POLYCHLORINATED BIPHENYLS

A PRESENTATION TO THE

ONTARIO HYDRO ELECTRIC COMMISSION

CANADIAN INTERDEPARTMENTAL WORKING PARTY ON PCBs

CANADIAN CAPACITOR AND TRANSFORMER MANUFACTURERS

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by

MONSANTO CANADA LIMITED

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HISTORICAL SUMMARY OF PCB ENVIRONMENTAL ISSUE

By

W. B. Papageorge

Polychlorinated biphenyls have been commercially available for over 40 years, and, as many of you are aware, are produced worldwide in many of the industrially developed nations.

As with many industrial chemicals, early studies to determine the toxicity properties of these materials were designed to provide the appropriate information to guide the manufacturers and users in its proper handling, storage and shipping. This understanding of the polychlorinated biphenyls resulted, through the years, in a remarkable record of very few incidences of human exposures resulting in observable effects. In each reported instance the existing evidence indicated that improper industrial hygiene practices were being followed.

During the late 1950's and 1960's increased interest in the presence and effects in the environment of chlorinated hydrocarbon pesticides resulted in the development of sophisticated analytical methodologies with capabilities of detecting these substances at extremely low levels of concentration.

In the use of gas-liquid chromatography for the determination of DDT and its metabolites, investigators were puzzled by the presence of response peaks which could not be identified. Generally, these peaks were ignored, and, in some laboratories, they were considered as possible metabolites of DDT.

In late 1966, Drs. Jensen and Widmark, Analytical Chemistry Laboratories, University of Stockholm, identified these peaks as polychlorinated biphenyls and claimed to have found these materials in many foods, human milk, infant hair, pine needles and in feathers from a mounted eagle in a museum. The results of this study were published in 1967.

During 1967 other investigators, using Jensen's method, established the presence of polychlorinated biphenyls in samples from the environment. By late 1967 and early 1968, presence in the environment was fairly well established, but in many instances could not be explained. All of the early reports indicated that the polychlorinated biphenyls being identified represented mixtures of the higher chlorinated isomers.

At this point, Monsanto launched a multi-point program aimed at obtaining more information about polychlorinated biphenyls and their presence and impact on the environment. This program included the following:

1. Develop analytical methodology
2. Conduct biodegradation studies

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3. Conduct animal toxicity studies

4. Develop alternative materials for PCB applications

5. Develop a program for the recycle or proper disposal of scrap polychlorinated biphenyls

6. Develop a continuing program of informing our customers of significant developments

7. Cooperate fully with industrial, governmental and academic laboratories

Studies performed throughout the world have resulted in the following findings:

1. The presence of polychlorinated biphenyls in the environment has been confirmed.

2. Some isomers of polychlorinated biphenyls are more resistant to degradation than others.

3. The early claims indicating that PCBs result in widespread thinning of eggshells in wild birds have not been confirmed.

4. Massive fish kills attributed to PCBs have not been confirmed.

5. Biological magnification in the food chain does occur.

6. Some species of marine and wildlife are very sensitive to low levels of PCBs, e.g. brown shrimp, some species of fish, invertebrates, mink.

7. PCBs identified in samples obtained in remote areas represent the higher chlorinated isomers. Samples obtained near a source of the commercial material contain the lower chlorinated isomers.

8. High doses of polychlorinated biphenyls present in rice bran oil resulted in the presence of toxic effects in over 1,000 Japanese.

9. The effects of chronic long-term, low-level exposure to humans has not been established.

10. High levels found in human food and animal feeds are traceable to known sources.

Because of its presence in the environment and indicated effect on some species of wildlife, coupled with the concern regarding

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the effect on humans of low-level, long-term exposure, Monsanto voluntarily instituted a worldwide program for terminating the sale of polychlorinated biphenyls to those uses in which control of escape to the environment was impractical.

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ASSESSMENT OF THE BIOLOGICAL PERSISTENCE OF POLYCHLORINATED BIPHENYLS

By Dr. E. S. Tucker

Presented by W. B. Papageorge

The research I will review today will focus upon one aspect of Monsanto's efforts to understand the environmental impact and behavior of our polychlorinated biphenyl or PCB products.

This research was initiated early in 1969 after development of the necessary PCB analytical methodology and subsequent confirmation of Dr. Soren Jensen's identification of PCB residues in fish and birds in Sweden.

At this point in time, PCB residue data from Monsanto and external environmental monitoring programs indicated that at the previous rate of use and release of these products that some PCB homologs were beginning to reach detectable levels in fish, birds and mammals. Conversely, these data indicated to us that with the exception of localized, controllable contamination, PCB homologs with less than five chlorine atoms per molecule had not accumulated to detectable levels; even though it was known that significantly greater amounts of the PCB homologs with less than 5 chlorine atoms per molecule had been manufactured and used over the years.

Now, before discussing our biological studies, I would like to review for you the gross homolog composition of our Aroclor products and then in a very brief fashion, try and illustrate to you the complexity of these materials and hence the complexity of the problem.

In the first slide (#1), is shown the most recent data on the weight % composition of four of our Aroclor products as a function of each detectable PCB homolog. The first column on the left lists the homolog in question and the subsequent columns under each product show the weight % distribution of each PCB homolog in each product.

As most of you probably know, with the exception of Aroclor 1016, the last two digits of each product number refer to the degree of chlorination. For example, Aroclor 1221 contains 21% chlorine by weight, and so on.

Aroclor 1016 is a special case in that while it contains about 41% chlorine by weight, its penta, hexa, and heptachloro biphenyl content has been significantly reduced with respect to Aroclor 1242, a product produced by direct chlorination, containing 42% by weight chlorine. Please note that the penta, hexa, and heptachloro biphenyl homologs in Aroclor 1016 have been reduced by factors of about 8, 10, and 10, respectively, with reference to Aroclor 1242.

As you can also see, the chief constituents of Aroclor 1221 are the mono- and dichloro biphenyls, while Aroclor 1016 and Aroclor 1242 contain predominantly di-, tri-, and tetrachloro biphenyls, and Aroclor 1254, tetra, penta, and hexachloro biphenyls.

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As I indicated earlier, this table represents our most recent efforts at determining the homolog distribution of our PCB products and as such a number of you may have seen estimations of the homolog content of these products which are significantly different. The analytical methodology used is currently in a very dynamic state and our understanding of the contents of these products increases as the methodology is improved. At this point in time, we regard these numbers as the most accurate ones currently available.

In the next slide (#2) are shown examples of low resolution - packed column electron capture chromatograms of Aroclor 1221, Aroclor 1242, Aroclor 1254, and Aroclor 1260. This is what these products look like to a residue analyst using the most commonly employed detection system.

From these chromatograms, it can be readily seen that we are dealing with multi-component products, which of course, increases the complexity of assessing every aspect of this problem - relative to a well defined single component system such as DDT.

I should mention at this point, that the PCB residues generally found in wildlife are most similar to Aroclor 1254 and Aroclor 1260 chromatograms.

The next slide (#3) demonstrates that in reality, these materials are even more complex than is generally realized. In the upper right portion of this slide is again shown a low resolution electron capture gas chromatogram of Arcclor 1242 under the optimum conditions normally employed by residue analysts. Under these conditions, Aroclor 1242 would appear to be a 15 component system.

In the lower portion of this slide is a flame ionization gas chromatogram of the same material using a high resolution S.C.O.T. column. If one carefully inspects this chromatogram, our simple 15 component product has now been resolved into 55 different components.

These facts simply indicate that all PCB products cannot be lumped together in terms of either their environmental impact or persistence.

The type of biological studies which we have carried out to date are shown in the next slide (#5). For discussion purposes, they can be conveniently divided into two categories: "Primary Bacterial Degradation Studies", an area in which research on PCBs is just beginning, and "Residue Accumulation Studies". Most of our bacterial degradation work has been centered around the fairly well known semi-continuous activated sludge degradation test.

Our residue accumulation studies have been fairly extensive and have involved the exposure of better than 2100 fish, chickens, rats and dogs to the various Aroclor products; resulting in the collection of over 1200 samples of which approximately 500 pooled samples were eventually analyzed for PCB residues.

The prime objective of these studies is given on Slide #6.

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Slide #7. The semi-continuous activated sludge test procedure we used to evaluate the primary bacterial degradation rates of the Aroclor products is the test method recommended by the Soap and Detergents Association for the evaluation of the biodegradability of linear alkyl benzene sulfonate type surfactants [JAOCS 42, 986 (1965) & 46, 432 (1969)].

> Primary Biodegradation - Minimum alternation of the chemical structure of the material in question to an extent that characteristic properties of the original material are no longer evident.

This procedure employs sludge from a sewage treatment plant as the source of microorganisms to which a specific amount of the material being evaluated and a synthetic sewage mixture are fed on a periodic basis in a specially designed aeration chamber. The next slide (#8) graphically illustrates what the aeration chamber looks like. It is simply a large glass cylinder with provisions for aeration, auxiliary stirring, a siphon for periodic removal of the supernatant and a septum for introduction of the test material.

The mixed liquor (sludge + water) obtained from the sewage treatment plant is initially adjusted with tap water to a suspended solids concentration of about 2500 mg/l, and 1500 ml of this mixture is then charged to the aeration chamber.

The mechanical cycle employed is shown in the next slide (#9). Each cycle is initiated by the addition of the synthetic sewage and 1 mg of the PCB product being tested.

Since the PCBs are quite water insoluble, they are fed to the unit via injection of 200 µls of a concentrated ethanol solution. In this manner, homogenous dispersion of the PCBs on the bacterial sludge is obtained.

