MAY 28 1974

Statement of Gilman D. Veith

My name is Gilman D. Veith. I am a research chemist at the Environmental Protection Agency National Water Quality Laboratory in Duluth, Minnesota. My duties involve the development of analytical methodology for isolating and identifying persistent organic chemicals in natural waters and aquatic organisms, and research concerning the bioconcentration of organic chemicals in aquatic organisms. I have been employed by the National Water Quality Laboratory since 1972.

I received a B.S. cum laude in chemistry from Augustana College in Sioux Falls, South Dakota, in 1966 and spent the following academic year in graduate studies in chemistry at Cornell University as a Woodrow Wilson Fellow. I completed the M. S. requirements in Water Chemistry at the University of Wisconsin at Madison in 1968 and received a Ph.D. in Water Chemistry from the University of Wisconsin - Madison in 1970.

From 1970 to 1972, I was an Assistant Professor in Water Chemistry at the University of Wisconsin - Madison. My teaching duties included graduate courses in water chemistry, water analysis and advanced techniques in water analysis. The research I have been engaged in during the past six years has centered largely around the occurrence of chlorobiphenyls (PCBs) in the environment. In particular, I have completed studies of the sources of PCBs in selected Wisconsin rivers in the Lake Michigan watershed and the identification and measurement of PCBs in fish from Lake Michigan and Lake Superior.

My testimony will be taken from completed and ongoing research, as well as pertinent results of related studies in the literature. My testimony will

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discuss the analytical limitations associated with PCB measurements and show that PCBs are bioconcentrated in fish by factors greater than 10^5, that the residues resulting by bioconcentration from less than 0.01 ug/l in water have decreased the value of the food resources in Lake Michigan, and that recent evidence confirms the presence of polychlorinated dibenzofurans in PCBs mixtures manufactured in the United States.

ANALYSIS OF CHLOROBIPHENYLS

The identification and measurement of PCBs in environmental samples is inherently difficult because multi-component mixtures are involved. The PCBs include mixtures of hydrophobic chemicals which vary considerably in chlorine content, chemical reactivity, bioconcentration potential, and biological activity. The analytical problems associated with developing methodology for the measurement of complex mixtures are not unique to PCBs but are encountered in numerous other analyses such as chlordane and toxaphene. The need to measure PCBs in large numbers of fish from a bioassay or the Great Lakes where biological variation is subtracted dictates that the methodology permit the necessary numbers of samples to be analyzed, and the interpretation of the residue data is based on more detailed analyses of a small number of representative samples.

A. Isolation of PCBs

The PCBs are generally extracted from water, tissue, or sediment with organic solvents such as hexane, acetonitrile, and acetone. Although the PCB mixtures contain chlorobiphenyls with varying water solubilities (Exhibit 1 summarizes estimates of vapor pressures and solubilities for PCBs and indicates the solubility is a function of composition and varies

by more than 100, the extraction of PCBs in water with immiscible solvents can be designed to assure the extraction is essentially quantitative.

The extraction of large quantities of water (i.e. more than 10 liters) to measure small concentrations of PCBs may require the use of large quantities of solvents which increase the possibility of sample contamination unless high purity reagents are used. To minimize reagent blanks, reverse liquid-liquid partitioning using supports coated with hydrocarbons (Exhibit 2) and adsorption on polymeric foams (Exhibit 3) have been used to extract up to 200 liters of water.

The isolation of the PCBs from the bulk of the co-extractable materials has been based largely on group separations using adsorption differences on florisil, partitioning differences with acetonitrile water systems, and chemical stability to oxidizing acids (Exhibit 4). Although the PCBs are separable from the co-extracted lipids and related materials, the PCBs are more difficult to isolate from interfering chlorinated pesticides, and additional isolation steps are necessary. A frequently encountered interference in PCB measurements is the presence of DDT and its analogs in the sample. One of the more commonly used methods for isolating the PCBs from DDT is silicic acid column chromatography (Exhibit 5) in which the PCBs are eluted with a non-polar solvent and DDT is eluted with a more polar solvent. However, the adsorption of the many PCBs and DDT analogs may not be restricted to two distinct groups, and incomplete iosolation is observed. Exhibit 6 discusses some of the commonly observed problems in using this group separation technique and specifically points out that DDE is often found in the PCB fraction whereas some lesser chlorinated PCBs are eluted in the polar solvent. Thus, the isolation procedure may

alter the composition of the PCB residue, and detailed studies of the separation must be included in the discussion of results.

