...." presumably in the rat. No further details were provided. The structure of this chemical and the higher chlorinated PCSs is suggestive, however, of persistence comparable to the PCBs and chlorobenzenes.

3. Occupational Exposure

A study of OCS and HCSs in workers in a probable occupation exposure situation (Lunde and Bjorseth, 1977) indicates that these substances can accumulate to at least 5 $\mu\text{g/L}$ in the blood (mean 1.5) of humans. Exposure levels were not reported. It is disturbing, however, that these chemicals were also found in the blood of groups with less probability of exposure (a polyvinyl chloride plant, mean 0.5 $\mu\text{g/L}$) and at a non-chemical, industrial plant, (mean 0.7 $\mu\text{g/L}$). PCSs may therefore be more widespread than might otherwise be expected.

4. Effects

Despite the observation of environmental accumulation in biota, very few reports are available on the toxic effects of these chemicals. In the currently published literature, Strik and Koeman (1976) observed porphyria in rats and Japanese quail fed at 500 mg/kg/day. In addition to increased levels of porphyrin in livers, observations included megalocytosis, basophilic spots, whorls and hypertrophy of hepatocytes as well as increases in cytochrome P-450 and δ -aminolevulinic acid synthetase.

Recently Chu, et al., (1982) have examined acute and subacute effects and Villeneuve, et al., (1982) the subchronic effects of OCS in rats. While OCS accumulated in fat and liver and caused biochemical histopathological changes, no deaths were observed within 14 days at dose levels as high as 3710 mg/kg. Doses of 1690 mg/kg or higher caused increased liver weight, increased activity of hepatic microsomal aniline hydroxylase and aminopyrine demethylase and elevated serum cholesterol and uric acid levels. When fed at dietary levels of 50 $\mu\text{g/g}$ for 28 days, liver hypertrophy and hepatic microsomal changes were observed and even at 5 $\mu\text{g/g}$, liver and thyroid histological changes were found as well as induction of mixed function oxidases.

Summary:

Inadequate information exists at present to permit an evaluation of the hazard represented by PCSs in the Great Lakes ecosystem or to develop an objective for any of these substances. While some information is available on exposure in the aquatic compartment, little is known of releases to the atmosphere or of non-mammalian toxicology. The possibility of mutagenic/carcinogenic activity of PCSs to mammalian species should also be investigated because of the possible formation of epoxides, by analogy with styrene (Sigiura, et al., 1976) and chlorinated ethylenes (Henschler, 1977). Specific information which should be developed is:

- PCSs in emissions from the combustion of PVC and the possibility of their atmospheric input to the Great Lakes from urban incinerators;
- PCS levels (particularly OCS and HCSs) in archived fish and sediment samples as well as for sediments at locations with identified concentrations in fishes;
- chronic effects of PCSs on aquatic organisms;

- persistence in the aquatic environment; and
- mutagenicity.

The more highly chlorinated PCSs should be of greater priority than lower congeners because they have been identified environmentally and by analogy with PCBs, they are more likely to persist and bioaccumulate.

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2.2 SILVER

Recommendation:

Concentrations of total silver in an unfiltered water sample should not exceed 0.1 $\mu\text{g/L}$ to protect aquatic life.

Addendum to the 1978 Recommended Objective for Silver:

Subsequent to the original publication of the review on silver and a recommendation for a water quality objective (IJC, 1978), further scientific evidence was presented to the AEOC by the Eastman Kodak Company, Rochester, New York. At the AEOC's request, the Science Advisory Board deferred recommending this objective to the International Joint Commission until this evidence had been examined. This evidence included four unpublished reports (Chudd, 1979; E.G. and G. Bionomics, 1980a, 1980b; Lockhart, 1980) that showed:

- (a) the majority of silver from photoprocessing occurs as insoluble silver forms (Lockhart, 1980);
- (b) theoretical considerations of the organic and inorganic complexes of silver (Table 1), particularly the high affinity of silver for sulfide and the low solubility of silver sulfide, suggest that little free silver ($< 10^{-12}$ $\mu\text{g/L}$) would occur at equilibrium in effluents or surface waters containing sulfide (Lockhart, 1980);
- (c) bioassays of 'free' silver, silver thiosulfate, and silver sulfide demonstrated mortality of fathead minnows at 5-16 $\mu\text{g/L}$ of free silver and no effects of the thiosulfate and sulfide salts at 11000-21000 $\mu\text{g/L}$ (E.G. and G. Bionomics, 1980a, 1980b);
- (d) a method for measuring "log silver ion activity" (pAg) by a specific ion electrode has been developed to measure "free" silver in surface waters (Chudd, 1979);
- (e) application of this method to surface waters near Rochester, New York, (Genessee River, Lake Ontario) gave values of pAg ranging from 8.5 to 11.1, with the majority of samples around 9.2 - 9.4 (Lockhart, 1980). These values were claimed to be equivalent to a range of free silver ion concentrations of 0.340 to 0.00079 $\mu\text{g/L}$ with the majority of concentrations around 0.054 - 0.63 $\mu\text{g/l}$.

