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Session VIII:

SUMMARY SESSION

John L. Buckley, Ph.D.
Session Chairman

DR. J. G. VOS (Rijks Instituut voor de Volksgezondheid, Bilthoven, The Netherlands). Recent findings on the biological action of PCB's, such as carcinogenicity in rodents and the disturbed reproduction in monkeys, greatly increase our concern of PCB's as a health hazard.

In summarizing the papers presented in the session on health effects, one is confronted already in Dr. Kuratsune's paper with the problem of PCB's and chlorinated dibenzofuran impurities. In the "Yusho" disease, one is struck by the persistence of symptoms present in patients, although there is a shift in the pattern, a decrease over the years in the skin lesions but a persistence of hypersecretion of Meibomian glands. In "Yusho" patients, increased urinary excretion of 17-ketosteriods was noted, as was an increase in serum triglyceride levels. Changes in the menstrual cycle were observed in a high percentage of female patients. Mean blood levels in "Yusho" patients were 7 ppb. This level conflicts with the high PCB concentrations in blood of workers who are occupationally exposed yet who, for the most part, show no indication of adverse effects.

A possible explanation for this difference was the relatively high concentration (5,000 ppm on PCB basis) of chlorinated dibenzofurans (including 2,3,7,8-TCDF) in rice oil. Apparently furans were formed in the PCB during its use as a heat exchanger, since the level of chlorinated dibenzofuran in Kanechlor KC-400 was approximately 17 ppm. Of particular significance was the relatively high concentration of chlorinated dibenzofurans versus PCB's in the liver of some patients who died, when compared with adipose tissue values. Further studies are required to solve the dilamma of the importance of furans in the etiology of "Yusho" disease; and in a wider context, to get information on possible changes in composition or concentrations of chlorinated dibenzofuran and other contaminants in used PCB's and on their fate in the environment.

During the 1971 PCB conference, there was some concern on a bladder tumor that was found in a rat by Dr. Kimbrough. Now we know that this tumor apparently developed spontaneously. But as we heard from Dr. Kimbrough, in recent studies certain PCB mixtures induce tumors in rats and mice. A spectrum of lesions are induced in livers of rats fed 100 ppm Aroclor 1260 for 21 months: hyperplastic or neoplastic nodules in 80 percent of the treated animals and in none of the controls, and hepatocellular carcinomas in 14 percent of the experimental animals and in one out of 173 controls. Metastases were not observed. However, hepatocellular carcinomas were not found in the chronic study in rats, as reported by Dr. Calandra. A possible explanation can be the small number of animals used in this study. Evidently, this question has to be solved. Hyperplastic nodules were seen in 25 to 50 percent of rats fed 100 ppm Aroclor 1242, 1254, or 1260. These three mixtures did not appear to be mutagenic or teratogenic. No-effect levels based on 2-year studies in rats and dogs and reproduction studies in rats were 10 ppm.

As reported by Dr Allen, adult monkeys and in particular the females are very sensitive to PCB's. When Rhesus monkeys were fed 2.5 or 5 ppm Aroclor 1248—that is, approximately 0.1 or 0.2 mg/kg body weight/day—skin lesions consisting of acne of face and neck, edema, and hair loss developed in some females already after 2 months. All females exhibited these changes after 6 months, but males were more resistant. Disturbances in reproduction were present in females and not in males. Menstrual cycles were irregular within 4 months. The conception rate in the 5-ppm group was decreased. Because of resorptions and abortions, the birth rate was reduced and the infants born were small. Fifty percent of them died before weaning, showing typical lesions. These effects on reproduction may be due to an estrogen/progesterone imbalance. Female rhesus monkeys on a PCB diet had increased urinary levels of ketosteriods.

By comparing the reports of Drs. Kuratsune and Allen, one is struck by the similarity of lesions present in "Yusho" patients and those produced experimentally in the monkey, with the exception of the effect on serum triglycerides. Both species seem also to be equally sensitive in a quantitative way.

Dr. Matthews studied the effect of chlorination on tissue distribution and excretion of PCB isomers in rats. Each of the PCB's studied was removed rapidly from blood to liver and muscle. Redistribution to skin and adipose tissue increased with increasing chlorine concentration, whereas elimination via urine or feces was highest with the low chlorinated isomers. After 6 weeks, 85 percent of the 2,4,5,2',4',5'-isomer was still present in adipose tissue and skin, while the residue of 2,4,5,2',5'-isomer was only 5 percent. Significant excretion occurs only after metabolism to polar compounds. The necessary factor could be the presence of two adjacent unsubstituted carbon atoms

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that facilitate the formation of arene oxide intermediates, as was also reported by Dr. Allen in his study with the 2,5,2'5'-isomers in the monkey.

Dr. Ecobichon reported on the influence of position and degree of chlorination of chlorobiphenyl isomers on the hepatic function in the rat. Substitution at the 4 and 4' positions, irrespective of chlorination at other positions, enhanced the activities of endoplasmic reticulum bound enzymes O- demethylase and aniline hydroxylase. This is probably due to their higher persistence. For enzymes less discretely localized in the liver cell, such as carboxylesterase and sulfobromophthalein -glutathion conjugating enzyme, the position of chlorine atoms appears of lass importance. Purified unsubstituted biphenyl did produce enzyme induction, though enhanced effects were noted when one or more chlorine atoms were present.