In addition to the possibility that the PCB residue may be altered, other chemicals or mixtures of chemicals may not be separated from PCBs under conventional methodology. Exhibit 7 illustrates that polychlorinated naphthalenes behave similar to the PCBs on silicic acid. Although analyses using gas chromatography/mass spectrometry (GC/MS) may provide the best estimate of the significance of interferences, other chromatographic techniques such as reverse-phase thin-layer chromatography have been used to complement GLC analyses when GC/MS facilities are not available (Exhibit 8).

B. Identification and Measurement of PCBs

Gas chromatography has served as the basis for PCB measurements due to the capability of separating mixtures and providing quantitative and some qualitative information about the mixtures (Exhibit 9). When the gas chromatograph is interfaced with a mass spectrometer, the mixtures can be resolved and identified with respect to chlorine content and carbon chelation skeleton.

The extent to which the PCB mixtures are resolved in GC/MS analyses is controlled by the GLC conditions. For example, Exhibit 10 illustrates that the PCB mixture, Aroclor 1254, containing 54 percent chlorine can be resolved into at least 69 components. Structures for the components have been proposed; however, since these analyses are prohibited on a routine basis due, in part, to the time required, the chromatograms of the PCB found in residues are often related to those of commercially available PCB mixtures under lower resolution GLC conditions. Under these conditions, the mixtures are resolved

into a series of multi-component peaks which provide characteristic chromatograms for most of the commercial mixtures. The composition of these components have been studied (Exhibit 11) and approximately 75 percent of the PCBs in Aroclor 1254 is represented by the six observed peaks having retention times of 70, 84, 98, 104, 125, and 146 relative to DDE=100. The PCB peak at RRT = 70 is comprised of tetrachlorobiphenyls (25 percent) and pentachlorobiphenyls (75 percent). The identification of the components in a residue can be unambiguously identified as the respective PCB components by GC/MS using isotopic abundance ratios as outlined in Exhibit 12.

The quantitation of the PCBs requires numerous analytical considerations. The total PCB content is difficult to measure by integrating total area in the mixture chromatograms because of possible interferences and because the electron capture (EC) response of the EC-GLC analysis varies widely with degree of chlorination and substitution (Exhibits 13 and 14). Webb and McCall (Exhibit 11) have discussed the rationale for the selection of methodology for PCBs. When studying a bioassay system in which a single commercial PCB mixture is added or an effluent which contains principally one PCB mixture, reliable estimates can be made by selecting several interference-free component peaks and comparing sample chromatograms to standard curves prepared from the PCB mixture present.

The same technique has been applied to samples from major watersheds and the oceans where the PCB residues resemble one of the commercially available PCB mixutes. For example, Exhibit 15 summarizes the concentration of PCB mixtures resembling Aroclor 1254 in Lake Michigan fish. It was observed that DDT and DDD interferences could be removed from the PCBs using the silicic acid technique; however, DDE could not be reproducibly removed.

Therefore, the quantitation of the major components of PCBs were estimated by summing the peak heights of the peaks at 70, 84, 125, 146 and 174 while omitting the doublet at 98 and 104 (relative to DDE = 100) because of the DDE interference. These estimates give a conservative estimate of total PCBs unless attempts to account for other possible mixtures of PCBs present are made.

For samples which contain mixtures of various PCB mixtures, only estimates of the various mixture fractions of the total PCBs present may be possible. The approach to these analytical problems is to use standard curves prepared from mixed PCB mixtures. Exhibit 11 demonstrates the feasibility of dividing complex chromatograms into three major regions corresponding to three PCB mixtures as standards--using selected peaks as the basis of comparison. Exhibits 16 and 17 discuss other methods of using mixed standards and mixtures of isolated components. The majority of monitoring studies reported to date appear to prefer the use of commercially available PCB mixtures as standards due, in part, to the fact that much of the studies of biological activities are conducted with the commercial mixtures rather than pure isomers.

The perchlorination of all PCB components to decachlorobiphenyl has been used successfully to estimate total PCB concentrations as well as confirm the presence of PCBs. The technique (Exhibits 18 and 19 using $SbCl_5$ or SCl_3AlCl_4 to convert all components of the mixutres to one component greatly enhances the analytical detection limit and, if the average percentage of chlorine of the original mixture can be estimated, the amount of decachlorobiphenyl can be used to calculate the original PCB concentration.