After about one hour of aeration an aliquot of the mixed liquor is withdrawn from the chamber and analyzed for PCBs via UV spectrophotometry and/or electron capture gas chromatography. Aeration is continued for about 48 hours and a second sample is withdrawn for analysis. At this point, the aeration is stopped and the sludge allowed to settle, the sludge volume and pH are then checked to insure that the unit is operating satisfactorily. Two-thirds of the supernatant is withdrawn and replaced with tap water; aeration is then resumed. The cycle is re-initiated by the addition of the synthetic sewage and Aroclor in question. This cycle is continuously repeated until a steady state and consistent degradation rates are obtained.

The per cent degradation rate is calculated as shown in the equation on the slide from the amounts found in the samples analyzed during each cycle.

Degradation testing of the Aroclor products shown in the next slide (#10) have been carried out over an eight month period in our laboratories. In this slide, we have shown graphically the results observed to date. Here we have plotted the mean per cent degradation

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rates for biphenyl, Aroclor 1221, MCS 1043, a research material containing 30% by weight chlorine, Aroclor 1016 (41% chlorine), Aroclor 1242, and Aroclor 1254 versus the weight per cent chlorine present in each. The actual mean per cent degradation rates and 95% confidence limits for each material are shown in the lower left portion of the slide. These data were all obtained by UV spectrophotometry which in essence follows the decrease in the aromatic ring content and is indicative of bacterial ring cleavage. The important point to note here is that as the degree of chlorination decreases the degradation rate increases.

In order to give you a feeling for the degradation rates observed with other materials, Aroclor 1221 degrades at about the same rate as a non-linear ABS surfactant.

We have also used this technique to study p,p'-DDT and have at this point in time noted no significant primary degradation.

The next slide (#11) shows the changes in homolog distribution observed for Aroclor 1242 via electron capture gas chromatographic analyses. The upper chromatogram shows the character of the residue one hour after addition. The numbers above each peak indicate the dominant homolog or homologs present in each. The lower chromatogram is of the residue after 72 hours of exposure to the bacterial sludge. It can be readily seen by comparing the two chromatograms that all the dichloro biphenyls, most of the trichloro biphenyls, and a significant portion of the tetrachloro biphenyls are degraded in 48 hours under these test conditions.

The conclusions which we draw from this preliminary data are shown in the next slide (#12).

Next, I will discuss our "Aroclor Residue Studies" (Slide #13).

Our white leghorn chicken studies (Slide #14) have consisted of a 90 day oral exposure of Aroclor 1242, Aroclor 1254, and Aroclor 1260 at 1, 10, and 100 ppm feed levels and a repeat 90 day study of Aroclor 1242 at the 2, 4, and 8 ppm feed levels. 336 Chickens were employed from which a total of 521 tissue, chick, and egg samples were collected. Of these 112 pooled samples were analyzed for PCB residues.

In the next slide (#15) are shown the results of the 90 day oral exposure of white leghorn chickens to Aroclor 1242. On the left side, we have shown the oral exposure levels which were 1, 10, and 100 ppm, the theoretical residue in ppm, which would have been found in the lipid if the chickens had retained all of the Aroclor 1242 which they orally injested. As you can see, these levels are ~125, 1250, and 12,500 ppm. Next is shown the actual average level in ppm found in the lipid of the muscle, fat, and liver samples and then the levels found after 30 days on a PCB free diet. The important points to note are that ~90% of all the Aroclor 1242 consumed is directly excreted and/or metabolized and that after 30 days on a PCB free diet 35%, 44%, and 57% of the PCBs retained after 90 days of continuous exposure at the 1, 10, and 100 ppm levels was excreted and/or metabolized.

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On the right hand side of this slide is shown the homolog distribution of the product fed and that of the residues isolated from the tissues after 90 days of exposure and 30 days on a PCB free diet. The numbers across the top simply refer to the number of chlorine atoms per biphenyl molecule. As you can see, Aroclor 1242 contains dominant amounts of the di- through pentachlorobiphenyls and a minor amount of hexachlorobiphenyl. After 90 days of exposure the dichlorobiphenyl was no longer observable and the dominant components were the tri- through pentachloro biphenyl homologs. After 30 days on a PCB free recovery diet, the hexachloro biphenyl is now a dominant component because of continued excretion and/or metabolism of the lower chlorinated homologs.

In the next slide (#16) are shown the results for the 90 day oral exposure of Aroclor 1254 in white leghorn chickens at the 1, 10, and 100 ppm exposure levels. The theoretical residues are the same as before and we have again shown the actual levels found in the tissues after 90 days of continuous exposure and 30 days on a PCB free diet. In this instance, ∿70-72% of the Aroclor 1254 ingested was directly excreted and/or metabolized and after 30 days on a PCB free diet, ∿45% of the residues retained were excreted and/or metabolized.

The homolog distribution of the product and residues is shown on the right of the slide, the product Aroclor 1254 contains minor amounts of the tri- and heptachloro homologs and dominant amounts of the tetra-, penta-, and hexachloro biphenyls. The residue after 90 days of exposure did not contain detectable amounts of the trichloro biphenyls and the tetrachloro biphenyls were no longer a dominant component. The dominant homologs were penta- and hexachloro biphenyls. After 30 days on a PCB free diet, the tetrachloro biphenyls were now not detectable, the pentachloro biphenyls were a minor component, and the hexachloro biphenyls the dominant component.

In the next slide (#17) are the results for Aroclor 1260. Again, the oral exposure level and theoretical residue levels are the same and the PCB residues found in the tissues after 90 days of continuous exposure and 30 days on a PCB free recovery diet are shown. After 90 days of exposure, 57-52% of all Aroclor 1260 consumed was directly excreted and/or metabolized and after 30 days on a PCB free diet ∿40% of the residues retained were excreted and/or metabolized.

As shown on the right, Aroclor 1260 contains dominant amounts of penta-, hexa-, and heptachloro biphenyls and a minor amount of octachloro biphenyl. The residues after 90 days of exposure and 30 days on a PCB free recovery diet contain minor amounts of the penta- and octachloro homologs. In both cases, the dominant homologs were the hexa- and heptachloro biphenyls.

Our albino rat work (Slide #18) has consisted of 30 day oral, 2 year chronic oral and a 3 generation rat reproduction exposure study with Aroclor 1242, Aroclor 1254, and Aroclor 1260 and a 90 day subacute

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oral exposure of Aroclor 1221. Approximately 1400 animals were used in these exposure studies from which about 400 muscle, liver, and fat samples were collected. Two hundred of these samples were analyzed for PCB residues.

In the next slide (#19) are shown the results of our two year chronic oral exposure study of Aroclor 1242 in albino rats. The oral exposure levels were 1, 10, and 100 ppm and the theoretical residues were 800, 8000, 80,000 ppm, respectively. The actual residues found in the tissue lipid are shown after 3, 12, and 24 months of exposure. Comparison of the residues found after 24 months to the theoretical residue levels indicates that 99% of the Aroclor 1242 fed was directly excreted and/or metabolized at all exposure levels.

As is shown on the right, Aroclor 1242 contains dominant amounts of the di- through pentachloro biphenyl homologs and a minor amount of the hexa-. The residues after two years did not contain a significant amount of the dichloro biphenyls and the dominant components were the tri-, tetra-, and pentachloro biphenyl homologs.

In the next slide (#20) are shown the results of the two year chronic oral exposure of albino rats to Aroclor 1254. The exposure and theoretical residue levels are the same as with Aroclor 1242. The residues found after 3, 12, and 24 months of exposure are also shown. Comparison of the residues after two years to the amount ingested demonstrates that 95-98% of the Aroclor 1254 consumed is directly excreted and/or metabolized.

The homolog distribution of Aroclor 1254 and the residues are shown on the right. Aroclor 1254 contains minor amounts of the tri- and heptachloro biphenyl homologs and dominant amounts of the tetra-, penta-, and hexachloro biphenyl homologs. The residues did not contain detectable levels of the trichloro homologs and the tetrachloro biphenyls were no longer a dominant component. The dominant homologs were the penta- and hexachloro biphenyls.

The next slide (#21) shows the the results for the two year exposure of Aroclor 1260 in albino rats. Again, the exposure and theoretical residue levels are the same and the residues found in the tissues after 3, 12, and 24 months of exposure are shown. In this case 93-95% of all Aroclor 1260 ingested was directly excreted and/or metabolized.

The dominant homologs in Aroclor 1260 and the residues isolated from the tissues were similar in all cases.

In order to demonstrate the relationship between residue storage levels and the degree of chlorination of the product fed (slide #22). I have plotted the average ppm PCB found in the lipid vs the weight per cent chlorine in the product fed. These data were taken from our 90 day subacute albino rat studies with Aroclor 1221, Aroclor 1242, Aroclor 1254, and Aroclor 1260 at an exposure level of 100 ppm. As you can see, the residue storage levels decrease exponentially as the weight per cent chlorine decreases, simply demonstrating the relationship between the higher homolog content of an Aroclor product and the tissue storage level.

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Our beagle dog studies (Slide #23) have consisted of a two year chronic exposure of Aroclor 1242, Aroclor 1254, and Aroclor 1260 and a 90 day subacute study of Aroclor 1221. In these studies, 108 beagle dogs were used, resulting in the collection of 263 samples, and the analyses of 146 for PCB residues.

The next slide (#24) shows the results of one two year study of Aroclor 1242 at exposure levels of 1, 10, and 100 ppm. In this study, the theoretical residue levels are ~500, 5000, and 50,000 ppm respectively. We have also shown on this slide the residue levels found after two years of exposure and after 30 and 60 day periods on PCB free recovery diets. The beagle dogs directly excreted and/or metabolized 99.6% of the Aroclor 1242 consumed and after 60 days on PCB free diets, 50-60% of PCB residue retained after two years of exposure was excreted and/or metabolized.