This information would support a recommendation of an objective of 0.1 $\mu\text{g/L}$ "free" silver in order to limit that fraction of total silver that is biologically active or toxic. While the AEOC accepts the argument that 'free' silver is a better measure of toxic silver than is total, it does not recommend the adoption of an objective based on 'free' silver. The reasons are that:

- (a) near an effluent, there is no evidence that silver is in equilibrium with all the complexing agents;
- (b) sulfide, the only reactant which is likely to reduce silver concentrations sufficiently, is easily oxidized to sulfate under environmental conditions of adequate oxygen supply (Chen and Morris, 1972). The half life of sulfide is about 50 h but oxidation rates may be increased by about 5x by metals such as calcium. This may be the reason why sulfide has not been found even at detection levels of 10^{-10} g/L in surveys of the Great Lakes (Table 1);
- (c) the weaker inorganic complexing agents for silver observed in surface waters of the Great Lakes will still permit 'free' silver to exist at concentrations near the proposed objective concentrations of $0.1 \mu\text{g/L}$ (Table 1);
- (d) the method presented by Kodak for measurement of silver ion activity (Chudd, 1979) is not adequate for low environmental concentrations. A review of the method by Dr. I. Sekerka, Canada Centre for Inland Waters, indicated difficulties with reproducibility, dependability and comparability. The method is reliable at levels of free silver of $11 \mu\text{g/L}$ or higher and the values for 'free' silver in surface water quoted by Lockhart (1980) may not be valid. The method does, however, show considerable promise and efforts should be made to evaluate the sensitivity and precision of commercially available Ag/Ag S electrodes for this purpose.

Therefore, until a reliable method is developed to measure 'free' silver at concentrations as low as $0.1 \mu\text{g/L}$, the AEOC reaffirms its recommendation to limit silver in water to $0.1 \mu\text{g/L}$ total silver.

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TABLE 1. Solubility Constants for Various Inorganic Complexes of Silver and the Estimated 'Free' Silver Concentration at Equilibrium for each in Great Lakes Water

COMPLEX	SOLUBILITY PRODUCT (1) (log K _{sp})	LAKE SUPERIOR				LAKE ONTARIO			
		MEAN CONCENTRATION OF COMPLEXING IONS (2)		ESTIMATED MAXIMUM 'FREE' SILVER CONCENTRATION		MEAN CONCENTRATION OF COMPLEXING IONS (2)		ESTIMATED MAXIMUM 'FREE' SILVER CONCENTRATIONS	
		(mg/L)	(M)	(M)	(μg/L)	(mg/L)	(M)	(M)	(μg/L)
sulfate (Ag ₂ SO ₄)	-4.8	3.3	3.4 x 10 ⁻⁵	6.8 x 10 ⁻¹	7.4 x 10 ⁷	27.9	2.9 x 10 ⁻⁴	2.3 x 10 ⁻¹	2.5 x 10 ⁷
hydroxide (Ag ₂ O)	-7.8	0.017(pH=8)	1.0 x 10 ⁻⁶	1.3 x 10 ⁻¹	1.4 x 10 ⁷	0.017(pH=8)	1.0 x 10 ⁻⁶	1.3 x 10 ⁻¹	1.3 x 10 ⁷
chloride (AgCl)	-9.7	1.3	3.7 x 10 ⁻⁵	5.4 x 10 ⁻⁶	5.8 x 10 ²	28.7	8.1 x 10 ⁻⁴	2.5 x 10 ⁻⁷	2.7 x 10 ¹
carbonate ⁽³⁾ (Ag ₂ CO ₃)	-11.2	17.0	2.8 x 10 ⁻⁴	1.5 x 10 ⁻⁴	1.6 x 10 ⁴	37.2	6.2 x 10 ⁻⁴	1.0 x 10 ⁻⁴	1.1 x 10 ⁴
phosphate ⁽⁴⁾ (Ag ₃ PO ₄)	-16.0	0.003	3.3 x 10 ⁻⁸	1.4 x 10 ⁻³	1.6 x 10 ⁵	0.025	2.6 x 10 ⁻⁷	7.3 x 10 ⁻⁴	7.8 x 10 ⁴
sulfide (Ag ₂ S)	-50.0	sulfide is undetected at levels of 10 ⁻¹⁰ g/L ⁽⁵⁾							

(1) from "Stability Constants" The Chemical Society (London) 1964

(2) STARFILE data summaries 1966-1981; IJC, 1979; Nriagu, 1973.

(3) Carbonate = alkalinity (CaCO₃) x 0.60

(4) Phosphate = soluble reactive phosphorous x 3.1

(5) J.O. Nriagu, Canada Centre for Inland Waters, Burlington, Canada, personal communication.

2.3 ASBESTOS

Recommendation:

Inadequate information exists on the effects on humans of ingested forms of asbestos minerals. Consequently, no recommendation for an objective can be made at this time.