As can be concluded from the report of Dr. Biocca, biological effects of symmetrical hexachlorobifenyl isomers differ not only quentitatively but also qualitatively. Such comparative studies are necessary for the ultimate goal—that is, the understanding of the biological effects produced by complex mixtures that endanger human health, mixtures that are different from those formulated commercially. Of the three isomers tested in mice, 3,4,5,3',4',5'-HCB was most toxic, followed by 2,4,6,2',4',6'-HCB and 2,4,5,2',4',5'-HCB, respectively. Liver weights were increased by all three isomers. Severe thymus atrophy and a decrease in α- and γ-globulins were produced only by 3,4,5,3',4',5'-HCB. In a study in chickens, these isomers along with 2,3,4,2',3',4'-HCB and 2,3,6,2',3',6'-HCB were given at 400 ppm in the diet for 3 weeks. Again, 3,4,5,3',4',5'-HCB was most toxic and was lethal even at 3 ppm. Chickens exhibited pronounced edema, thymic involution, and marked liver pathology. However, chickens that were fed 100 ppm died earlier and had only mild liver pathology. The 2,4,6,2',4',6'-HCB was less toxic (no deaths at 400 ppm) but caused marked liver pathology and highest liver weight increase. The toxicological effects of 3,4,5,3',4',5'-HCB differ qualitatively from the other HCB isomers studied, and resemble the lesions produced by 2,3,7,8-TCDF.

Dr. McKinney reported on metabolism studies of HCB isomers in the chicken using low resolution mass spectrometry. When metabolites were detected, the three basic reactions were isomerization, reductive dechlorination, and oxidation with and without chlorine loss. Significant metabolites were not detected in excreta of chickens fed 2,3,4,2',3',4', 3,4,5,3',4',5'-, or 2,3,6,2',3',6'-HCB Metahydroxylation followed by parahydroxylation of the same ring are favored processes for 2,4,5,2',4',5'-HCB Further oxidation could give quinone. The presence of a metabolite with a trihydroxypentachlorobiphenyl structure indicated that dechlorination can be concomitant with hydroxylation A dibenzofuran metabolite was not detected.

In the case of 2,4,6,2',4',6'-HCB, several reaction types occurred: dechlorination, isomerization, and dibenzofuran formation This isomer had lowest effect on body weight, did not give a high liver residue, but produced most severe liver pathology despite the dibenzofuran formation. In contrast, 3,4,5,3',4',5'-HCB accumulated most in liver and fat, was most toxic with "furan"-type effects, but metabolites were not detected in the excreta. However, one has to consider in the case of 2,4,6,2',4',6'-HCB and possibly 3,4,5,3',4',5'-HCB the possibility of covalently bound metabolites that may be of toxicological significance A good correlation, which may have predictive value, was observed between the retention indices from gas chromatography with the adipose tissue concentration. An exception was the 2,4,6,2',4',6'-isomer, which had the smallest retention index but relatively high tissue accumulation. The strong ortho effect could be responsible for this discrepancy

Dr. Moore reported on the first toxicity studies with 2,3,7,8-TCDF. Marked thymus atrophy and the presence of edema are seen in chickens dosed daily with 1 μg/kg Only mild liver pathology was present at the 5-μg dose level, which produced 100 percent mortality. The LD_{50} in guinea pigs after a single oral dose was approximately 7 μg/kg body weight. In chicken and guinea pigs, 2,3,7,8-TCDF is lethal at dose levels that are less than one order of magnitude higher than that of 2,3,7,8-TCDD and share a number of biological effects. Mice and rats are more resistant to TCDF. A single subcutaneous dose of 6,000 μg/kg did not reduce body weight but gave thymus atrophy and mild liver toxicity in mice No effect was noted in rats intubated with 1,000 μg/kg body weight. Clearly, more research is needed with different chlorinated dibenzofurans isomers in order to assess their health hazards.

SUMMARY OF SESSION II

MR. DAVID GARRETT (Environmental Protection Agency, Washington, D.C.): In Session II, Dr. James Mieure, who is research group leader, Monsanto Industrial Chemicals of St. Louis, spoke of PCB's, their properties and mixtures, and presented physical and chemical properties of commercial Aroclor products.

Dr. Stephen Safe, Associate and Professor, Department of Chemistry, University of Guelph, Ontario, presented an overview of analytical identification and spectroscopic properties. Key among the points stressed were that sophisticated methods and equipment are available for identification and quantification of PCB's at extremely low levels.

Dr. Robert Durfee, Vice President of Versar, Inc., presented topical information on the manufacture and uses of Aroclors in the United States and also gave a vivid description of the use of Aroclors in the manufacture of closed electrical systems—in particular, capacitors and transformer products. In addition he presented an overview of PCB's uses in investment casting waxes and the casting process itself was reviewed.

Thomas E. Kopp of the Office of Toxic Substances in the Environmental Protection Agency reviewed past, present, and possible future regulatory activities of EPA concerning PCB's in the water environment. He discussed proposed voluntary standards being prepared by NEMA, ANSI concerning labeling and safeguards for handling askarels and askarel-containing equipment.

Then, Mr. Stanton Kleinert, who is Chief of Surveillance for the Wisconsin Department of Natural Resources, discussed sources of PCB's in the State of Wisconsin, emphasizing the probable role of intermedia transfer from air to water and describing some possible sources of contamination for food and water.

And lastly in this section, Mr. John Hesse, Supervisor of the Toxic Material Unit, Department of Natural Resources in Michigan, described uses of PCB's and losses to the environment of Michigan. Mr. Hesse also emphasized PCB losses to air and the probably significant transfer of these PCB's into the water medium. Data was presented on PCB concentrations in municipal treatment effluents and sludges, which undoubtedly contributes to the continuous cycling in the environment of these persistent pollutants.