Aroclor 1242 contains dominant amounts of the di-, tri-, tetra-, and pentachloro homologs and a minor amount of the hexa- homolog. The residue found after two years of exposure contained no detectable levels of the dichloro homologs and dominant levels of the tri-, tetra-, hepta-, and octachloro biphenyls. The pentachloro homolog, although dominant in the product fed, was not a dominant component of the residue. After 30 days on a PCB free recovery diet, the di-, tri-, and tetrachloro biphenyls were not detectable components of the residue. At this point, the dominant components were the hexa-, hepta-, and octachloro biphenyls. The trend toward excretion and/or metabolism of the lower chlorinated homologs continued to the extent that after 60 days on the recovery diet the hexachloro biphenyl was no longer a dominant component, and the hepta- and octachloro biphenyls became the dominant constituents in the residue.

In the next slide (#25) are the results for the two year exposure of beagle dogs to Aroclor 1254. The oral exposure and theoretical residue levels are the same and the PCB residue levels found in the tissues after two years of exposure and after 30 and 60 day periods on PCB free recovery diets are again shown.

In this instance, the dogs excreted and/or metabolized 98-99% of all Aroclor 1254 consumed over a two year period. After 60 days on a PCB free recovery diet, 30-40% of the residues retained were excreted and/or metabolized. The product fed, Aroclor 1254, contains minor amounts of the tri- and heptachloro biphenyls and dominant amounts of the tetra-, penta-, and hexachloro homologs. After two years of exposure, the residue retained from the product did not contain detectable levels of the tri- or tetrachloro biphenyls, the penta-, and hexachloro biphenyls remained dominant components, and the heptachloro biphenyls became dominant constituents.

After 30 days on the PCB free recovery diet, the pentachloro homologs became a minor component of the residue, the hexa- and heptachloro biphenyls remained dominant components and the octachloro homologs became a minor component. After 60 days on the PCB free recovery diet, the pentachloro biphenyls were excreted and/or metabolized to the extent that the octachloro homologs became a dominant constituent of the residue.

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The next slide (#26) shows the results for the two year oral exposure residue study of Aroclor 1260 in beagle dogs. The exposure and theoretical residue levels are the same as those for the Aroclor 1242 and Aroclor 1254 studies. Next is shown the residues which accumulated after two years of continuous exposure and the residues retained after 30 and 60 day recovery periods on PCB free diets. With this Aroclor 98-99% of the amount consumed over two years was directly excreted and/or metabolized. After 60 days on the recovery diet ~13% of the retained residues were excreted and/or metabolized.

The homolog distribution of Aroclor 1260 is as shown, dominant amounts of the penta-, hexa-, and heptachloro biphenyls with a minor amount of the octachloro homologs. After two years, the PCB residue contains no detectable level of the pentachloro homologs, a minor amount of the heptachloro biphenyls, and dominant amounts of the hexachloro and octachloro homologs. After 30 days on the recovery diet, the dominant homologs are now the hexa-, hepta-, and octachloro biphenyls becoming a dominant component of the residue via loss of some of the hexachloro biphenyls. After 60 days on the recovery diet, the hexachloro biphenyls are no longer dominant components of the residue and it is now mainly the hepta- and octachloro biphenyls.

The next slide (#27) illustrates the residue fall off as a function of Aroclor and recovery period. These data are from the two year beagle dog studies and the exposure level is 1 ppm. In this graph, I have plotted the average ppm PCB found in the lipid for Aroclor 1260, Aroclor 1254, and Aroclor 1242 after two years of continuous oral exposure and then after 1 month and 2 month recovery periods on PCB free diets. This plot simply demonstrates that the PCB residues retained from Aroclor 1242 fall off more quickly than those retained from Aroclor 1254 and Aroclor 1260.

The table in the next slide (#28) shows the relative ability of fowl, small mammals, and large mammals to retain orally ingested PCBs. These data are for Aroclor 1242 at the exposure levels and periods shown. The concentration factor is calculated by dividing the maximum PCB level found in the lipid by the exposure level. As you can see from the factors, chickens retain PCBs to a greater extent than do rats or dogs.

Our fish residue work is not very extensive at this point - primarily because we have had problems in finding consulting laboratories capable of carrying out dynamic low level fish exposure studies, and secondly, because government laboratories such as those in Duluth, Minnesota, Columbia, Missouri, and Gulf Breeze, Florida were, and are, still in better positions to carry out and evaluate these types of studies.

We have done some very preliminary 21 day dynamic exposures of catfish and bluegill fingerlings to some of our Aroclor products and it generally supports the conclusions which can be drawn from literature data.

The general conclusions which we draw from these residue studies are shown in the next three slides.

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Slide #29 - Build-Up - Conclusions

Slide #30 - Fall-Off - Conclusions

Slide #31 - Alteration of Homolog Distribution - Conclusions

In summary, we feel that the results of our preliminary research support, what has and is being observed via residue analysis of environmental samples; that is to say, from a residue viewpoint, that the bulk of the PCB homologs released to the environment (PCBs with less than 5 chlorines) are subject to environmental degradation of one sort or another at measurable rates and as such have not accumulated.

E. S. Tucker

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TYPICAL % COMPOSITION OF POLYCHLORINATED BIPHENYL PRODUCTS *

HOMOLOG # Cl/BIPHENYL	AROCLOR 1221	AROCLOR 1016	AROCLOR 1242	AROCLOR 1254
0	11	<0.1	<0.1	<0.1
1	51	1	1	<0.1
2	32	20	16	<0.5
3	4	57	49	1
4	2	21	25	21
5	<0.5	1	8	48
6	ND	<0.1	1	23
7	ND	ND	<0.1	6
8	ND	ND	ND	ND

*PER CENT (W/W) BY GC/MASS USING AREA CORRECTION FACTORS BY HOMOLOG RESPONSE

NONE DETECTED, <0.01% = ND

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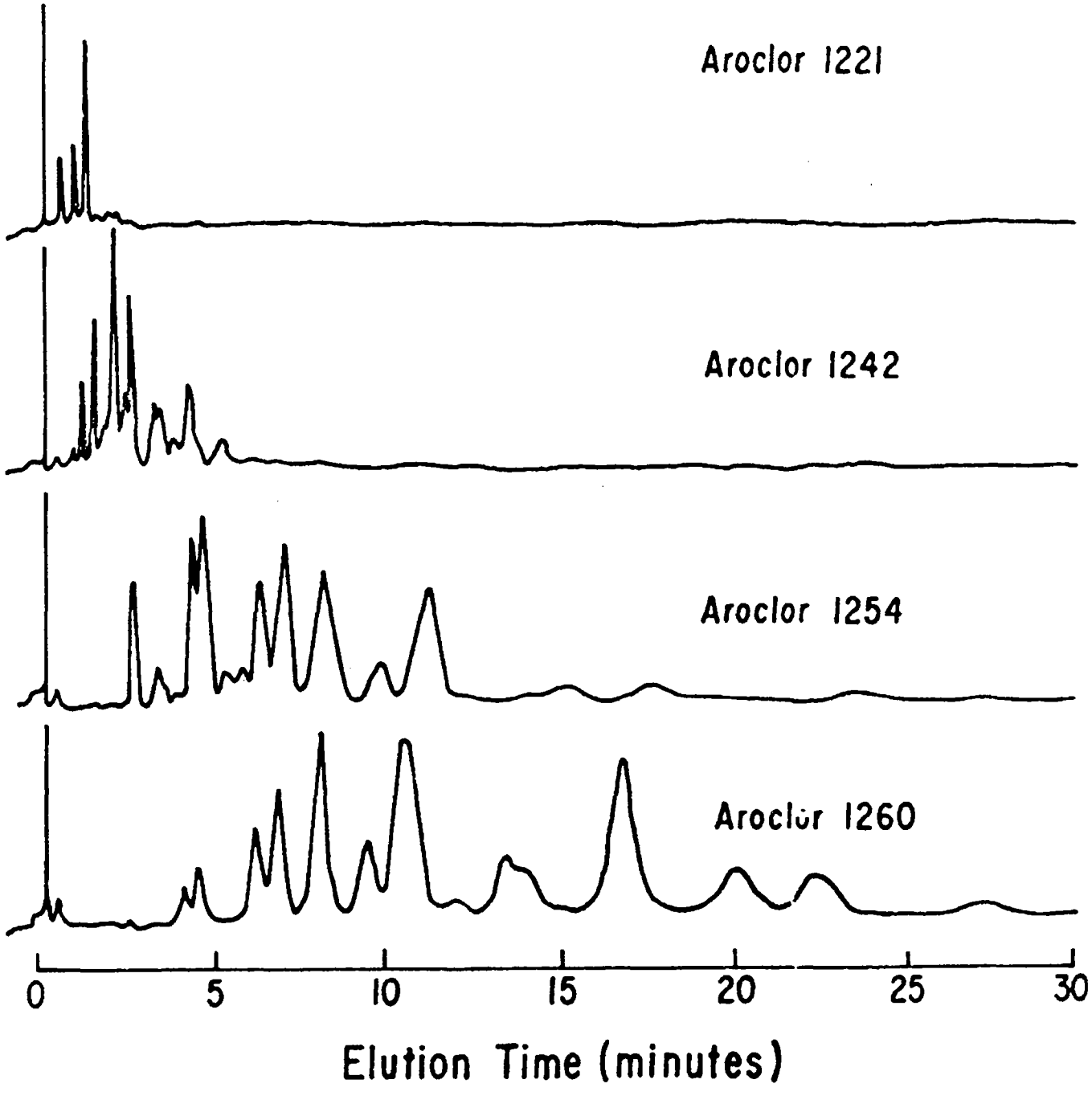
Electron Capture Gas Chromatograms