Rationale:

Asbestos is the generic name for a group of fibrous silicate minerals belonging to the amphibole and serpentine groups. Natural background concentrations in the Great Lakes prior to man's influence were probably less than 100,000 fibers per liter (Philip Cook, personal communication). Present day sources of the fibers include natural weathering and erosion, mining and manufacturing activities and the use of asbestos products. Until recently, the disposal of taconite-process iron ore tailings (wastes) into Lake Superior by the Reserve Mining Company at Silver Bay was the largest single anthropogenic source of fibers in the Great Lakes Basin. This cummingtonite-grunerite amphibole mineral was discharged at a rate of 10^{21} fibers daily for 18 years (Cook, et al., 1976) but was discontinued in April, 1980. The fibers were distributed widely in the lake by currents creating concentrations in Duluth, Minnesota, drinking water ranging from 10 to 1,000 million fibers per liter. Filtration of municipal water was instituted by Duluth and other communities along the north shore of Lake Superior in the late 1970's. Current (1982) levels in raw municipal intake water at these sites range from less than one to 10 million fibers per liter (Philip Cook, personal communication).

Recognition of the elevated concentrations of fibers in Duluth drinking water, in the municipal water of a few other cities and in various foods and beverages has generated concern for the possible health consequences of ingesting asbestos fibers. Inhalation of asbestos has long been recognized as a health hazard posing an increased risk of pulmonary fibrosis, or cancer of the respiratory tract, G.I. tract or mesentery tissues (Harrington, 1976). It appears well-established that inhaled fibers can move from the lung or trachea to other tissues (Godwin and Jagatic, 1970), but the migration of ingested fibers, considered an important factor in their potential for promoting the above cancers has been less well demonstrated. Recent studies by Cook and Olson (1979) showed that amphibole fibers in drinking water migrated across the intestinal mucosa to the blood stream and were eliminated by the kidneys in urine, thus providing the first direct evidence of passage through tissues in humans.

Only in studies where rats were fed chrysotile asbestos in crushed filter material has a clear-cut effect (cancer) been observed following ingestion (Gibel, et al., 1976). A marginally significant association that needs to be confirmed between chrysotile fiber concentrations in drinking water and stomach cancer incidence was observed for 5 San Francisco Bay Area counties in California (McCabe and Millette, 1979; Kanarek, et al., 1978). Epidemiology data for several other municipalities with elevated fiber levels, including Duluth, show no such relationship. It has been suggested that a long latency period of 20 to 40 years, observed in cases of occupational exposure, is required before obtaining final evidence of ingestion-caused disease.

Meanwhile, pursuit of laboratory evidence for pathologies using amphibole fibers at known exposure concentrations is continuing. Some negative or inconclusive results have been reported for mice, rats and hamsters (e.g., Moore, 1978; Cunningham, et al., 1977); further studies are underway. Concern has been expressed that laboratory exposure factors such as fiber size, shape and distribution in the dosage medium might not have been the same in some studies as they exist in environmental samples (Cook, 1981). Based on these somewhat equivocal data and numerous assumptions drawn from them, the U.S. EPA has proposed a relationship between the human health lifetime cancer risk of 10^{-5} , 10^{-6} and 10^{-7} excess deaths per 100,000 individuals and 300,000, 30,000 and 3,000 fibers per liter, respectively (U.S. EPA, 1980). This is regarded as a conservative limitation that takes the state-of-knowledge into consideration.

Some uncertainty exists also about the effect of asbestos fibers on aquatic organisms, but in general they appear to be less vulnerable than man. Halsband (1974) investigated the short term effects of asbestos intake on the mussel (Mytilus edulis), a marine mollusk filter feeder. He exposed mussels to the fine fraction of asbestos in ore tailings from the Ungava Peninsula on Hudson Bay, Canada. Mussels were exposed for 5 days at extremely high concentrations of 100 mg/L and 10 mg/L. Some were removed after exposure and prepared for tissue examination while others were placed in asbestos-free water to provide an opportunity for purging. Examination showed that asbestos fibers penetrated the epithelial tissue of the stomach and intestinal tract, and that the "foreign bodies" were not disposed of after several weeks in control water. He concluded that tissue damage had occurred but offered no explanation of specific effects. It is worth noting that other investigators have found the optical microscope fiber examination procedure employed by Halsband inadequate because most fibers have less width than the resolving power of optical microscopes.

Fish living in water with elevated asbestos fiber concentrations do not accumulate amounts posing a health threat to humans eating them. Batterman and Cook (1981) found concentrations of fibers in muscle tissue of lake trout living in a contaminated (100×10^6 fibers/litre) area of Lake Superior to be less (10^2 X) than water concentrations. Similar results were obtained for fish collected from another source containing elevated fiber levels (Hudson Bay, Quebec). Somewhat higher concentrations were found in kidney tissues. Channel catfish (Ictalurus punctatus) and brook trout (Salvelinus fontinalis) reared in amphibole fiber-contaminated laboratory water but fed uncontaminated food did not accumulate fibers, indicating that ingestion of food organisms containing fibers might be the primary source for lake trout in nature. In general, however, ingestion of exposed fish by humans appears to be less of a hazard than drinking the water to which they are exposed.