Some of the salient points generally brought forth in the meeting either presented or implied were that PCB losses to air could be an important contributor to the problems we encounter in water. Disposal of PCB's waste to municipal sewage treatment does not necessarily curtail the cycling and environmental damage from PCB's. And undoubtedly there should be a greater sense of accountability among users of PCB's and a closer control of inventory.

Additionally, there is presently no corrective U.S. authority which could regulate importation of PCB's and PCB-containing products, nor other serious environmental contaminants which are not pesticides, drugs, and the like.

And lastly, judging from estimates of PCB's already contaminating the environment and its inhabitants, the task of cleanup is monumental, even if we had proven technology with which to accomplish this task. Thank you.

SUMMARY OF SESSION III

DR. IAN C. T. NISBET: Eleven major points came out in the course of our session on transport and accumulation of PCB's in the environment.

1. We know almost nothing about chlorinated dibenzofurans, except that they are present in Aroclor 1242 and 1254, and we learned during Session I that they are formed in use and they are formed by metabolism. We know nothing whatsoever about their subsequent behavior in the environment.

2. PCB's themselves remain universally distributed in the environment. Although some releases have been curtailed, other releases continue. These include releases from manufacturing, leaks from supposedly closed systems, scrapping of PCB's manufactured before 1971 and of materials containing them, and use in nonclosed systems of material that

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is either imported or diverted from other uses.

3. Surprisingly large quantities of PCB's which match Aroclor 1254 or 1260 are still being found in air and in dry fallout and precipitation. It is difficult to account for these quantities in terms of known past uses, and accordingly we may have to look for a significant current source of air emissions. Perhaps this may be air emissions from transformers, or disposal of scrap materials from them.

4. There is circumstantial evidence that PCB's that are now trapped in large quantities in sediments in lakes, rivers, and estuaries will remain available for resuspension and will continue to move slowly downstream. We do not have any precise information about their persistence or about the time it will take them to move downstream into the sea, but we believe that it is to be measured in years, if not decades.

5. Although PCB levels have decreased considerably in some components of the environment such as terrestrial birds or the mussels collected off California, as yet there is no clear indication of a consistent decline in PCB residues in fish. We should not expect a rapid decline, because of the long retention time of PCB's in the environment and in human tissue.

6. In addition, many items containing PCB's have service lives of 10 to 20 years before they are discarded, so that we are still experiencing releases of materials manufactured before 1971.

7. Because of time lags in response we may not yet have reached peak levels in some compartments in the environment. I am thinking here particularly of estuaries, where levels of PCB's may continue to increase as sediments are transported downstream.

8. Most human exposure to PCB's in the diet is via fish, although there is some human exposure via other routes, such as milk, meat, and by inhalation in the air. The information from the FDA total diet program suggested that the dietary exposure of an average adult in the United States is of the order of 10 micrograms per day. However, an average for PCB's has little meaning because of the very wide variations in individual consumption of fish and enormous variations in the contamination levels.

9. Individuals who have a dietary preference for freshwater fish will take in much more than the average—in some cases at least a hundred times as much as the average. Breast-fed infants appear to have extremely high dietary intakes of PCB's, averaging about 50 times higher than that of their mothers on a milligram per kilogram basis. The breast-fed infant appears to be one of Dr. Kolbye's special consumers who is imprudent enough to eat the same diet every day.

10. Monitoring of PCB residues in human fat in the United States and Canada shows that the median PCB concentration is of the order of 1 ppm. Again there are enormous variations, at least a hundredfold variation between the highest level recorded and lowest level detectable

11. Finally, although tetrachlorobiphenyls are more easily degraded in the environment than pentachloro- or higher chlorinated compounds, the tetrachlorobiphenyls are nevertheless accumulated and retained by fish. Accordingly there are significant human intakes of tetrachlorobiphenyls, even though they are not retained in significant quantities in human tissues. Therefore, release of either Aroclor 1016 or 1242 into aquatic systems will lead to some human exposure to tetrachlorobiphenyls.

SUMMARY OF SESSION IV

DR. DONALD I. MOUNT (Environmental Protection Agency, Duluth, Minnesota): Among and between the birds, mammals, and aquatic organisms there are marked differences in sensitivity to PCB's. Even so, these differences are not large when compared to species differences found for other pollutants. Likewise, there are differences in the toxicity of various Aroclors and isomers of PCB's that are real but not large.

While increasing chlorine content increases toxicity in warm-blooded animals, increasing chlorine content decreases toxicity of PCB's to aquatic animals. This observation is exceedingly important in determining the future actions to be taken on PCB's. Increased chlorine content seems to increase biological half-life and bioconcentration in all animal groups, but the evidence is not entirely clear cut on this point.

To generalize, we can say that in most cases acute lethal toxicity in birds and mammals occurs from 10 to 100 ppm in the food, while more sensitive species may suffer death from 1 to 10 ppm in the food. Concentrations of about 5 ppm in bird eggs produced death. And concentrations of PCB's from .5 to 5 ppm in food produced reproductive or growth effects. For aquatic animals, water concentrations of 10 to 100 micrograms per liter are acutely lethal. Concentrations of 1 to 10 micrograms per liter produced chronic reproductive or growth effects and water concentrations of 1 to 10 nanograms per liter (ppt) produced residues of biological or public health significance.

Direct uptake from water into aquatic organisms is very significant and appears to produce concentration factors on the order of one hundred thousand or more times. Water uptake supplemented by food intake results in concentration factors of five hundred thousand or more times.