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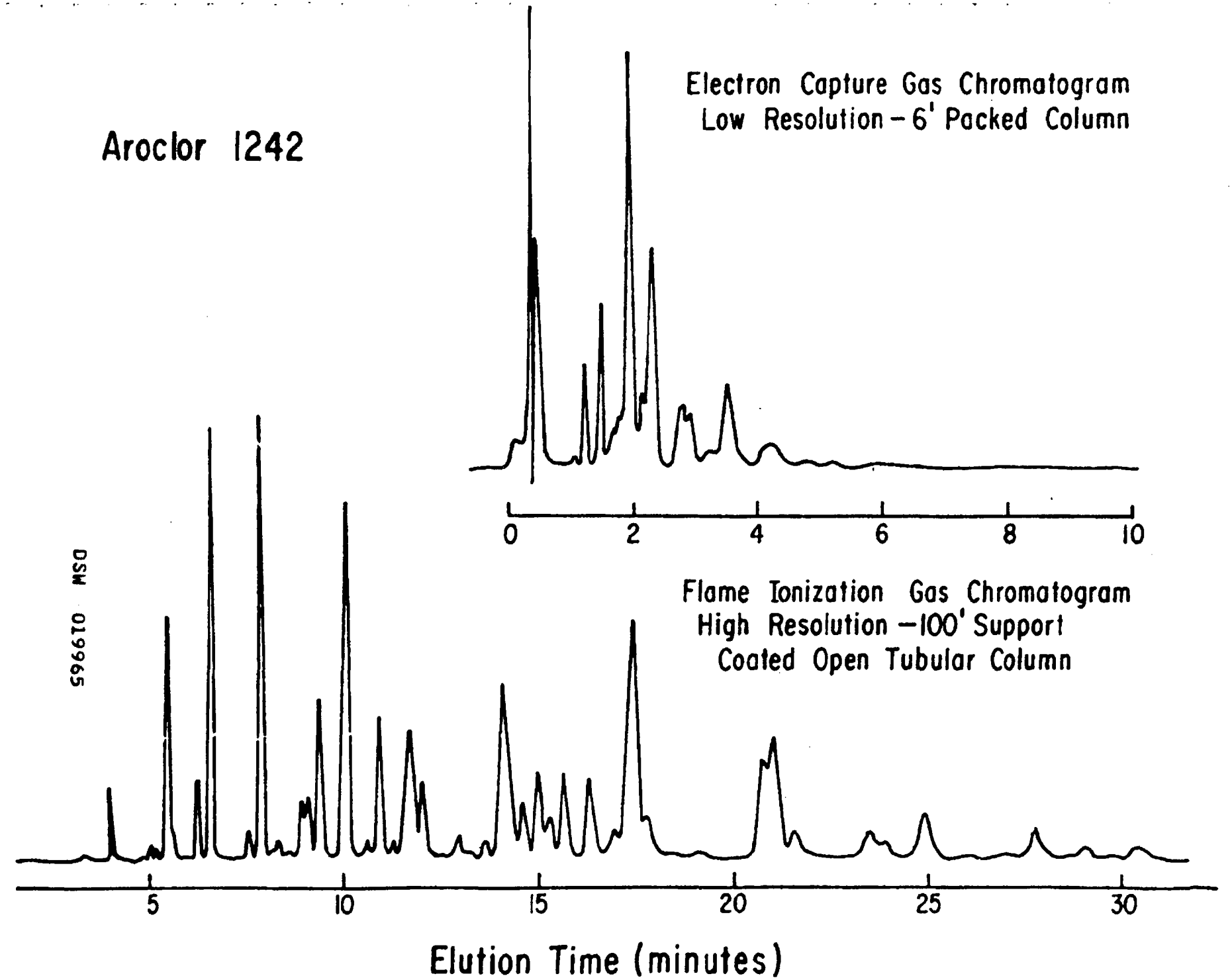

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- PCB PRODUCTS ARE NOT A SINGLE ENTITY, BUT COMPLEX MULTI-COMPONENT MIXTURES

- PCB RESIDUES FOUND IN WILD LIFE ARE DOMINANTLY PENTA-, HEXA-, HEPTA-, AND OCTA-CHLORO BIPHENYLS

- PCB RESIDUE ARE MOST SIMILAR TO AROCLOR 1254 AND AROCLOR 1260 PRODUCTS

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PRIMARY BACTERIAL DEGRADATION STUDIES

- SEMI-CONTINUOUS ACTIVATED SLUDGE DEGRADATION

RESIDUE ACCUMULATION STUDIES

- FISH - CATFISH AND BLUEGILLS
- BIRDS - WHITE LEGHORN CHICKENS
- MAMMALS - ALBINO RATS AND BEAGLE DOGS

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ASSESSMENT OF THE PERSISTENCE OF POLYCHLORINATED BIPHENYLS IN BIOLOGICAL SYSTEMS

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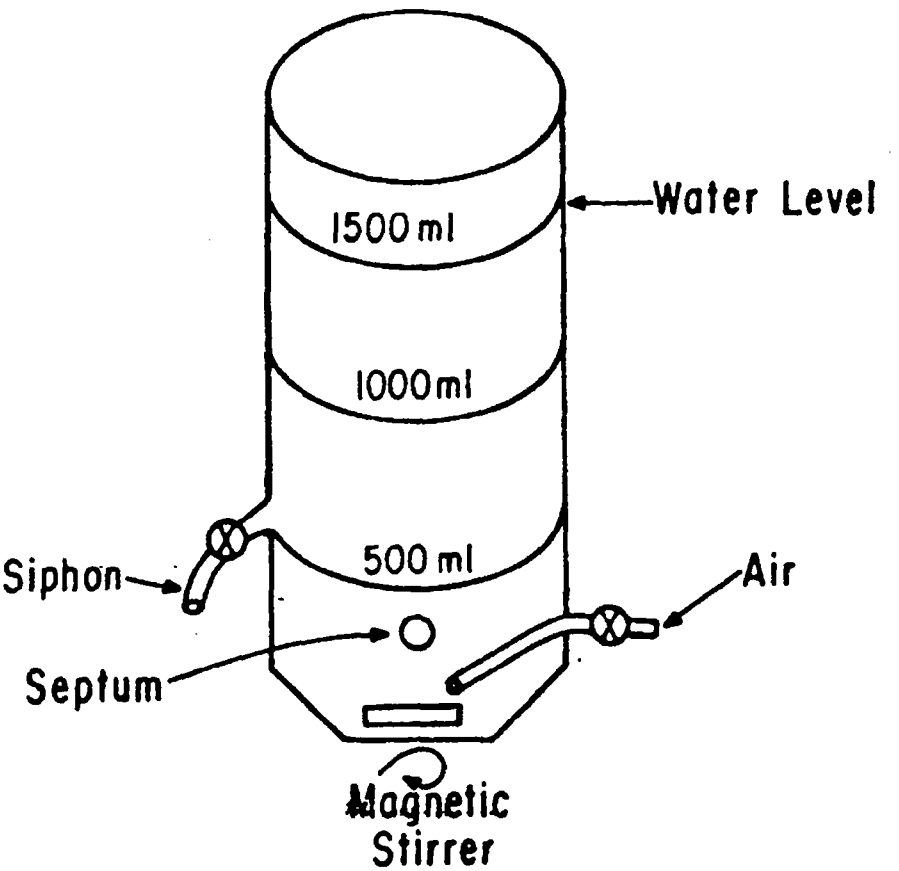
AROCLOR SEMI-CONTINUOUS ACTIVATED SLUDGE PRIMARY DEGRADATION STUDIES

DSW 019969

Semi-Continuous Activated Sludge Test Unit



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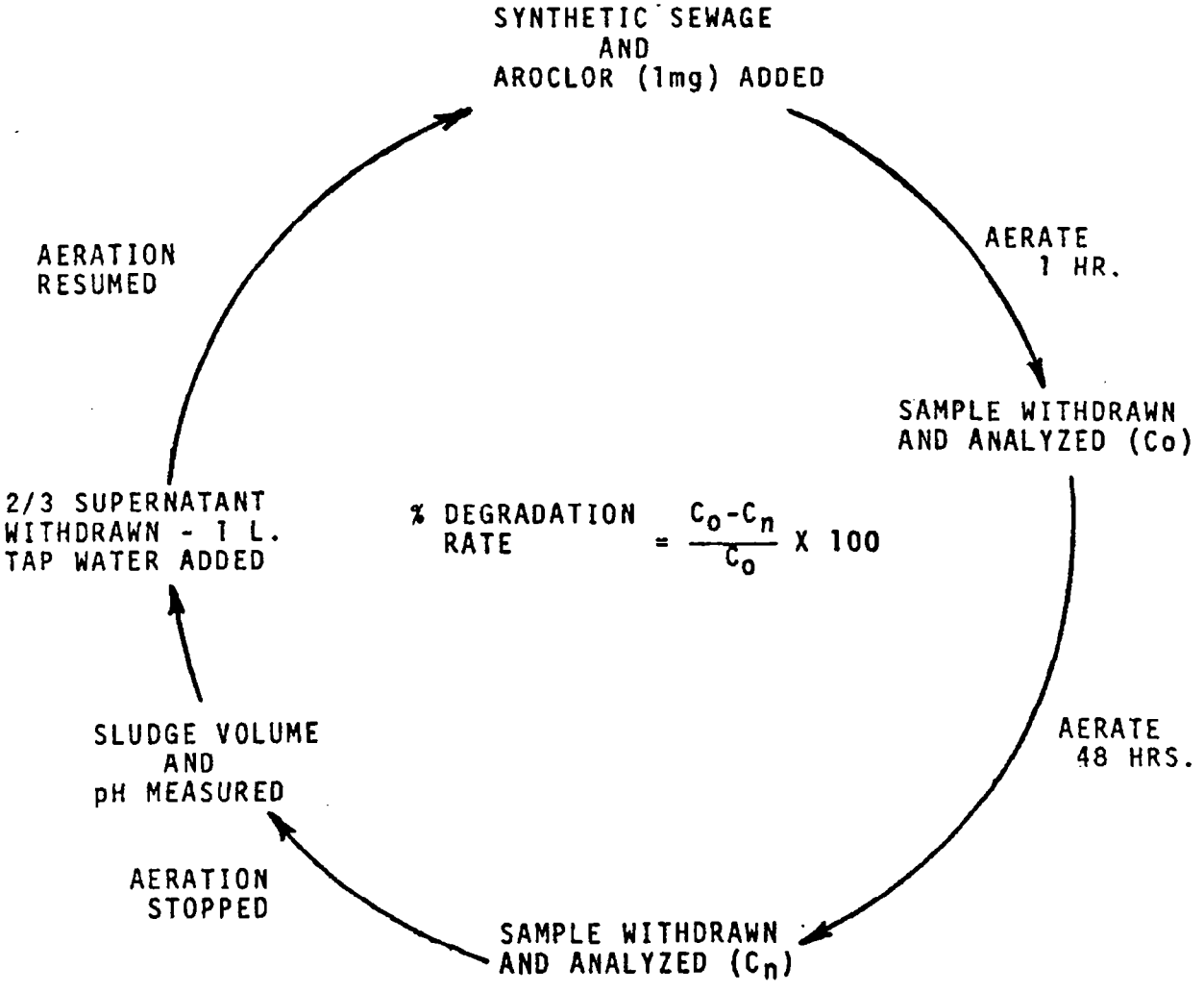
MECHANICAL CYCLE