Another study was conducted to determine if asbestos fibers in taconite tailings influence the effect levels of co-existing toxic chemicals (Carlson, et al., 1982). Concentrations of tailings up to 0.95 mg/L, near the maximum level recorded at the Duluth municipal water supply intake, had no demonstrable effect on the chronic toxicity of cadmium to flagfish (Jordanella floridae) or of endrin to fathead minnows (Pimephales promelas).

Summary:

In summary, the one large-volume source of contamination of the Great Lakes has been stopped and no other important point sources are known. Humans appear to be at greatest risk from elevated asbestos concentrations in surface waters, but an accurate appraisal of the threat from ingestion of different mineral forms is unavailable. Based on this information, recommendation of a numerical objective for asbestos fibers in the Great Lakes is deemed scientifically indefensible at this time.

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3. Future Directions

POLYNUCLEAR AROMATIC HYDROCARBONS

AEOC has undertaken to review the literature on PAH's relevant to the Great Lakes Ecosystem. A draft review document has been prepared and presented for peer review at the 7th International Symposium on Polynuclear Aromatic Hydrocarbons. This was held October 26-28, 1982 at the Battelle Laboratories and included a special session on aquatic effects. A special IJC workshop with invited participants was held in conjunction with the Symposium to review the document. Based on comments received and those of AEOC members, the draft is being revised and will be presented at a later date along with any recommended objective.

POLYCHLORINATED DIBENZOFURANS

A review of the information relevant to the Great Lakes system and freshwaters has been undertaken. A draft objective is nearing completion and will be subjected to peer review prior to submission.

MICROBIOLOGICAL INDICATORS

A draft objective and review of microbiological indicators in the Great Lakes is largely complete. It has been subject to extensive peer review and submission is expected during 1983. An objective for pathogens is being considered separately.

DIAZINON

A re-examination of the existing objective including new information has been presented as a first draft. It is anticipated that this will be completed, including peer review, by 1983.

TOXAPHENE AND LINDANE

An objective currently exists for lindane but reports of its occurrence in the Great Lakes system need re-examination. Recent information indicating toxaphene interference in some PCB determinations raises concerns about the levels and possible impact of this pesticide. A first review for each of these substances is planned during 1983.

ISHOW AND HEALTH EFFECTS REPORT

The AEOC is evaluating the use of ISHOW* and other data bases as a possible means of determining its selection of compounds for objectives. This approach is currently being applied to the substances in Table 3 of the 1981 Report of the Committee on the Assessment of Human Health Effects of Great Lakes Water Quality.

* Information System for Hazardous Organics in Water, Univ. of Minnesota, Duluth.

LIAISON

Two liaison opportunities have arisen, with both of which the AEOC intends to continue. The first is with the Water Quality Board's Toxic Substances Committee to formulate and undertake work plans addressing issues raised in their 1981 Annual Report. The second is with the same Board's Surveillance Work Group to assist them in evaluating the significance of surveillance data. The AEOC looks forward to such cooperation.

4. Information Needs

In 1982, the AEOC identified a number of research and other information topics necessary for the development of objectives. It recommended that funding agencies should consider these needs when establishing their priorities. The items are still required and are reproduced below.

In particular, the committee wishes to emphasize the need to assess existing information on Great Lakes fish population dynamics and related environmental factors to enable formulation of an aquatic ecosystem objective. A task force was established to effect this and it is anticipated that the 1983 Annual Report will be able to show substantial progress in this direction.

1. Analysis of Appropriate Fish Community Data Bases

There is a need to evaluate one or more fish community data bases which will provide as minimal requirements:

- a) lake trout demographic characteristics prior to the advent of the sea lamprey, major inputs of toxic substances or cultural eutrophication; and
- b) information for other species, particularly of Lake Superior, which may follow closely the pattern established by the lake trout because of similar responses to the same set of stresses.

2. Sediments as a Source of Toxic Chemicals for Aquatic Biota

Water Quality Objectives indicate that metals can be transferred from the sediments to aquatic biota to the detriment of fish or consumers of fish. There are indications that organic contaminants may similarly be transferred but probably by different mechanisms. Research is required to define and evaluate transfer mechanisms as well as conditions controlling rates and routes and in particular threshold sediment concentrations causing adverse effects in aquatic biota.

3. Metal Speciation

Research on metal speciation has clearly indicated that some metal species are more toxic to aquatic biota than others and that 'total' is a practical rather than an appropriate basis for water quality objectives. However, a major impediment to research and surveillance of metal species is the lack of practical analytical techniques to measure specific metal forms at concentrations of 0.001 to 1.0 $\mu\text{g/L}$; therefore, research is required to develop such sensitive practical techniques.

4. Air Sampling Methodology

Atmospheric deposition is a major source of contaminants to the Great Lakes ecosystem. While methods for measurement of wet deposition are available for both soluble and absorbed fractions, the same is not true for dry deposition. Techniques for the collection of such samples are urgently needed.