The metabolic pathways, biological half-life, and selected isomer concentrations appear to be different, especially between cold-blooded and warm-blooded animals and for various mixtures and isomers of PCB's. Enzyme systems of poikilotherms are vastly different among the various groups and are also different from the enzyme systems of the homeotherms.

Measurable harmful effects of PCB's in the environment on organisms are not abundantly documented, and for the most part the effects that have been found are limited to subtle ones except for specific instances such as in mink and certain bird populations. Based upon laboratory toxicity data and contamination levels found in the environment, one would predict only subtle effects to occur. This is not to say they are not significant.

The greatest concern continues to be residues as they affect the organisms carrying that residue—especially in the eggs and sex products—and as they effect the higher consumers. Apparently water concentrations will have to be kept in the range of .1 to .5 nanograms per liter if unacceptable residues are to be avoided. And the evidence to date is unconvincing that 1016 is an acceptable substitute as far as aquatic organisms are concerned.

SUMMARY OF SESSION V

DR. NICHOLAS A. ASHFORD (Massachusetts Institute of Technology, Cambridge, Massachusetts): While the effects of PCB's and their possible control are being pursued it is quite necessary and natural that development of substitutes and their economic and health implications also be examined. In what follows, my purpose is to summarize the conference section dealing with economics and substitutes for PCB's. I shall present the summary in an order different from that in which the participants appeared, so as to follow a logical sequence most meaningful to the substitute issue. Duncan McArthur from the Foster Snell operation presented an analysis of the PCB case which was part of a larger study (called "the Snell Report") of the probable effects of a Toxic Substance Control Act. In the PCB analysis, they addressed the direct and secondary impact of a complete banning of PCB's in the absence of technological breakthroughs and new substitutes. They postulated this prohibition would be effected over a period of 76 months, 38 months of which would be consumed with hearings and the promulgation of standards, with 38 months remaining for the technological response to eliminate the use of PCB's. The analysis focused on transformer and capacitor manufacturing having a volume capacity of 45 million pounds in 1973. On this basis, they calculate a one-time cost to society of $13.7 million, $8.8 million of which would effect the secondary users. Thereafter, an annual cost of $110 million per year was anticipated, of which $16.5 million fell upon primary users and $93.3 million on the secondary. There was no detailed examination of the health and economic benefits to be derived from a banning of PCB's.

Dr. Dale Hattis from MIT's Center for Policy Alternatives reported on an examination of both economic and environmental health changes that may have occurred as a result of the past partial withdrawal of the product from commerce by Monsanto. One of the factors covered was the increase in fire insurance premiums, estimated as possibly in the tens of millions of dollars and which presumably represented the increased risk as viewed by the insurance industry. It is important to note that the methodology was restricted by the availability of information on the nature of substitutes. This points out the complication of trade secrecy and proprietary information, which, while presumably legitimate for other reasons, does complicate the assessment of costs and benefits.

Two surprises appeared in the study. One had to do with the use of PCB's in paint systems. It was noted that a major group of substitutes evolved which were more economical than the PCB's which they replaced. This evidences a common inertial resistance to technological change even when it could be anticipated to be more beneficial (in a strictly economic sense) than technology already in use. A secondary benefit which should result from the decreased use of PCB's is a reduction in the threat to sport fishing. A calculation of recreational value could be very large even compared with the alternative recreational activities which occur as second best choices on the part of sport fishermen. The enormous size of the valuation inferred for sport fishing makes it easily the largest of the defined costs of unrestricted PCB disposal.

A third participant, Richard Rollins, spoke for the Electronic Industries Association, which is concerned for the manufacturers and users of capacitors. He cited the issues of flammability and reliability, and he urged the development of less toxic substitutes. This latter remark was consistent with one very clear message embodied in remarks by the group, namely that his industry was much more concerned with the environmental consequences than cost increases in the product. He stated that there are no commercially available substitutes in AC capacitors, including the substitutes presented at this meeting, which are acceptable for safety and reliability. One interesting point made was that since the components of capacitor-grade PCB (Aroclor 1016) are not what are found in the environment, protection of the environment might not profitably be served by attacking the issue of capacitor use and disposal. It appeared to him that PCB contamination must be coming primarily from some other industrial source.

Dr. E. J. Inchalik for Exxon Chemical reported on capacitor substitutes based on diisononylphthalates with a flashpoint of 430° Fahrenheit and which are essentially already developed, but not yet fully proved and tested for health and environmental effects.

The Prodelec operation from France presented an approach which is an incremental modification of previous technology. For transformer use, they recommend keeping trichlorobiphenyl in mixtures with chlorobenzene. Both compounds of course, being chlorinated, have problems in that regard. Secondly, for capacitors they propose a mixture of dichlorobiphenyls and their alkylated derivatives, a commercial mixture of which is called chloralkylene. These products are now being examined by an institute in Bonn for environmental behavior and he indicates that tests already show there is more biodegradation and lower toxicity for these compounds than for their PCB counterparts.

Mr. David Wood from Monsanto Company described two new products, MCS-1238 and MCS-1588, for capacitor usage. He warns that neither is fire resistant although they have much better environmental characteristics. Their degradation is more rapid and their accumulation potential in the environment is considerably reduced. Occupational and environmental health considerations indicate a better product with lower acute toxicity. He also announced that they do have candidates with intermediate fire resistance between PCB's and mineral oil, but did not elaborate on this further.