Despite all of the possible errors in the extraction of PCBs and the lack of standard techniques for quantitation, Holden (Exhibit 20) has reported that collaboratove studies among 17 laboratories indicated the coefficient of variation for six pesticides and PCBs requiring full processing ranged from ± 10 to ± 18 percent.

BIOCONCENTRATION OF CHLOROBIPHENYLS

An understanding of the bioconcentration of chemicals in organisms is essential to understand the dynamics of the chemicals in the environment. Considerable confusion exists regarding the relative significance of various uptake mechanisms due, in part, to the absence of detailed definition of the systems studied. Much of the early literature assumed that bioconcentration in the aquatic environment was based on the trophic level or food chain concepts.

However, exposures of fish to water containing many hydrophobic chemicals demonstrated that fish can bioconcentrate the chemicals directly from the water. Uptake can be approximated as a first order rate process and that the process appeared to be that of chemical partitioning from the water and the lipids in the tissue. This has led to proposals such as that in Exhibit 21 where the food chain bioconcentration model is rejected in favor of the chemical partitioning model. As with many kinetic models of dynamic systems, multiple pathways are often observed and the relative significance of the various rate expressions is dependent on the conditions imposed. Therefore, the selection of either the food chain or the partitioning model for the aquatic environment requires that the conditions of the ecosystem being considered are defined.

The bioconcentration of PCBs under laboratory conditions in which the mixtures are added only to the water has been studied for a number of aquatic organisms and the observed bioconcentration factor for PCBs in the aquatic environment may differ in different organisms and conditions. For example, Exhibit 21 illustrated that bioconcentration is inversely related to the water solubility (assuming relatively constant lipid solubility). Exhibits 21 and 22 demonstrate that not only does bioconcentration increase with increasing chlorine content, but also that the lipid variations between male and female fish may produce substantial sex-related differences if only the wet weight concentrations of PCBs are considered.

Exhibits 22 and 23 show that the bioconcentration factor of Aroclor 1254 in fathead minnows ranged from 1.1×10^5 to 2.4×10^5 and that the bioconcentration factor for the PCBs to the fathead minnow (where the tissue is generally less than 10 percent lipid) at 25° C ranges from about 0.3×10^5 to 2.5×10^5 with the more highly chlorinated PCBs accumulating to a greater extent. Exhibit 24 shows that Aroclor 1254 is accumulated in pinfish approximately 2×10^4 times that in the water after 35 days of exposure at a salinity of 14 - 34%. Exhibit 25 suggests that increasing salinity decreases the rate of uptake or lipid-soluble chemicals.

Exhibit 26 shows that the nymph E. danica accumulated Clophen A 50 by an approximate first order process to bioconcentration factors of 3×10^3. Exhibit 27 presents evidence that the bioconcentration factor of Aroclor 1254 in the scud, Gammarus pseudolimnaeus, (was approximately 2.2×10^4), 4.5×10^4 after 48 hours in Daphnia magna, and 1.3×10^4 in mosquito larvae. Culex tarsalis after only 24 hours. After 60 days of exposure to Aroclor 1242 and Aroclor 1248, the maximum bioconcentration factor in Gammarus was found to

be approximately 3×10^4 and 5×10^4 respectively (Exhibit 28). Exhibit 27 also reports bioconcentration factors ranging from 2×10^4 to 6×10^4 for bluegills and catfish exposed to Aroclor 1248 and 1254.

Some evidence exists that the bioconcentration factors measured in the laboratory are essentially the same as that found in the river environment. For example, Exhibit 22 shows that the laboratory derived bioconcentration factor for Aroclor 1248 in fathead minnows (≈10 percent lipid) ranged from 1×10^5 to 2.4×10^5. Exhibit 29 and 30 report that goldfish in the lower Milwaukee River accumulated Aroclor 1248 approximately 0.7×10^5 to 2×10^5 times (depending on the lipid content) the estimated PCB concentration in the river water. Exhibit 31 presents evidence that the maximum concentration of Aroclor 1254 in Saginaw River shed was 165 ug/gm whereas typical water concentrations averaged 1.1 ug/l to a maximum of 2.9 ug/l. This is equivalent to a bioconcentration factor of 0.6×10^5 to 1.5×10^5, in good agreement with other measurements.

In summary, for river systems and in laboratory studies many of the aquatic organisms studied appear to bioconcentrate PCB mixtures containing 3, 4, 5, and 6 chlorine atoms per molecule approximately 3×10^3 to 2×10^5 times the concentration in the water they are exposed to.