5. Epidemiological Models

Many of the epidemiological models can give variable results depending upon which model is utilized, the number of assumptions made and the magnitude of safety factors. While such models cannot be exact, a more detailed and uniform methodology for their design must be developed. This is especially true for models involving both human health related food consumption as well as acceptable levels of contaminants in drinking water.

6. Environmental Mapping

The allocation of limited use zones, will undoubtedly require the identification of sensitive inshore areas as called for in the 1978 Water Quality Agreement (Annex II, paragraph 2e). Environmental mapping is recommended to identify biologically sensitive areas or those areas subject to intensive recreational use.

7. Quantitative Structure-Activity Relationships

Structure-activity relationships may significantly reduce the effort required for environmental hazard evaluation by predicting the behavior and/or toxicity of chemicals. Research is needed to define quantitative relationships either generally or for specific classes of chemicals.

8. Mixtures

Objectives developed to date have addressed the biological activity of single compounds due to the lack of data dealing with multiple toxicant interactions in the aquatic environment. Chapter 5 in the 1981 AEOC Report outlined a practical approach to assessing the combined activity of metal mixtures, but the assumption of additive toxicity is not well supported. Research and evaluation of surveillance data are required to develop a sound theoretical basis for future objectives to control mixtures.

5. Issues Related to Objectives Development

Over the years, a number of questions recur which are related to Water/Ecosystem Quality Objectives. The AEOC has gathered its responses to some of these and presents them below in the hope that this will further an understanding of the work of the Committee.

1. What is the AEOC's mandate for developing objectives?

The preamble to the 1978 Agreement states that the 1972 Agreement and subsequent reports form a sound base for the 1978 Agreement. The former Agreement notes that "...Objectives may be modified and additional specific water quality objectives ... may be adopted..." (Article III, paragraph 2). Reports during the lifetime of that Agreement are also informative with respect to the intent of the Parties. In particular, the International Joint Commission's 1978 Annual Report on the Great Lakes Water Quality contains several instructive passages:

- "The Aquatic Ecosystem Objectives Committee on the Research [now Science] Advisory Board will develop specific aquatic ecosystem objectives based on broad ecological considerations.";
- "Restoration and enhancement ... will necessitate that current programs be conducted with a broadened perspective and awareness. Air, water, minerals and living organisms, including man are all interacting parts of the Great Lakes Basin Ecosystem. ... The Commission believes that these problems [contaminants] will require a broader, holistic approach for their solutions. The resolution of these problems, will require an ecosystem approach ..."; and
- ".... considering the various individual components of the Great Lakes System in isolation of others may be insufficient to resolve these problems. The ecosystem approach, recommended by the Commissionprovides the framework by which these components can be more fully integrated with one another."

Based upon the above and upon Annex I, paragraph 1 of the 1978 Agreement (which states that Objectives may be amended or added to), the AEOC believes that it has a strong mandate to develop Objectives. These may be of the traditional sort - chemical levels in water - or they may be more broadly based in keeping with the foregoing. Initial attempts in this latter direction are being focussed upon an oligotrophic ecosystem, the health of which will be indicated by its lake trout population among other indicators.

2. What is the difference between Standards and Objectives?

Objectives and standards or comparable regulatory measures are not the same. In both the 1972 and 1978 Agreements, it is clearly indicated that regulatory measures, such as Standards and Ministerial Orders, are legal

measures to be employed by the jurisdictions in order to achieve the General and Specific Objectives. When the various state and provincial agencies consider establishing regulations to apply to point source discharges, they are constrained by the Agreement to take the Objectives into consideration. But they may consider uses for the receiving waters other than the most sensitive use which the AEOC has identified; they will also take socio-economic factors into account. Consequently, objectives and standards may often differ.

This topic has been examined in the Water Quality Board papers:

"a) Review of the Impact of Water Quality Agreement Objectives on Water Quality Standards" by K.H. Walker, IJC Regional Office, Windsor, Ontario, June 1980; and

b) "Comparison of the 1978 Great Lakes Water Quality Agreement Water Quality Objectives to State Standards and Ontario Objectives Applicable to the Great Lakes", U.S. EPA, Great Lakes National Program Office, Chicago, June 1980;

which concluded that the Objectives have had an impact on the regulations. This does not require that the AEOC should consider the regulatory difficulties and "back-off" from its stated protective stance; on the contrary, the AEOC is encouraged by such results. Concerning socio-economic impact assessment statements, the AEOC is not constituted for nor charged with this aspect in developing Objectives. A Social and Economic Impact Assessment (SEIA) was attempted for the chlorine objective in a separate IJC Great Lakes Water Quality Board report in 1980 ("Alternatives for Managing Chlorine Residuals: A Social and Economic Assessment") which concluded that, in future, SEIA statements should be developed by the jurisdictions. The AEOC endorses this.

3. What sort of Peer Review do the Objectives receive?

In developing Objectives, the AEOC draws upon its own and associated information sources and expertise. One member is assigned the lead role to prepare drafts which are reviewed by the other members and their associates, revised and again reviewed until the Committee is satisfied. The members are always cognizant of the various philosophical issues in the Introduction.