Dr. Dean Branson from Dow Chemical Company announced a substitute for use in power capacitors. This compound is called XFS-4169L and is a butylated monochlorodiphenyl oxide. Once again we find that a substitute is like the original, a chlorinated compound. Its properties are worth noting however. Dielectric losses are lower or slightly lower than for capacitor-grade PCB, while the discharge inception voltage is significantly higher. The size or volume per unit of high-voltage power factor correction, called kVAR, is about that of the PCB counterpart, which means that no redesign is necessary for capacitors. There is little fire and explosion risk indicated by comparing the flashpoints and firepoints of PCB and XFS. The flashpoint for PCB is 166° centigrade, for XFS 174°. The firepoint for PCB is greater than 316° centigrade, while XFS is 199°. This substitute is reported to be more reliable and is anticipated to have a reasonable long-term price. The increased expense is estimated to be less than $20 for a 200 kVAR unit. The capacity in the first quarter of 1976 should be in the range of 1 million pounds per year, and a multimillion pound per year volume capability is estimated by the end of 1976. This substitute is more biodegradable by a factor of 45 and the bioconcentration is 30 times less. There is little toxic activity in acute and in 90-day tests, although longer-term tests need to be carried out. The accumulation in fat is 22 times less. The toxicity in fish is on the order of 20 times less than for PCB's.

carried out. The accumulation in fat is 22 times less. The toxicity in fish is on the order of 20 times less than for PCB's.

Perhaps the most exciting substitute for use in transformers was announced by Dow-Corning (represented by Richard Montgomery). He indicated that the global silicone industry had been looking for a replacement for the transformer fluid PCB's for 5 years, and the technology was now developed for the new fluid. It was to be commercially available in 1976 and had no known environmental problems. Commercial production was available to handle the global market. In the United States there has been field-testing for 4 years and the product is now ready to be used. The product is called Q2-10 90 dielectric fluid, and is a dimethyl silicone which has been used in the military, in Japan, and in a small experiment in Midland, Michigan. He pointed out that this was not very dissimilar to "di-gel," which is used of course for human consumption. It is less flammable than many PCB's with low heat of combustion, high flashpoints and firepoints, and the product is self-extinguishing in case of ignition by violent transformer breakdown. Insurance companies have OK'd the substance for use indoors. The cost is higher than PCB's but "not outrageous," giving rise to an estimated cost increase of about 6 percent in the transformer equipment. Of course, the fluid itself is more expensive, with a higher percentage increase in cost. PCB transformers now in service can be retrofitted and he believes that the economics are favorable enough to stimulate competition. It is worthy to note that unlike the trade industries representing the capacitor users presented at the conference, there was no transformer user or producer represented. It would be interesting to see what General Electric's viewpoint would be on the potential use for this transformer fluid substitute since they have the capability to manufacture silicone fluids. Their absence at the meeting might leave one with an unwarranted optimism for the use of these fluids in transformers. One further reflection is that we are badly in need of a frank assessment of flammability risk requirements since the substitute products vary in their flammability over the great range between mineral oil and PCB's. It is not clear what tradeoffs should be made between the fire risks and the safety risks in the industrial setting and the possible damage to humans from substitute products which might get into the environment. It is also not clear that PCB's flammability characteristics should remain the benchmark for compliance although the insurance industries may see this differently.

SUMMARY OF SESSION VI

MR. CHRISTOPHER M. TIMM (Environmental Protection Agency, Region V, Chicago, Illinois): From a very broad mixture of topics and points of views that we were listening to last night, I believe the following four points should be emphasized.

First, on top of all the human health and wildlife effects that have been documented and thoroughly discussed, PCB's are having a definite and drastic effect on the livelihood and future of the freshwater fishery and fishermen. This is a very real problem to the people in various parts of the continent and they see no improvement in the near future.

Second, a ban on PCB's and better control of other toxic substances to protect our natural resources is long overdue. However, the actions of the regulatory agencies such as EPA and FDA must be based on scientific fact in the overall impact on the nation.

Third, universally there is a belief that the governmental bodies and agencies for whatever reason are far, far too slow in solving environmental problems like PCB's. This is a frustration to everybody.

And finally, there is a need to find some way to compensate the people like fishermen whose livelihood is impacted by environmental pollution which is PCB's. They do not cause the problem, they cannot control the problem, and they often cannot find anyone to blame or even talk to about it. But they suffer the consequences of decades of incomplete evaluations and testing of new compounds. Thank you.

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SUMMARY OF SESSION VII

MR. CHARLES N. GREGG, JR. (Environmental Protection Agency, Washington, D.C.). Because most of you have heard the discussion this morning, I will try not to repeat it, but to provide some insights and perhaps some of the highlights. I will not try to give equal time to the various speakers.

First, there is an obvious distinction between physical and technical methods of control, which have been discussed in other sessions, and the regulatory and voluntary actions for achieving those controls that were discussed by this morning's panel.

Second, there is a distinction between the direct control of human exposures as, for instance, through limitations on PCB's in fish that can be sold for human consumption, and limitations on use or limitations on emissions into the environment, which in the long run contribute to diminished exposure. In our present situation, as you were told by the speakers this morning, there are a vast number of Federal agencies with roles. Our Government and the Canadian Government both contribute to solutions of the Great Lakes problem. We have a lot of State Governments with roles to play. One of the major problems will be sorting out roles, and finding adequate cooperation in performing those roles, among the several agencies and units concerned.

A further complication is that both in Canada and here we not only have a number of regulatory authorities now, but in each case we are looking for additional authority which it is anticipated will permit much more finely applied solutions. And at the same time that we plan for the future, we do not know for certain what authority we will have available for use.