Occurrence of PCBs in Lake Michigan

The concentration of PCBs in Lake Michigan fish has been studied near Milwaukee in 1969 (Exhibit 9) and throughout the lake in 1971 (Exhibit 5). The data from 1969 indicated that trout and salmon caught near the Wisconsin shore contained from 6 to 25 ug/gm PCBs resembling Aroclor 1254. The more detailed study presented in Exhibit 15 shows that the PCBs resembling Aroclor 1254 were found at mean concentrations ranging from 2.7 ug/gm in smelt to 15.5 ug/gm in lake trout. The predominant PCB components present in the fish were the tri-, tetra-, penta-, hexa-, and heptachlorobiphenyls by GC/MS studies of com-

posite samples.

Exhibit 30 reported concentrations of PCBs similar to Aroclor 1242 in the Milwaukee River, a major tributary to Lake Michigan, up to 2.8 ug/1. Exhibit 32 shows that Aroclor 1242 was found in Illinois tributaries at 0.14 to 1.8 ug/1 in 1971 and from 0.01 ug/1 to 0.7 ug/1 in 1972. Aroclor 1254 was found in the same tributaries at concentrations up to 0.8 ug/1. In an extensive study of PCBs in municipal wastewater effluents in Michigan, the overall mean PCB concentration is all eight-hour composite samples collected was 2.6 ug/1. However, only one of the 50 effluents averaged over 10 ug/1 and 44 of the 50 effluents averaged less than 1 ug/1 PCB. Exhibit 33 reports similar results for eleven municipal effluents in southeastern Wisconsin in that only one of the eleven effluents contained an average PCB concentration greater than 1 ug/1.

Exhibit 31 provides evidence that the concentrations of PCBs in the intake water of municipalities along the Michigan shore are, with one exception, all below 10 ng/1 (ppt). This indicates the minimum bioconcentration factor for smelt in the lake (mean concentration of 2.7 ug/gm) is approximately 3×10^5 and that the minimum bioconcentration factor for the large trout is approximately 15×10^5.

The PCB residues present in the Lake Michigan biota have adversely affected the value of the biological resources of the lake as a food supply for animal feeds. Exhibit 34 is an early indication that Great Lakes fish were suspected of interfering with normal reproduction of mink feeding on fish. Exhibit 35 showed that the effect on mink could not be correlated to the degree of oxidative rancidity or mercury concentration in the fish. Exhibit 36 presents evidence that 5 ug/gm of Aroclor 1254 in the coho salmon diet of mink significantly reduced reproduction and that 1 ug/gm of Aroclor 1254 in the diet caused a slight decrease in reproduction. Exhibit 37 presents similar evidence for mink feed diets enriched with Aroclor 1254. The data indicate that 0.64 ug/gm of the

PCB in the rations resulted in only one of 12 mink producing three kits, all of which dies on the first day. Exhibit 15 has shown that the mean concentration of PCBs in coho salmon in Lake Michigan was 11.5 ug/gm in 1971, well above the FDA tolerance level.

Occurrence of PCBs in Lake Superior

Exhibit 38 presents data concerning the mean concentrations of PCBs measured in Lake Superior fish captured in 1972 and 1973 from western Lake Superior. The data indicate that mean PCB concentrations in the smaller, low-lipid content fish contain up to approximately 1.5 ug/gm (on a wet tissue basis) whereas the larter trout contained up to 5.6 ug/gm. Exhibit 39 presents corroborating data for the PCB concentrations in Lake Superior trout obtained by the Michigan Department of Agriculture.

There have been some estimates of PCBs in western Lake Superior water. Exhibit 40 presents estimates of PCBs in the water intake and a bioassay control tank of the National Water Quality Laboratory in Duluth. The estimates were made using the foam plug extract to extract 20 liters of water in triplicate, perchlorinating the extracts with $SbCl_5$, and measuring the decachlorobiphenyl formed. The data indicate that approximately 1-2 ng/l PCBs (ppt as Aroclor 1254) are present in western Lake Superior nearshore water.

The mean concentration of PCBs in the smaller fish is approximately 0.9 ug/gm. This indicates the overall bioconcentration factor in western Lake Superior fish is approximately 9×10^5.

In summary, the data from the Great Lakes demonstrate that PCBs are present in the waters at concentrations below 10 ng/l (ppt), that the concentration of PCBs in the fish are more than 10^5 times that measured in the water, and that the PCB residues which bioconcentrate in fish from water concentrations below 10 ng/l have affected the use of the Lake Michigan resources as a food resource.