Objectives are developed with the philosophy of protecting all uses of the waters of the Great Lakes. They are intended to apply everywhere except in "limited use zones" contiguous to point source discharges; it is assumed that the locations, numbers and total impact of these zones will be controlled so that they are not harmful to the Great Lakes ecosystem.

The Objectives are developed from the scientific literature available at the time of their proposal and they may be revised at any time that a review of the data base so indicates.

Objectives as proposed by the AEOC do not consider socio-economic factors nor are they regulations or standards. They are considered as the minimum basis for developing such regulations or standards by the jurisdiction.

In the course of their development, the Objectives have been subject to iterative reviews within the Committee and by scientific colleagues in relevant fields. The Committee, however, welcomes any comments which are applicable to any of the Objectives and which are consistent with the above

philosophy. These should be sent to the secretary, whose address appears in the Committee Membership List of this Report.

4. What are the uses to be Protected?

The 1972 and 1978 Agreements speak of the beneficial uses of the Great Lakes which the Parties wish to secure. The Objectives are intended to describe conditions (maximum levels of substances for Specific Water Quality Objectives) which will protect the lakes for these uses. Unfortunately, there is no guidance in the Agreements which would indicate which uses nor where any of those uses applies. This uncertainty was addressed by the AEOC's predecessors - WQOS and SBWQC - and is discussed in their 1974 Report to the Water Quality Board. The issue was resolved by the Water Quality Board in that all uses were to be provided for everywhere in the Great Lakes. The WQOS/SBWQC and the AEOC interpreted this to mean the most sensitive use which frequently is based on the provision of a "safe" habitat for aquatic life, although it may be based on other uses if these are more sensitive.

5. What is meant by "zero" or "absent" in an Objective for a persistent substance?

The 1972 Agreement, Annex 1, called for the system to be made "free" of toxic metals and that persistent organic contaminants should be "substantially absent". These requirements were interpreted to mean analytically zero if no safe level could be established. Such safe levels could not be established for a number of the organochlorine contaminants in the water column although data were available to establish levels for some in fish tissues. The WQOS/SBWQC discussed the use of quantification limits as the level for "substantially absent" (ie. below detectable levels as defined by present analytical techniques) in setting Objectives in the 1974 Report to the WQB. It should be stressed that these limits were for routine laboratory analyses and as such can generally be exceeded in research laboratories.

This approach was employed for mirex and has been recommended for dioxins and furans. The methods for achieving these quantification levels were not specified because it was not the AEOC's intent to prevent, through enshrining the status quo, the further refinement of tests. Rather, such levels are meant to encourage the development of scientific data to define "safe" levels of specific contaminants.

6. What is the AEOC's approach to the use of safety factors?

The development of Objectives, to date, has attempted to avoid the use of safety factors applied to data on lethality. With the exception of the procedural objective (0.05 x 96 hr LC₅₀) for complex effluents, the basis has been on "subtle" responses to the chemicals for which Objectives were recommended. In some cases, the effects noted in the literature were not subtle although not lethal. In these cases, the arbitrary safety factor of 0.2 was employed, consistently, to arrive at levels of the particular substance which were less than those causing the effects. The use of this factor, 0.2, was noted in the 1974 Report of the WQOS/SBWQC.

7. What is the most appropriate test species to employ?

In a practical sense, it is not possible to test for all species in the Great Lakes. In any event, the AEOC itself does not carry out such tests; they examine the existing literature which is generally never extensive enough to provide absolute "proof" of hazard. The AEOC takes the approach that laboratory test species are surrogates for their counterparts in the real world and that the organisms there are at least as varied in sensitivity to toxic chemicals as are their laboratory cousins. Therefore, the most sensitive species in either laboratory or field is employed in determining the response of aquatic life to a substance. Some discussion of test species was presented in the 1974 Report of the WQOS/SBWQC, where it was noted that the Objectives could be modified in local situations. This modification required that it be established that no indigenous local species was adversely affected by higher levels of a substance than were specified in a locally modified Objective. Due to the large number of species present in any aquatic ecosystem, the difficulty in maintaining and testing many of these species in the laboratory and the extensive migration of many 'non-resident' species, this latter approach has not been pursued.

2. How to Use This Handbook

In a practical sense, it is impossible to test for all species in the Great Lakes. In the past, the IJC has not carried out such tests; they will be carried out in the future. It is generally never extensive enough to provide for the control of species. The IJC takes the approach that it should be possible to determine for each species in the Great Lakes whether it is a pest or not. It is possible to vary in sensitivity to control measures. Therefore, the most sensitive species should be given the highest priority in developing the control program. The IJC has determined that the species of test species are those which are most likely to cause the most damage. It is also possible to determine the relative damage caused by different species. The IJC has determined that the species which cause the most damage are those which are most likely to be introduced. The IJC has determined that the species which cause the most damage are those which are most likely to be introduced. The IJC has determined that the species which cause the most damage are those which are most likely to be introduced.