One observation I made was that there seemed to be very little real optimism. If we applied all our available resources and used all of our authorities as best we could, we could solve in any short time frame the most pressing problem, which appears to be the high levels in fish in a number of places where they are caught and consumed in substantial quantity. This lack of optimism did not, nevertheless, suggest to the speakers that we should not take action. Everybody seemed to agree that it was appropriate to move ahead as best one could with the full range of authorities and voluntary programs available.

Also, there was considerable emphasis on nonregulatory action, and increasing communication with people who have the opportunity to affect the flow of PCB's first from industrial situations into the environment and thereafter within the environment to locations where they can lead to higher human and environmental exposures. In my view, a voluntary program seems to present a very great opportunity for improvement, perhaps much greater than a strictly regulatory program in the light of some of the difficulties experienced in using our current authorities.

Relatively less, it seemed to me, was said by this morning's speakers about just how to control PCB's, particularly how to control, through regulation, those PCB's which are currently in industrial use or elsewhere in products but not yet released generally to the environment. There was some reference to controls over disposal, but to my best recollection, there was no indication that we had any directly applicable authorities with respect to disposal.

Let me touch on a couple of this morning's highlights. Dr. Ahmed of the NRDC asserted that the government had failed to carry out its responsibilities adequately, particularly under Section 307(a) of the Federal Water Pollution Control Act. He felt that we had a schedule on which we should have produced regulations a couple of years ago, with compliance a year ago, and he criticized EPA's lack of attention and priority to toxics in our Water Pollution Control program. He made several recommendations: a phaseout of the manufacture and use of PCB's, a ban on exports and imports, development of an inventory of point sources, additional monitoring in fish and elsewhere, a moratorium on river bottom dredging until we have better indications of the trouble we stir up, effluent standards that would allow us to arrive at 1 ppt in water, lower FDA tolerance levels, and the passage of the Toxic Substances Control Act.

Mr. Wessel of the Food and Drug Administration referred to its action in 1972 and 1973 to set tolerance levels, indicating that various concerns had to be balanced in setting levels under Section 406 of the Food, Drug, and Cosmetic Act. He indicated that FDA was examining the current tolerance level in fish and considering whether or not to lower it. He said that there would be adequate opportunity for public comment on any proposal that was made. But he felt that this would not solve the PCB problem and it would not necessarily prevent consumption of fish with high levels of PCB's by private fisherman.

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Dr. Kolbye of FDA added a discussion of some of the problems in setting tolerance levels, and something else I thought was significant: that steps are particularly needed to identify where PCB's are located so we can look to their proper disposal, and education to this end is needed. He did feel that the average consumer is fairly well protected against PCB's by the current tolerance level, but acknowledged that there would be higher exposures in some cases and that this was not a concern to pass over lightly.

Mr. Barber of the Environmental Protection Agency, after talking about some of our authorities and programs we have undertaken so far, gave considerable attention to some of the realities involved in EPA decisionmaking: the complexity and implications of taking various regulatory courses, and the fact that there are limited resources in EPA, particularly people, to handle a wide array of regulatory responsibilities. He pointed out the importance of the State role, and indicated that the Federal Government's role can best be viewed as one way of encouraging the State to find ways to perform a great deal of the regulatory and enforcement activity. He felt that regulation must represent some sort of consensus and be enforceable in order to be productive. He felt that a number of PCB problems were difficult to control because of the numbers of nonpoint sources.

He urged that we try for more awareness among the people who use PCB's, particularly the utilities, and suggested voluntary labeling and use of the planning process under Section 208 of the Federal Water Pollution Control Act.

Secretary Reed described both the environmental problem caused by PCB pollution and the resulting fisheries resource problem. High investment in restoring the Great Lakes fishery and future investment in this and other fisheries would be hard to justify unless we can control the PCB situation. He suggested particularly that since we find great reductions in DDT and mercury as a result of regulation, it would certainly be worth a try to see if we can reduce PCB levels in the water and in fish by taking all of the regulatory steps we now can. He endorsed the Toxic Substances Control Act, and suggested we cut off the importation of PCB's.

Dr. Rhoden outlined the plans of NIOSH.

Mr. Billy of the Marine Fisheries Service indicated their environmental, consumer, and public information concerns. They recommend not lowering the FDA level until there has been a sound attempt to understand the course to be followed, and the avoidance of unproductive and unnecessary adverse publicity.

Mr. Grella of DOT briefly described their incipient program to apply DOT authorities to PCB's, though not much has yet been done.

The Coast Guard has a number of functions under the Federal Water Pollution Control Act in the event of spills, but the Coast Guard representative told us that until we in EPA have designated PCB's as a hazardous substance, the Coast Guard is unable to go forward to use its authorities. He urged public awareness of the needs for good handling and precautions in transportation.

Dr. Millson of the Canadian Government urged a systematic approach, and outlined six regulatory control packages that Canada was considering. He emphasized that Canada does not have a use control act yet, but that such authority together with their other authorities would permit them over some period of time to do a great deal about controlling PCB's.

Since Dr. Highland spoke last, and I have exhausted my time, with apologies to him I hope you remember what he said.

CONFERENCE HIGHLIGHTS

Richard A. Carpenter*

A summary of this complex and comprehensive conference may be more useful if the information is organized in the format shown in the accompanying figure (figure 1). The presentations have dealt with three general topics:

A. The occurrence of PCB's in the environment—sources, rates, routes, and sinks;
B. The toxicity of PCB's—inadvertent human exposure, laboratory animal experiments, wildlife, fish, and ecosystems;
C. The uses and benefits of PCB's to industrial society and the possibilities of control.