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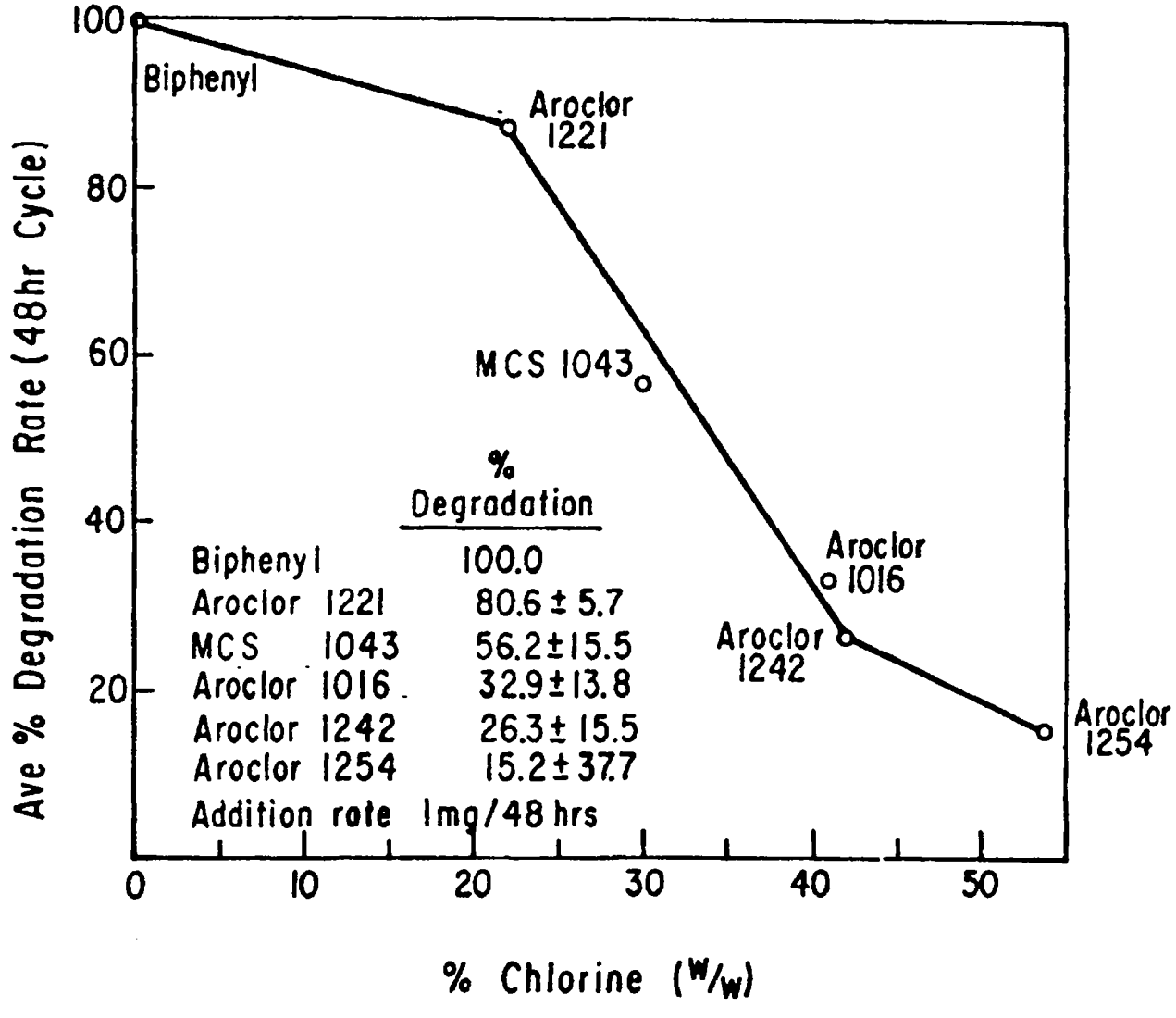
Semi-Continuous Activated Sludge Degradation of Polychlorinated Biphenyls



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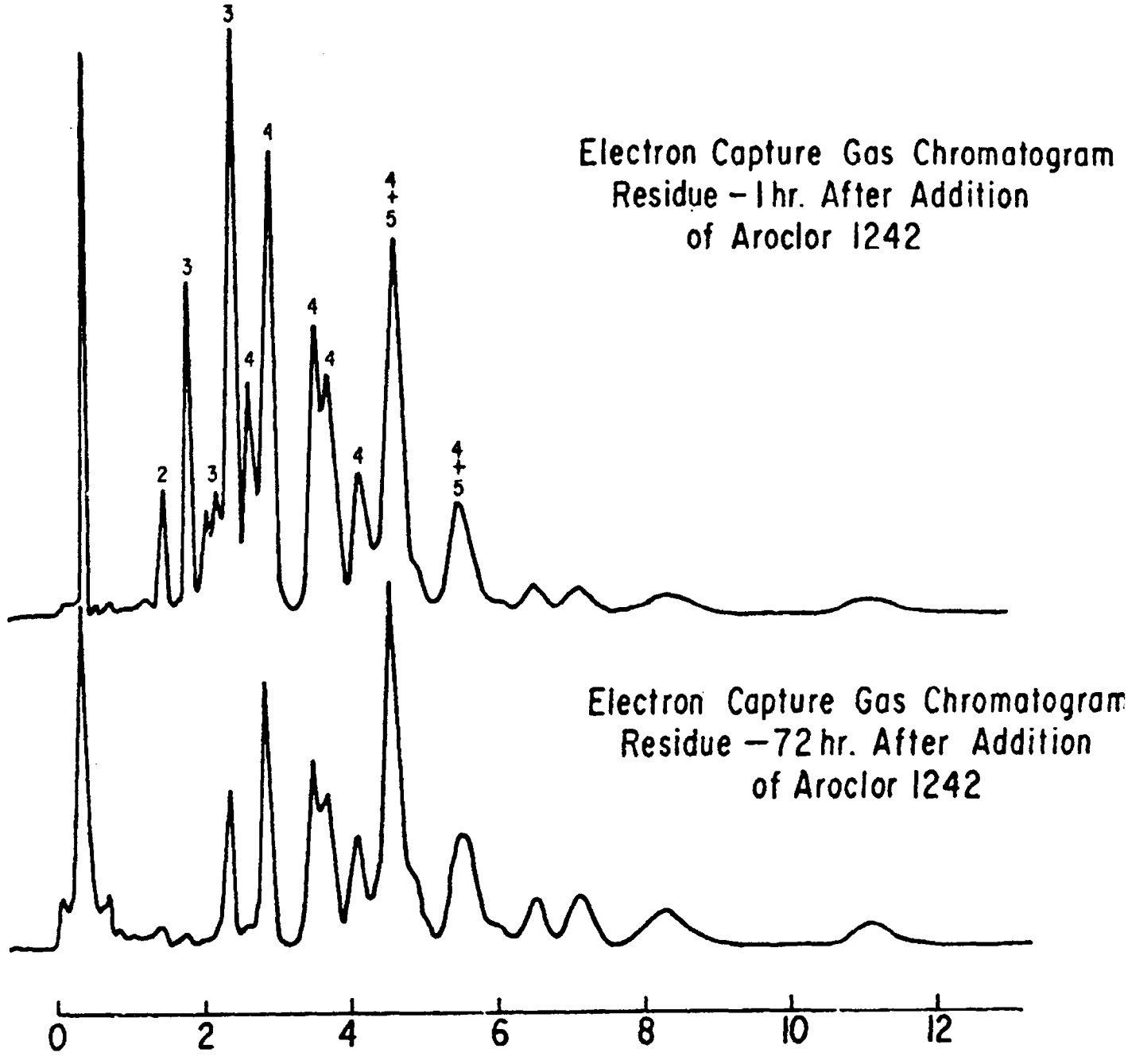
Semi-Continuous Activated Sludge Degradation of Aroclor 1242



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BACTERIAL DEGRADATION STUDIES