Appendix

- LIST OF REFERENCES
- LIST OF SPECIES
- LIST OF AGENCIES

TERMS OF REFERENCE FOR THE
AQUATIC ECOSYSTEM OBJECTIVES COMMITTEE OF THE
SCIENCE ADVISORY BOARD

The Aquatic Ecosystem Objectives Committee (AEOC) of the Science Advisory Board will:

1. Develop aquatic ecosystem objectives. Where feasible, these should be in the form of use effect curves, for various uses, and always including the most sensitive use.
2. Regularly review objectives and recommend amendment or introduction, based upon all available criteria.
3. Establish task forces to develop position papers on which to base the development of new or altered objectives.
4. Set general guidelines under which the objectives will be developed and define some minimum levels of scientific information at which an objective can be defined.
5. Develop an approach for the selection and ordering of parameters to be addressed.
6. Identify gaps in the knowledge needed to develop objectives and recommend the research required to fill the gaps.

MEMBERSHIP

The AEOC will consist of eight members: two aquatic toxicologists, three water quality specialists (one each from the provincial, state, and one of the federal governments), a limnologist, an aquatic chemist, and a human health aspects expert.

SUBMISSION OF PROPOSED OBJECTIVES

"Since the Science Advisory Board has the responsibility for advising on scientific matters, and since the Water Quality Board will deal with the policy implications of proposed objectives on an ad hoc basis, the Commission plans to advise the Science Advisory Board to take the initiative in the study of new or revised water quality objectives, in consultation with the Water Quality Board as required, and to forward reports simultaneously to the Commission and the Water Quality Board. Thus, the study of objectives will not be dependent on actions of the Water Quality Board, but there will be an opportunity for the Board to advise the Commission on the practicability of the objectives under consideration or on the need for additional study from the Water Quality Board perspective." (Excerpt from a letter dated May 03, 0980, from the International Joint Commission to the Secretary of the Water Quality Board).

REVISED AND APPROVED BY THE
SCIENCE ADVISORY BOARD
SEPTEMBER 3, 0980.

TERMS OF REFERENCE FOR THE
AQUATIC ECOSYSTEM OBJECTIVES COMMITTEE OF THE
SCIENCE ADVISORY BOARD

The Aquatic Ecosystem Objectives Committee (AEOC) of the Science Advisory Board will:

1. Develop aquatic ecosystem objectives. Where feasible, these should be in the form of measurable criteria, for various uses, and always including the word "ecosystem".
2. Regularly review objectives and recommend amendments or introduction based upon available criteria.
3. Establish task forces to develop position papers on which to base the development of new or revised objectives.
4. Set general guidelines under which the objectives will be developed and define some minimum levels of scientific information on which an objective can be based.
5. Develop an approach for the selection and working of parameters to be addressed.
6. Identify gaps in the knowledge needed to develop objectives and recommend the research required to fill the gaps.

MEMBERSHIP

The AEOC will consist of eight members, two aquatic toxicologists, three water quality specialists (one each from the provincial, state, and one of the federal governments), a hydrologist, an aquatic chemist, and a human health aspects expert.

SUBMISSION OF PROPOSED OBJECTIVES

"Since the Science Advisory Board has the responsibility for advising on scientific matters, and since the Water Quality Board will deal with the policy implications of proposed objectives on an ad hoc basis, the Commission plans to advise the Science Advisory Board to take the initiative in the study of new or revised water quality objectives. In consultation with the Water Quality Board as required, and to forward reports simultaneously to the Commission and the Water Quality Board. Thus, the study of objectives will not be dependent on action of the Water Quality Board, but there will be an opportunity for the board to advise the Commission on the practicability of the objectives under consideration or on the need for additional study from the Water Quality Board perspective." (Excerpt from a letter dated May 23, 1980, from the International Joint Commission to the Secretary of the Water Quality Board).

REVISED AND APPROVED BY THE
SCIENCE ADVISORY BOARD
SEPTEMBER 3, 1980

MEMBERSHIP
AQUATIC ECOSYSTEM OBJECTIVES COMMITTEE

Mr. G.P. Brezner
Manager of Technical Services
ORSANCO
414 Walnut Street
Cincinnati, Ohio 45202
(513) 421-1151

Mr. J. Eaton
Environmental Research Lab-Duluth
U.S. Environmental Protection Agency
6201 Congdon Boulevard
Duluth, Minnesota 55804
(218) 727-6692 (FTS) 783-9557

Dr. P.V. Hodson
Great Lakes Fisheries Research Branch
Department of Fisheries and Oceans
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 637-4559

Dr. A. Robertson
Deputy Director
Office of Marine
Pollution Assessment -NOAA
RD/MP Rockwall Bldg. Room 320
Rockville, Maryland 20852
(301) 443-8906 (FTS) 443-8906

Dr. W.M.J. Strachan (Chairman)
National Water Research Institute
Department of Environment
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6
(416) 637-4222

Secretariat Responsibilities

Dr. C.J. Edwards (until April, 1982)
Dr. A.E.P. Watson (Eff. April, 1982)
International Joint Commission
100 Ouellette Avenue, 8th Floor
Windsor, Ontario N9A 6T3
(519) 256-7821
(313) 963-9041