In each topic, information can be characterized as to:

1. What is known and generally agreed upon with a reasonable degree of confidence.
2. Remaining uncertainties and the reasons why a lack of understanding continues. Science is probabilistic in nature and this concept of uncertainty must be recognized when technical information is used in deciding issues of public policy.
3. Finally, the conference discussions have suggested some courses of action which are pru-

	A. Occurrence in the Environment	B. Toxicology	C. Uses, Benefits and Control
1. What is known			
2. Remaining Uncertainties			
3. Prudent Actions			

Figure 1. Organization of information about polychlorinated biphenyls.

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dent, i.e., could and should be set in motion. These include setting priorities for obtaining more information and reducing uncertainties through additional research and monitoring.

The conference was not designed to produce consensus judgments or to make recommendations. Thus, the following summary must be viewed as the responsibility of the author alone.

A-1 What is known about the occurrence of PCB's in the environment

We have learned what should have been apparent from the start—that any persistent, mobile, and foreign or exotic compound is going to be detected everywhere in the environment. In addition to current production and uses, which may result in leaks, a nonpoint source situation exists in that about 400 million pounds of PCB's are already discarded in the environment and substantial amounts are apparently recirculating in sludge, sediments, in air and dust, and in contaminated organisms.

There are about 300 million pounds in industrial service and this material will be difficult to contain completely as it moves toward disposal. The sediments in lakes, rivers, and estuaries provide a very large reservoir of PCB's for contacting aquatic organisms. The material in dumps (three-fourths of the total discarded) appears to stay there for the most part. Current processing losses are important and can be decreased.

Eventual removal is to sediments in the deep ocean and we need to know more about the fate of this material in the marine environment.

It is too early to see the effects of the 1972 voluntary action to limit uses to nondispersive applications, but certainly it was a justified decision and a move in the right direction.

There will be occasional catastrophic spills which can cause substantial damage to fisheries in the future. These will be localized impacts, and will be costly to clean up.

Incineration is an effective method of destroying PCB's if the temperature is high enough (i.e., about 2,700° F).

Analytical procedures now give confidence that we can measure PCB's qualitatively and quantitatively down to a few parts per trillion.

A-2. Uncertainties about PCB's in the environment

There is a real question as to whether the PCB content of the waters of the Great Lakes (particularly Lake Michigan) can be lowered by any degree of tightening-up of the current use situation, because of the recirculating contamination that is already there. There is the question as to the role of air transport and the recirculation of material that is deposited in rain or in dust back into the air so that it is continually redistributed around the world. The composition change of PCB's in the environment with aging is not well understood; there are questions as to their chlorine content changing and regarding formation of diobenzofurans.

We need a mass balance and a model for transport and removal in order to estimate the time that will be required for these materials to eventually move to an ultimate sink in the deep ocean sediments

A question has been raised as to the possible conversion of these materials into higher chlorinated compounds during sewage chlorination.

We need to know more about the presence of the materials in whole water; i.e., are we measuring material on suspended sediments, in very small organisms, in micelles, or actually dissolved in water? We need to know about the biological activity of these various forms of occurrence of PCB's in water.

A-3. Prudent actions

What can we do based on this information and uncertainty? We can separate, to some extent, the problem of what is already in the environment from the control of material that has not yet been released. Even if all manufacture and use were stopped immediately, environmental contamination would remain for some time to come. The PCB problem should be considered in the context of other halogenated hydrocarbons in the environment and it should not be separated from investigation and control of the residues of pesticides and other halogenated materials. Work should begin on a more systematic monitoring system and on the use of indicator organisms, such as the suggested "mussel watch," on a worldwide basis.

We can use some ingenuity in devising means of cleaning up contaminated water. This problem is of a magnitude that allows one to think about filtration or adsorption concepts for waters that are somewhat confined.

Ingenuity may suggest ways to make contaminated fish suitable for use in animal feeds or human consumption. Perhaps segregation of certain organs or particular methods of cooking would serve this purpose, or some other way of decontaminating these valuable animals might be found.

B-1 What is known about toxicity

The Yusho incident proved the toxicity of used heat transfer fluid to humans at a concentration in cooking oil of about 1,000 ppm of PCB's. But interpretation of this incident is confounded by dibenzofuran contamination of the PCB fluid. Industrial hygiene experience is somewhat reassuring as to toxicity to humans except that the occasional symptoms and illnesses cannot be related to known exposure doses in most instances The good housekeeping practiced by some large users and the American manufacturer will probably be better than that of the variety of secondary users. No human deaths have been caused directly, but reports of serious illness and persistent skin problems continue.

Exposure of the general public can be controlled by avoiding food (mainly fish) contaminated with PCB's. Exposure from environmental contamination or direct introduction into humans is unlikely. Averages for dietary intake can be misleading since some persons may eat large quantities of fish.

Laboratory animals show effects when fed diets containing contamination levels found in fish. Fish are affected at the range of PCB levels found near industrial outfalls into ambient waters, and the occurrence of fin rot in fish near these "hot spots" is a direct confirmation of laboratory tests as to the effects on fish.

Ecosystem simplification (fewer species and lower populations) has been found in laboratory experiments to occur at concentrations similar to those in hot spots in natural ambient waters and could be expected to be found at sludge disposal sites. It is hard to find evidence of damage to terrestrial ecosystems. Biomagnification, i.e., the ratio of the PCB content in aquatic organisms to that of the water in which they live, can be as high as several hundred thousand.

B-2. Uncertainties as to toxicity

There is confusion over the interpretation by pathologists of organ damage. It would be helpful if the highly technical problems of ascertaining carcinogenicity could be worked out by those scientists involved apart from the complexity and emotionalism of a specific issue such as the PCB problem. The effect of dibenzofurans, which may be present as impurities or as metabolites, is still in question.