CONCLUSIONS

- RATE OF PRIMARY DEGRADATION INCREASES AS THE DEGREE OF CHLORINATION OF THE AROCLOR PRODUCT DECREASES

BIPHENYL>AROCLOR 1221>MCS 1043
>AROCLOR 1016>AROCLOR 1242>AROCLOR 1254

- BIPHENYL, MONO-, DI-, TRI-, AND TETRACHLORO BIPHENYL HOMOLOGS UNDERGO PRIMARY BACTERIAL DEGRADATION

DSW 019974

AROCLOR RESIDUE STUDIES

DSW 019975

WHITE LEGHORN CHICKEN STUDIES

PRODUCTS STUDIED		90 DAY ORAL AROCLOR 1242 AROCLOR 1254 AROCLOR 1260	90 DAY ORAL AROCLOR 1242
NUMBER OF CHICKENS	FEMALE	200	80
	MALE	40	16
NUMBER OF SAMPLES	MUSCLE	40	8
	LIVER	40	8
	FAT	40	8
	EGGS	~250	~60
	CHICKS	30	10
NUMBER OF SAMPLES ANALYZED	MUSCLE	14	5
	LIVER	12	4
	FAT	18	5
	EGGS	25	8
	CHICKS	11	10
TOTAL SAMPLES COLLECTED		400	121
TOTAL ANALYZED		80	32

ORAL EXPOSURE CARRIED OUT BY
INDUSTRIAL BIO-TEST LABORATORIES, INC.
NORTHBROOK, ILLINOIS

DSW 019976

RESIDUE STUDY OF AROCLOR 1242 IN WHITE LEGHORN CHICKENS

90 DAY ORAL

	PPM PCBs			HOMOLOG DISTRIBUTION									
				1	2	3	4	5	6	7	8	9	10
ORAL EXPOSURE LEVEL	1	10	100										
†THEORETICAL RESIDUE	126	1260	12602	-	(2)	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 12 WEEK EXPOSURE	14	136	1312	-	-	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 30 DAY RECOVERY	9	77	749	-	-	(3)	(4)	(5)	(6)	-	-	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 01977

STLCOPCB4007910

RESIDUE STUDY OF AROCLOR 1254 IN WHITE LEGHORN CHICKENS

90 DAY ORAL

	PPM PCBs			HOMOLOG DISTRIBUTION									
				1	2	3	4	5	6	7	8	9	10
ORAL EXPOSURE LEVEL	1	10	100										
†THEORETICAL RESIDUE	126	1260	12602	-	-	3	(4)	(5)	(6)	7	-	-	-
*RESIDUE, 12 WEEK EXPOSURE	38	362	3506	-	-	-	4	(5)	(6)	7	-	-	-
*RESIDUE, 30 DAY RECOVERY	17	164	1580	-	-	-	-	5	(6)	7	-	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSW 019978

STLCOPCB4007911

RESIDUE STUDY OF AROCLOR 1260 IN WHITE LEGHORN CHICKENS

90 DAY ORAL

	PPM PCBs			HOMOLOG DISTRIBUTION									
				1	2	3	4	5	6	7	8	9	10
ORAL EXPOSURE LEVEL	1	10	100										
†THEORETICAL RESIDUE	126	1260	12602	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 12 WEEK EXPOSURE	65	607	5909	-	-	-	-	5	(6)	(7)	8	-	-
*RESIDUE, 30 DAY RECOVERY	26	232	2363	-	-	-	-	5	(6)	(7)	8	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019979

STLCOPCB4007912

ALBINO RAT STUDIES

		30 DAY ORAL	2 YEAR CHRONIC ORAL	3 GENERATION RAT REPRODUCTION	90 DAY SUBACUTE ORAL
PRODUCTS STUDIED		AROCLOR 1242 AROCLOR 1254 AROCLOR 1260	AROCLOR 1242 AROCLOR 1254 AROCLOR 1260	AROCLOR 1242 AROCLOR 1254 AROCLOR 1260	AROCLOR 1221
NUMBER OF RATS)	FEMALE	115	500	~20	60
	MALE	115	500	~20	60
NUMBER OF SAMPLES)	MUSCLE	18	33	-	7
	KIDNEY	18	-	-	-
	LIVER	18	33	-	7
	FAT	18	33	-	7
	PUPS	-	-	10	-
NUMBER OF SAMPLES ANALYZED)	MUSCLE	18	33	-	7
	KIDNEY	18	-	-	-
	LIVER	18	33	-	7
	FAT	18	33	-	7
	PUPS	-	-	10	-
TOTAL SAMPLES COLLECTED		144	198	20	42
TOTAL ANALYZED		72	99	10	21

ORAL EXPOSURE CARRIED OUT BY
INDUSTRIAL BIO-TEST LABORATORIES, INC.
NORTHBROOK, ILLINOIS

DSW 019980

RESIDUE STUDY OF AROCLOR 1242 IN ALBINO RATS

TWO YEAR CHRONIC ORAL EXPOSURE

ORAL EXPOSURE LEVEL	PPM PCBs 1	10	100	HOMOLOG DISTRIBUTION 1	2	3	4	5	6	7	8	9	10
†THEORETICAL RESIDUE	80'3	8037	80373	-	(2)	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 3 MONTH EXPOSURE	6	23	90	-	-	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 12 MONTH EXPOSURE	9	37	155	-	-	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 24 MONTH EXPOSURE	12	53	240	-	-	(3)	(4)	(5)	6	-	-	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019681

STLCOPCB4007914

RESIDUE STUDY OF AROCLOR 1254 IN ALBINO RATS

TWO YEAR CHRONIC ORAL EXPOSURE

ORAL EXPOSURE LEVEL	PPM PCBs			HOMOLOG DISTRIBUTION									
	1	10	100	1	2	3	4	5	6	7	8	9	10
†THEORETICAL RESIDUE	803	8037	80373	-	-	3	(4)	(5)	(6)	7	-	-	-
*RESIDUE, 3 MONTH EXPOSURE	13	94	679	-	-	-	4	(5)	(6)	7	-	-	-
*RESIDUE, 12 MONTH EXPOSURE	24	189	1471	-	-	-	4	(5)	(6)	7	-	-	-
*RESIDUE, 24 MONTH EXPOSURE	42	355	3038	-	-	-	4	(5)	(6)	7	-	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019982

STLCOPCB4007915

RESIDUE STUDY OF AROCLOR 1260 IN ALBINO RATS

TWO YEAR CHRONIC ORAL EXPOSURE

	PPM PCBs			HOMOLOG DISTRIBUTION									
				1	2	3	4	5	6	7	8	9	10
ORAL EXPOSURE LEVEL	1	10	100										
†THEORETICAL RESIDUE	803	8037	80373	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 3 MONTH EXPOSURE	18	134	970	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 12 MONTH EXPOSURE	35	270	2099	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 24 MONTH EXPOSURE	59	507	4338	-	-	-	-	(5)	(6)	(7)	8	-	-

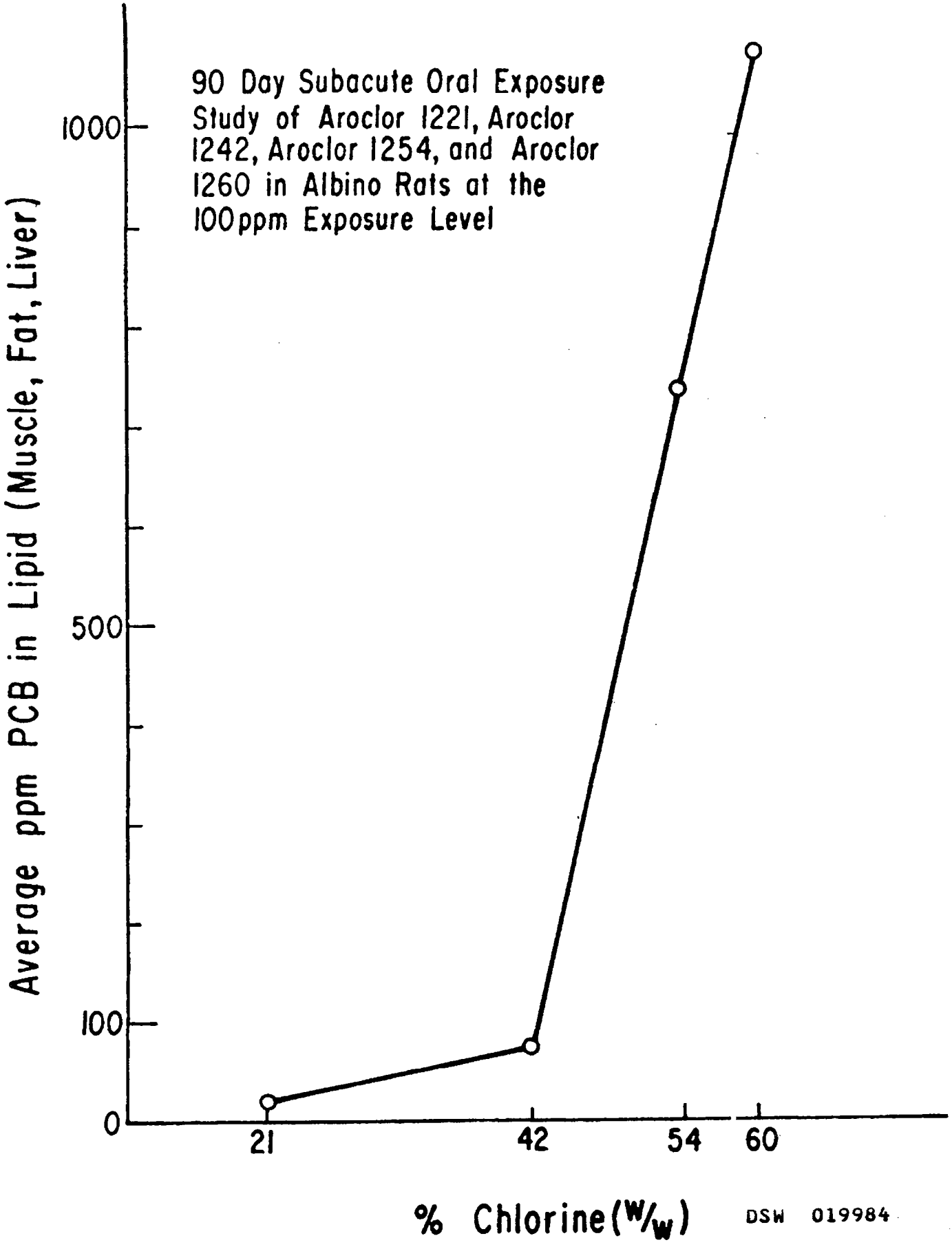
†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019983