Mr. G. Craig (Eff. May 15, 1981)
Limnology and Toxicology Section
Ontario Ministry of the Environment
P. O. Box 213
Rexdale, Ontario M9W 5L1
(416) 248-3011

Dr. D.J. Hallett
Wildlife Toxicology Division
Canadian Wildlife Service
National Wildlife Research Inst.
Department of Environment
Ottawa, Ontario KIA 0E7
(613) 997-1410

Dr. E.V.D.K. Perrin
Dept. of Laboratory Medicine
Children's Hospital of Michigan
Wayne State University
Detroit, Michigan 48201
(313) 494-5502
Mailing Address
23618 Dundee
Huntington Woods, Michigan 48070

Mr. R.A. Ryder
Fish and Wildlife Research Branch
Ontario Ministry of Natural Resources
P.O. Box 2089
Thunder Bay, Ontario P7B 5E7
(807) 683-6232/31

SAB Liaison Members

Dr. W.E. Cooper (until March, 1982)
Department of Zoology
Michigan State University
East Lansing, Michigan 48823

Dr. D.C. McNaught (from April, 1982)
Minnesota Sea Grant Program
1988 Fitch Avenue
University of Minnesota
St. Paul, Minnesota, 55108
(612) 373-1708

MEMBERSHIP
 AQUATIC ECOSYSTEM QUALITY COMMITTEE

Mr. E. Craig (May 18, 1981)
 Planning and Technology Section
 Bureau of the Environment
 P. O. Box 218
 Ottawa, Ontario K1A 0L7
 (416) 492-3011

Dr. B. G. Bell
 Wildlife Technology Division
 Canadian Wildlife Service
 Regional Wildlife Research Inst.
 Department of Environment
 Ottawa, Ontario K1A 0L7
 (416) 967-1410

Dr. E. G. R. Rennie
 Dept. of Laboratory Medicine
 Children's Hospital of Michigan
 Wayne State University
 Detroit, Michigan 48201
 (313) 424-8004
 Mailing Address
 4225 Cass
 Pontiac, Michigan 48070

Mr. A. J. Fisher
 Fish and Wildlife Research Branch
 Bureau of the Environment
 P.O. Box 208
 Ottawa, Ontario K1A 0L7
 (416) 967-3231

524 Leland Avenue
 Dr. W. J. Cooper (until March, 1982)
 Department of Zoology
 Michigan State University
 East Lansing, Michigan 48824

Dr. D. C. Schmitt (from April, 1982)
 Minnesota Sea Grant Program
 1888 Fifth Avenue
 University of Minnesota
 St. Paul, Minnesota, 55108
 (612) 375-1708

Mr. G. P. Brennan
 Manager of Technical Services
 ORSA/CO
 414 Walnut Street
 Cincinnati, Ohio 45202
 (513) 451-1181

Mr. J. Eaton
 Environmental Research Lab-Duluth
 U.S. Environmental Protection Agency
 6501 Canyon Boulevard
 Duluth, Minnesota 55804
 (518) 734-6505 (FTS) 743-9087

Dr. P. V. Hodson
 Great Lakes Fisheries Research Branch
 Department of Fisheries and Oceans
 Canada Centre for Inland Waters
 P.O. Box 2050
 Burlington, Ontario L7R 4A8
 (416) 637-4229

Dr. A. Robertson
 Deputy Director
 Office of Marine
 Pollution Assessment - ROM
 ROMR Rockwell Blvd. Room 250
 Rockville, Maryland 20851
 (301) 443-8006 (FTS) 443-8906

Dr. W. M. J. Szechenyi (Chairman)
 National Water Research Institute
 Department of Environment
 Canada Centre for Inland Waters
 P.O. Box 2050
 Burlington, Ontario L7R 4A8
 (416) 637-4229

Secretary: Rosemary H. H. H.
 Dr. C. J. Edwards (until April, 1982)
 Dr. A. E. R. Watson (until April, 1982)
 International Joint Commission
 100 Waterloo Avenue, 8th Floor
 Windsor, Ontario N9A 6T3
 (813) 256-7871
 (416) 967-3041

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SILVER

H.B. Lockhart, Jr.
Health, Safety and Human Factors
Laboratory
Eastman Kodak Co.,
Rochester, New York

W.H. Crane
Director, Government Relations,
Kodak Canada, Inc.
3500 Eglinton Ave. West,
Toronto, Ontario

I. Sekerka
Analytical Methods Division
National Water Research Institute
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6

POLYCHLORINATED STYRENES

D.C. Villeneuve
Environmental and Occupational Toxicology
Toxicology Division
Bureau of Chemical Hazards
Environmental Health Directorate
Tunney's Pasture
Ottawa, Ontario KIA 0L2

MICROBIOLOGICAL INDICATOR

L.T. Vlassoff
Ontario Ministry of the Environment
P. O. Box 213
Rexdale, Ontario

A.P. Dufour
U.S. Environmental Protection Agency
Health Effects Research Laboratory
Cincinnati, Ohio

B.J. Dutka
National Water Research Institute
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6