There is a great variation as to the response of different species in laboratory animal tests. The range of sensitivity is large. More needs to be known as to whether the reproductive problem is the most important effect. Fat metabolism is not well understood and since a great proportion of the human population is carrying around a few ppm of this material, we need to know more about it.

Wildlife toxicity data is poor and we need to know which wildlife species may react as do chickens and mink.

The relationship of toxicity to chlorine content of the PCB's is uncertain. Is the ability to metabolize these compounds (which varies with the chlorine content) desirable or not? The possibility of dioxin as a degradation product has been raised. We need to know about the equilibrium distribution of these materials between fish and water. Is it possible that depuration can be a help? Are PCB's further accumulated up the food chain after the biomagnification from water to the first organism?

B-3 Prudent actions based on toxicity knowledge

Certainly more experimental work in animals and careful replication of reported tests are necessary. Priority should be given to chronic tests in various species, detection of behavior change in animals, and laboratory work at true environmental levels, rather than to greatly increased levels of dose. Obviously it is of great importance to determine unequivically whether the PCB materials are carcinogenic.

We need to coordinate this work with experiments and observations on other halogenated hydrocarbons, particularly the chlorinated hydrocarbons, and to look at combined effects on organisms, communities, and ecosystems.

NIOSH should extract the maximum from industrial hygiene data because these human exposures do not necessitate the inferences from animal tests to human toxicology.

The widespread occurrence of PCB's in the environment constitutes an inadvertent experiment on human populations and the biosphere. A concerted effort at monitoring and analysis is indicated in order to gain the most useful knowledge for further decisions concerning toxic substances at low levels in the environment.

C-1. What is known about uses, benefits, and control problems

We know that about 700 million pounds of PCB's have been manufactured, but the current annual production volume is down to 40 million pounds from an 80 million pound level in 1970. About one quarter of present production is going into small capacitors that are scattered very widely throughout our industrial society.

The fire retardent benefits of PCB's are real and important. An abrupt change in the availability of PCB's would be disrupting, but that is unlikely in any event. The estimate of 76 months to reach an end to manufacture if the Toxic Substances Act existed today suggests that industry will have a substantial transition period. Forty-five years of use has imbedded PCB's in U S industrial practice and it will be costly to replace these unique materials. Alternative dielectric fluids are on the way, but will not be suitable as replacements in existing transformers.

C-2. Remaining uncertainties

The decision by Japan apparently to move further to eliminate these compounds is a real challenge in the public mind to the regulatory policy of the United States If that Nation can do without PCB's, why cannot we?

Is a total ban worldwide necessary in order to reduce and eliminate contamination to the North American environment? An inventory of PCB's in existence is required and this must be international We need to know more about the changes in PCB's in use, i.e., dibenzofuran formation. How nondispersive are "closed" electric systems?

We need to reconcile the differences in human food tolerance limits as established by the United States (5 ppm) and Canada (2 ppm) and in alternative proposals from various protagonists on all sides of that question.

Cost/benefit analysis will not be very helpful in the PCB contamination problem because of the great number of subjective judgments and different value systems involved in arriving at a balance. In any event, the marginal costs and the marginal benefits are what must be determined.

We need to know how to remove PCB's from wastewater, i.e., what would be best practicable technology economically achievable in order to get to an effluent standard, and whether that should be 5 ppb, or zero, or what level. We need to know whether 1 ppt is a reasonable ambient water standard in view of the large biomagnification factor

C-3. Prudent actions

EPA has a responsibility to determine priorities and it needs to review the PCB issue in terms of the total set of pollution problems and the agency's resources. EPA should proceed with effluent standard possibilities in Section 307 of the Water Quality Act (PL 92-500), although such action may end up in court tests. The Endangered Species Act may be a means of cooperative action by other Federal agencies.

Voluntary housekeeping by industry can be increased to a substantial extent, but this requires special attention to the weakest firms, always a problem with voluntary cooperation.

Payment of compensation to fishermen may require an act of Congress similar to the experience with heptachlor in milk some years ago

It is my personal opinion that the inadvertent and unavoidable addition of PCB materials to foods could be covered by the Delaney Clause if they are found to be carcinogenic in appropriate animal tests.

This conference has addressed a real problem and was not just a demonstration of the prowess of analytical chemistry. However, as with any environmental management issue, the PCB problem must be put in perspective.

PCB's will be in the environment for a long time Fisheries resources in some of the Great Lakes and rivers have been lost. We can protect against any imminent hazard to human health. Ecosystems are resilient but local damage has occurred. Further leaks from the industrial system must be prevented. Internalizing costs will lead the market to produce replacements for PCB's Human health is most important but environmental quality is a reflection of the ecosystem that we all share. In this case there may be a coincidence, in that if we protect human health adequately, we will have protected the environment.

All elements of society are in this together and recriminations are not very helpful. Scientists and engineers can generate and deliver information for rational enforcement decisions, searching for equity as the inevitable tradeoffs are made. Verified technical facts and their implications must be communicated efficiently to the public through education and information programs Most importantly, we must use our ingenuity in solving little parts of the problem when they are all that can be solved as well as in working on an ultimate solution for the problem as a whole.

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16. ABSTRACT

The objectives of the conference where to bring together the latest data and best available expertise to help clarify the problems associated with the manufacture, use and disposal of PCBs ... help assess the effectiveness of steps taken to reduce the problems associated with PCBs ... provide a platform for interested parties to present previous neglected data concerning PCBs ... help clarify the feasibility and complications of steps to reduce the problems associated with PCBs.

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