STLCOPCB4007916


90 Day Subacute Oral Exposure Study of Aroclor 1221, Aroclor 1242, Aroclor 1254, and Aroclor 1260 in Albino Rats at the 100ppm Exposure Level
Average ppm PCB in Lipid (Muscle, Fat, Liver)
1000
500
100
0
21
42
54
60
% Chlorine (W/W)
DSW 019984

BEAGLE DOG STUDIES

		2 YEAR CHRONIC ORAL	90 DAY SUBACUTE ORAL
PRODUCTS STUDIED		AROCLOR 1242 AROCLOR 1254 AROCLOR 1260	AROCLOR 1221
NUMBER OF DOGS	FEMALE	40	14
	MALE	40	14
NUMBER OF SAMPLES	MUSCLE	54	7
	LIVER	54	7
	FAT	54	7
TOTAL SAMPLES COLLECTED		242	21
NUMBER OF SAMPLES ANALYZED	MUSCLE	42	7
	LIVER	40	7
	FAT	43	7
TOTAL ANALYZED		125	21

ORAL EXPOSURE CARRIED OUT BY
INDUSTRIAL BIO-TEST LABORATORIES, INC.
NORTHBROOK, ILLINOIS

DSW 019985

RESIDUE STUDY OF AROCLOR 1242 IN BEAGLE DOGS

TWO YEAR CHRONIC ORAL EXPOSURE

	PPM PCBs			HOMOLOG DISTRIBUTION									
				1	2	3	4	5	6	7	8	9	10
ORAL EXPOSURE LEVEL	1	10	100										
†THEORETICAL RESIDUE	519	5186	51865	-	(2)	(3)	(4)	(5)	6	-	-	-	-
*RESIDUE, 2 YEAR EXPOSURE	2	6	12	-	-	(3)	(4)	5	6	(7)	(8)	-	-
*RESIDUE, 30 DAY RECOVERY	1	4	10	-	-	-	-	5	(6)	(7)	(8)	-	-
*RESIDUE, 60 DAY RECOVERY	0.8	3	6	-	-	-	-	5	6	(7)	(8)	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019986

STLCOPCB4007919

RESIDUE STUDY OF AROCLOR 1254 IN BEAGLE DOGS

TWO YEAR CHRONIC ORAL EXPOSURE

ORAL EXPOSURE LEVEL	PPM PCBs 1	10	100	HOMOLOG DISTRIBUTION 1	2	3	4	5	6	7	8	9	10
†THEORETICAL RESIDUE	519	5186	51865	-	-	3	(4)	(5)	(6)	7	-	-	-
*RESIDUE, 2 YEAR EXPOSURE	7	30	132	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 30 DAY RECOVERY	5	24	109	-	-	-	-	5	(6)	(7)	8	-	-
*RESIDUE, 60 DAY RECOVERY	4	20	88	-	-	-	-	5	(6)	(7)	(8)	-	-

†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019987

STLCOPCB4007920

RESIDUE STUDY OF AROCLOR 1260 IN BEAGLE DOGS

TWO YEAR CHRONIC ORAL EXPOSURE

	PPM PCBs			HOMOLOG DISTRIBUTION									
ORAL EXPOSURE LEVEL	1	10	100	1	2	3	4	5	6	7	8	9	10
†THEORETICAL RESIDUE	519	5186	51865	-	-	-	-	(5)	(6)	(7)	8	-	-
*RESIDUE, 2 YEAR EXPOSURE	8	63	388	-	-	-	-	-	(6)	7	(8)	-	-
*RESIDUE, 30 DAY RECOVERY	7	60	363	-	-	-	-	-	(6)	(7)	(8)	-	-
*RESIDUE, 60 DAY RECOVERY	7	55	337	-	-	-	-	-	6	(7)	(8)	-	-

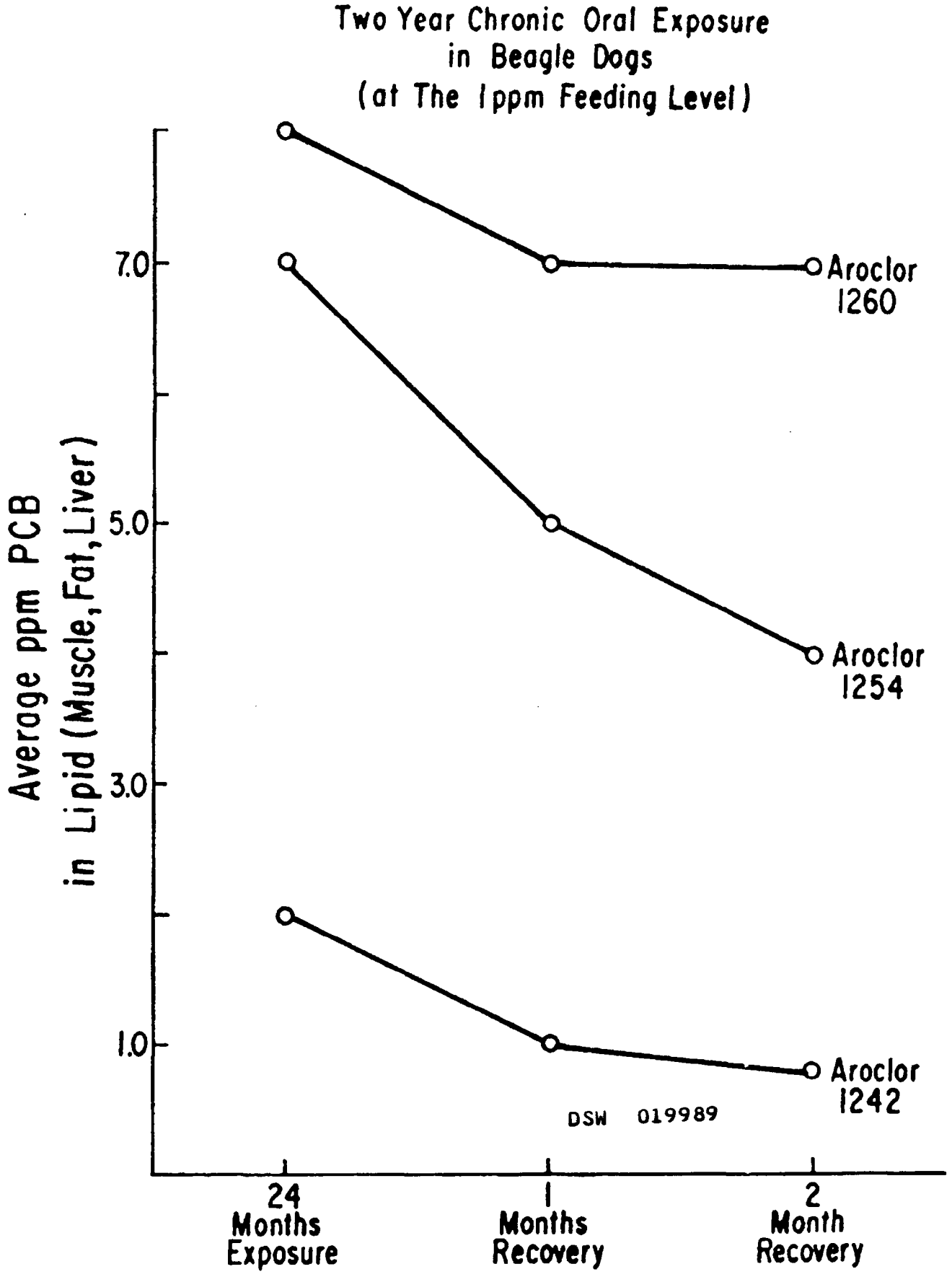
†IF TOTAL PCB CONSUMED WERE RETAINED

*AVERAGE PPM IN LIPID - ALL TISSUES

( )ELECTRON CAPTURE PEAKS GREATER THAN 5% OF TOTAL

DSM 019988

STLCOPCB4007921



STLCOPCB4007922

	EXPOSURE LEVEL (PPM)	EXPOSURE PERIOD	CONCENTRATION FACTOR*
WHITE LEGHORN CHICKENS	1.0 (FEED)	12 WEEKS	20
ALBINO RATS	1.0 (FEED)	2 YEARS	9
BEAGLE DOGS	1.0 (FEED)	2 YEARS	2

*CONCENTRATION FACTORS DO NOT TAKE INTO ACCOUNT EXPOSURE PERIODS

DSW 019990

CONCLUSIONS

RESIDUE BUILDUP STUDIES

- FOR ALL PRODUCTS THE PCB RESIDUE LEVEL INCREASED AS THE EXPOSURE LEVEL AND PERIOD INCREASED

- RELATIVE TO AROCLOR 1260, THE HIGHEST CHLORINATED PRODUCT STUDIED, THE PCB RESIDUE LEVEL DECREASED EXPONENTIALLY AS AS THE WEIGHT % CHLORINE OF THE PRODUCT DECREASED

- RELATIVE LEVELS OF PCB RESIDUES FOUND WERE -

  FISH>>>>>CHICKENS>RATS>DOGS

- RELATIVE PCB RESIDUE LEVELS IN TISSUES WERE -

CHICKENS	FAT = MUSCLE>LIVER
RATS	LIVER>FAT = MUSCLE>KIDNEY
DOGS	LIVER>FAT = MUSCLE

- FOR ALL PRODUCTS THE DOGS AND RATS EXCRETED AND/OR METABOLIZED 93 TO 99% OF THE TOTAL AROCLOR ORALLY INGESTED

- CHICKENS EXCRETED AND/OR METABOLIZED PRODUCTS INJESTED ORALLY AS FOLLOWS -

  90% OF AROCLOR 1242
  70% OF AROCLOR 1254
  50% OF AROCLOR 1260

DSW 019991

CONCLUSIONS

RESIDUE FALL-OFF

- DOGS AND CHICKENS CONTINUED TO EXCRETE AND/OR METABOLIZE PCB RESIDUES, INCLUDING PENTA AND HEXA HOMOLOGS, RETAINED WHEN PLACED ON PCB FREE RECOVERY DIETS