Chlorodibenzofurans in Aroclor® PCB Mixtures

Exhibit 41 presents confirmations tetra-, penta- and hexachlorodibenzofurans in the Aroclor® brand of PCBs prepared in the United States. The chlorinated dibenzofuran concentrations decrease with increasing chlorine content of the PCB mixture. Aroclor 1254 contained eleven chlorodibenzofurans comprised of two tetra, four penta and five hexachlorodibenzofurans.

REFERENCE LIST FOR GILMAN D. VEITH

Ex. 1. Mackay, D. and A.W. Wolkoff. Rate of Evaporation of Low-Solubility Contaminants from Water Bodies to Atmosphere. Environmental Science & Technology 7:611-614(1973)

Ex. 2. Ahling, B. and S. Jensen. Reversed Liquid-Liquid Partition in Determination of Polychlorinated Biphenyl (PCB) and Chlorinated Pesticides in Water. Analytical Chemistry 42:1483-1486(1970)

Ex. 3. Gesser, H.D., A. Chow, F.C. Davis, J.F. Uthe and J. Reinke. The Extraction and Recovery of Polychlorinated Biphenyls (PCB) Using Porous Polyurethane Foam. Analytical Letters 4:883-886(1971)

Ex. 4. Jensen, S., L. Renberg, and R. Vaz. Problems in the Quantitation of PCB in Biological Material. PCB Conference II Stockholm 1972

Ex. 5. Armour, J. and J.A. Burke. Method for Separating Polychlorinated Biphenyls from DDT and Its Analogs. Journal of the AOAC 53:761-768 (1970)

Ex. 6. Masumoto, H.T. Study of the Silicic Acid Procedure of Armour and Burke for the Separation of Polychlorinated Biphenyls from DDT and Its Analogs. Journal of the AOAC 55:1092-1100(1972)

Ex. 7. Armour, J.A. and J.A. Burke. Behavior of Chlorinated Naphthalenes in Analytical Methods for Organochlorine Pesticides and Polychlorinated Biphenyls. Journal of the AOAC 54:175-177(1971)

Ex. 8. Stalling, D.L. and J.N. Huckins. Reverse Phase Thin Layer Chromatography of Some Aroclors, Halowaxes, and Pesticides. Journal of the AOAC 56:367-372(1973)

Ex. 9. Armour, J.A. Gas Chromatographic Data for Polychlorinated Biphenyl Components in Six Aroclors. Journal of Chromatography 72:275-282 (1972)

Ex. 10. Sissons, D. and D. Welti. Structural Identification of Polychlorinated Biphenyls in Commercial Mixtures by Gas-Liquid Chromatography, Nuclear Magnetic Resonance and Mass Spectrometry. Journal of Chromatography 60:15-32(1971)

Ex. 11. Webb, R.G. and A.C. McCall. Quantitative PCB Standards for Electron Capture Gas Chromatography. Journal of Chromatographic Science 11:366-373(1973)

Ex. 12. Rote, J.W., and W.J. Morris. Use of Isotopic Abundance Ratios in Identification of Polychlorinated Biphenyls by Mass Spectrometry. Journal of the AOAC 56:188-198(1973)

DSW 315472

Ex. 13. Gregory, N.L. Electron Capture by Chlorinated Biphenyls. Journal of The Chemical Society,Section B:295-300(1968)

Ex. 14. Zitko, V., et al. Retention Times and Electron-Capture Detector Responses of Some Individual Chlorobiphenyls, Bul.Env. Cont. Toxicology6:160-163(1971).

Ex. 15. Veith, G.D. Chlorinated Hydrocarbons in Fish from Lake Michigan. EPA Project 16020 PBE

Ex. 16. Rote, J.W. and P.G. Murphy. A Method for the Quantitation of Polychlorinated Biphenyl (PCB) Isomers. Bulletin of Environmental Contamination & Toxicology 6:377-384(1971)

Ex. 17. Beezhold, F.L. and V.F. Stout. The Use and Effect of Mixed Standards on the Quantitation of Polychlorinated Biphenyls. Bulletin of Environmental Contamination & Toxicology 10:10-14:23:(1973)

Ex. 18. Armour, J.A. Quantitative Perchlorination of Polychlorinated Biphenyls as a Method for Confirmatory Residue Measurement and Identification. Journal of the AOAC 56:987-993(1973)

Ex. 19. Hutzinger, O. W.D.J. Jamieson, S.S. Safe, and V.Z. Zitko. Exhaustive Chlorination as a Technique in the Analysis of Aromatic Hydrocarbons. Journal of the AOAC 56:982-986(1973)

Ex. 20. Holden, A.V. Monitoring PCB in Water and Wildlife. PCB Conference II Stockholm 1972

Ex. 21. Hamelink, J.L., R.C. Waybrant, and R.C. Ball. A Proposal: Exchange Equilibria Control the Degree Chlorinated Hydrocarbons are Biologically Magnified in Lentic Environments. Transactions of the American Fisheries Society 100:207-214(1971)

Ex. 22. Nebeker, A.V., F.A. Puglisi, and D.L. DeFoe. Effect of Polychlorinated Biphenyl Compounds on Survival and Reproduction of the Fathead Minnow and Flagfish. Transactions of the American Fisheries Society 103: (3) (July, 1974)

Ex. 23. Snarski, V.M., and F.A. Puglisi. Exposure of Brook Trout to Aroclor 1254. A Summary of NWQL Research Concerning the Effects of Polychlorinated Biphenyl on Water Quality and Aquatic Life. EPA May 1973

Ex. 24. Hansen, D.J., P.R. Parrish, J.I. Lowe, A.J. Wilson, Jr., and P.D. Wilson. Chronic Toxicity, Uptake, and Retention of Aroclor 1254 in Two Estuarine Fishes. Bulletin of Environmental Contamination & Toxicology 6:113-119(1971)

DSW 315473

Ex. 25. Murphy, P.G. Effects of Salinity on Uptake of DDT, DDE and DDD by Fish. Bulletin of Environmental Contamination & Toxicology 5:404-407(1970)

Ex. 26. Sodergren, A. and Bj. Svensson. Uptake and Accumulation of DDT and PCB by Ephemera Danica (Ephemeroptera) in Continuos-Flow Systems.

Ex. 27. Annual Report Progress in Sport Fishery Research (1970)

Ex. 28. Nebeker, A.V. and F.A. Puglisi. Effect of Polychlorinated Biphenyls (PCB's) on Survival and Reproduction of Daphnia, Gammarus, and Tanytarsus. Transactions of the American Fisheries Society 103: (4) (October, 1974)

Ex. 29. Veith, G.D. and G.F. Lee. Chlorobiphenyls (PCBs) in the Milwaukee River. Water Research 5: 1107-1115(1971)

Ex. 30. Veith, G.D. and G.F. Lee. PCBs in Fish from the Milwaukee Region. Proc. 14th Conf. Great Lakes Res. 1971:157-169 Internat. Assoc. Great Lakes Res.

Ex. 31. Report to: Lake Michigan Toxic Substances Committee May, 1973. Monitoring for Polychlorinated Biphenyls in the Aquatic Environment. Report done by: Michigan Water Resources Commission, Bureau of Water Management, Department of Natural Resources, Environmental Protection Branch. Unpublished.

Ex. 32. PCB's in Lake Michigan. Unpublished.

Ex. 33. Dube, J.D. Polychlorinated Biphenyls in Effluents from Sewage Treatment Plants in Southeastern Wisconsin. Unpublished.

Ex. 34. Aulerich, R.J., R.K. Ringer, H.L. Seagran, and W.G. Youatt. Effects of feeding Coho Salmon and other Great Lakes Fish on Mink Reproduction. Canadian Journal of Zoology 49:611-616(1971)

Ex. 35. Hartsough, G.R. Great Lakes Rish Now Suspect as Mink Food. News of GLMA(Great Lakes Mink Association) pages 25 and 27.

Ex. 36. Ringer, R.K., R.J. Aulerich and M. Zabik. Effect of Dietary Polychlorinated Biphenyls on Growth and Reproduction of Mink. Papers Presented at 164th Nat'l. Meeting American Chemical Society 12:149-154(1972)

Ex. 37. Platonow, N.S. and L.H. Karstad. Dietary Effects of Polychlorinated Biphenyls on Mink.

Ex. 38. Veith, G.D., and G.E. Glass. PCBs and DDT in Fish from Western Lake Superior. Unpublished.

Ex. 39. _____ on Polychlorinated Biphenyls in Michigan Waters. June 1973. Unpublished.

Ex. 40. Puglisi, F.A. Measurements of PCB (Aroclor 1254) in Lake Superior Diluent Water During a Brook Trout Chronic Exposure. Unpublished.

Ex. 41. Bowes. Identification of Chlorinated Dibenzofurans in American Polychlorinated Biphenyls (Aroclor). Unpublished.