  DOGS > CHICKENS

- RELATIVE RESIDUE FALL-OFF RATES SHOWED -

  DOGS: AROCLOR 1242>AROCLOR 1254 >AROCLOR 1260

  CHICKENS: AROCLOR 1242>AROCLOR 1254>AROCLOR 1260

DSW 019992

CONCLUSIONS

RESIDUE STUDIES

ALTERATIONS OF AROCLOR HOMOLOG DISTRIBUTION

- ALTERATION OF THE HOMOLOG DISTRIBUTION OF ALL PRODUCTS WAS OBSERVED IN ALL STUDIES EXCEPT FISH

- LOWER CHLORINATED HOMOLOGS PRESENT IN ALL PRODUCTS WERE PREFERENTIALLY EXCRETED AND/OR METABOLIZED

- ALTERATION OF THE HOMOLOG DISTRIBUTION INCREASED AS THE WEIGHT % CHLORINE OF THE PRODUCTS DECREASED (INCLUDING PENTA AND HEXA HOMOLOGS)

  AROCLOR 1221>>AROCLOR 1242>AROCLOR 1254
  >AROCLOR 1260

  DOGS>RATS>CHICKENS>>>>>FISH

DSW 019993

WHAT HAPPENS TO PCBs IN THE ENVIRONMENT?

By Dr. R. H. Munch

Presented by W. B. Papageorge

Because they can be detected by the same analytical methods, and because some suspect that they may have similar biological effects to DDT, polychlorinated biphenyls in the environment (PCBs) have become a cause of concern. It is, therefore, important to present data to show that PCBs do disappear from the environment.

Probably the most effective way to do this is to compare what has been put into the environment with what is found there now. This can be done in the following way:

The commercial PCB products are mixture of chlorinated biphenyl homologs containing from one to ten atoms of chlorine per biphenyl molecule. If there were no degradation in the environment, or if all homologs degraded at the same rate, the ratio of homologs in "aged environmental samples" (samples taken at a distance from a known source) should be the same as that in the products introduced into the environment. On the other hand, if the homolog ratio in "aged environment samples" differs from that of material produced, some process must be operating in the environment to remove different homologs at different rates. Monsanto, the major U.S. producer, recently released data on its sales of the various commercial grades of PCB for the years 1957-72. Rest-of-world sales by other producers and production before 1957 probably represent a similar product mix. Using the Monsanto data and known homolog analyses of each of the commercial grades, the percentage of each homolog in the total U. S. production can be calculated.

The other required datum is an estimate of the homolog distribution in "environmentally aged samples." Analysts experienced in this field generally agree that material recovered from such samples is similar to Aroclor 1254 or 1260, the Monsanto trade name for mixtures of PCBs with chlorine contents corresponding to an average of five and six chlorine atoms per biphenyl molecule respectively (1-8). In order to present a conservative comparison and because most analysts cite Aroclor 1254, we shall use the homolog content of that material in our comparison.

STLCOPCB4007927

The homolog contents of the material produced in the U. S. from 1957 to 1971 and that of Aroclor 1254 are tabulated below:

	Homolog							
0	1	2	3	4	5	6	7	8
U. S. Sales 1957 - 1971								
0.1	1.3	14.8	29.9	21.9	16.1	10.5	4.2	1.1
Aroclor 1254								
<.1	<.1	<.5	1	21	48	23	6	ND

It is apparent that the homolog ratio of the material sold is quite different from that of Aroclor 1254. There must, therefore, be one or more processes in the environment which remove the lower homologs at much greater rates than the higher ones. The precision of the data is too low to permit accurate calculations of the relative rates of loss. However, it would appear that the homologs containing less than four chlorine atoms may be degraded at rates approximately thirty times those for the five and six chlorine homologs. Laboratory data which we hope to publish later show that the rate of bacterial degradation is an inverse function of the chlorine content for PCBs and might, therefore, be one of the degradative processes responsible for the relative decrease in the lower homologs.

STLCOPCB4007928

1) L. M. Reynolds, Pesticide Residue Analysis in the Presence of Polychlorinated Biphenyls Residue Reviews 34, 27, 32, 41, 42, 44 (1971).

2) R. W. Risebrough, P. Reiche and H. S. Scott - Current Progress in the Determination of the Polychlorinated Biphenyls - Bulletin of Environmental Contamination & Toxicology 4, 192, 199 (197).

3) G. E. Bagley, W. L. Reichel and E. Cromartie - Identification of Polychlorinated Biphenyls in Two Bald Eagles by Combined Gas-Liquid Chromatography-Mass Spectrometry - Journal of the AOAC 53, 251, 252, 257 (1970).

4) Albert C. Tas and Rudolf H. deVos - Characterization of Four Major Components in a Technical Polychlorinated Biphenyl Mixture - Environmental Science & Technology 5, 1216 (1971).

5) Judith A. Armour and Jerry A. Burke - Method for Separating Polychlorinated Biphenyls from DDT and Its Analogs - Journal of the AOAC 53, 763, 765 (1970).

6) Ian Prestt, D. J. Jeffreries and N. W. Moore - Polychlorinated Biphenyls in Wild Birds in Britain and Their Arian Toxicity - Environmental Pollution 1, 3, 15 (1970).

7) V. Zitko - Polychlorinated Biphenyls and Organochlorine Pesticides in Some Freshwater and Marine Fishes - Bulletin of Environmental Contamination & Toxicology 6, 464, 467 (1971).

8) PCBs & The Environment - Interdepartmental Task Force on PCBs - Washington May, 1972 - COM-72-10419 - Table 6, P. 93.

WHAT HAPPENS TO PCBs IN THE ENVIRONMENT?

1. WE CANNOT DETERMINE IF PCBs DEGRADE IN THE ENVIRONMENT FROM THE TOTAL CONCENTRATIONS FOUND THERE.

2. THE PCBs ARE MIXTURES OF HOMOLOGS.

3. THEREFORE, COMPARISON OF HOMOLOG RATIOS IN "ENVIRONMENTALLY AGED SAMPLES" WITH HOMOLOG RATIOS IN MATERIAL PRODUCED CAN BE USED TO GAIN INSIGHT AS TO WHAT IS HAPPENING IN THE ENVIRONMENT.

STLCOPCB4007930

HOW DO WE GET THE DATA NEEDED?

1. PRODUCTION FIGURES FOR ALL MONSANTO PCB PRODUCTS AND HOMOLOG CONTENT OF EACH PRODUCT ARE AVAILABLE FOR 1957-71. WE USE THESE DATA TO CALCULATE HOMOLOG RATIOS FOR 1957-71 PRODUCTION.

2. EUROPEAN PRODUCERS MAKE SIMILAR PRODUCTS IN ABOUT THE SAME RATIOS AS MONSANTO.

3. PRODUCTION BEFORE '57 WOULD NOT AFFECT THE FIGURES GREATLY SINCE PRODUCT RATIOS WERE SIMILAR AND PRODUCTION SMALLER.

4. ANALYSTS GENERALLY AGREE THAT MATERIAL FOUND IN "AGED ENVIRONMENTAL SAMPLES" IS SIMILAR TO AROCLOR 1254 OR IN RARE CASES EVEN TO AROCLOR 1260.

STLCOPCB4007931

HARVEY, MIKLAS AND BOWEN OF
WOODS HOLE OCEANOGRAPHIC INSTITUTE
AROCLOR 1254 VS ENVIRONMENTAL MATERIAL CURVES

AROCLOR 1254



PLANKTON
K-19-4-STA. 10



DSW 019999

A COMPARISON OF THE HOMOLOG RATIOS FOR PCBs SOLD
WITH THOSE FOUND IN AGED ENVIRONMENTAL SAMPLES

	HOMOLOG								
	0	1	2	3	4	5	6	7	8
U.S. SALES '57 - '71	0.1	1.3	14.8	29.9	21.9	16.1	10.5	4.2	1.1%
AROCLOR 1254	<.1	<.1	<.5	1	21	48	23	6	ND

DSW 020000

STLCOPCB4007933

CONCLUSIONS

1. THERE ARE MARKED DIFFERENCES BETWEEN THE RATIOS OF HOMOLOGS IN PCBs FOUND IN "AGED ENVIRONMENTAL SAMPLES" AND THE RATIO OF HOMOLOGS FOR MATERIAL PRODUCED.

2. THESE DIFFERENCES CAN BEST BE EXPLAINED BY ASSUMING THAT THE PCBs WITH 3 OR LESS CHLORINE ATOMS PER MOLECULE DEGRADE MUCH MORE RAPIDLY THAN THE HIGHER HOMOLOGS.

3. THE HOMOLOG RATIO DATA DO NOT GIVE INFORMATION ON THE RATE OF DEGRADATION OF HIGHER HOMOLOGS. HOWEVER, SEMI-CONTINUOUS ACTIVATED SLUDGE TEST DATA SHOW THAT THESE TOO DEGRADE BUT AT A SLOWER RATE.

STLCOPCB4007934

MONSANTO PCB ACTIONS

IN CANADA

by

D. Goodwillie

DSW 020002

MAJOR TRADITIONAL USES OF PCB [1]

- OPEN SYSTEMS
  - PLASTICIZERS
  - SOLVENTS FOR CARBONLESS COPY PAPER[2]
- CLOSED SYSTEMS
  - DIELECTRICS
  - HEAT TRANSFER
  - INDUSTRIAL HYDRAULIC FLUIDS

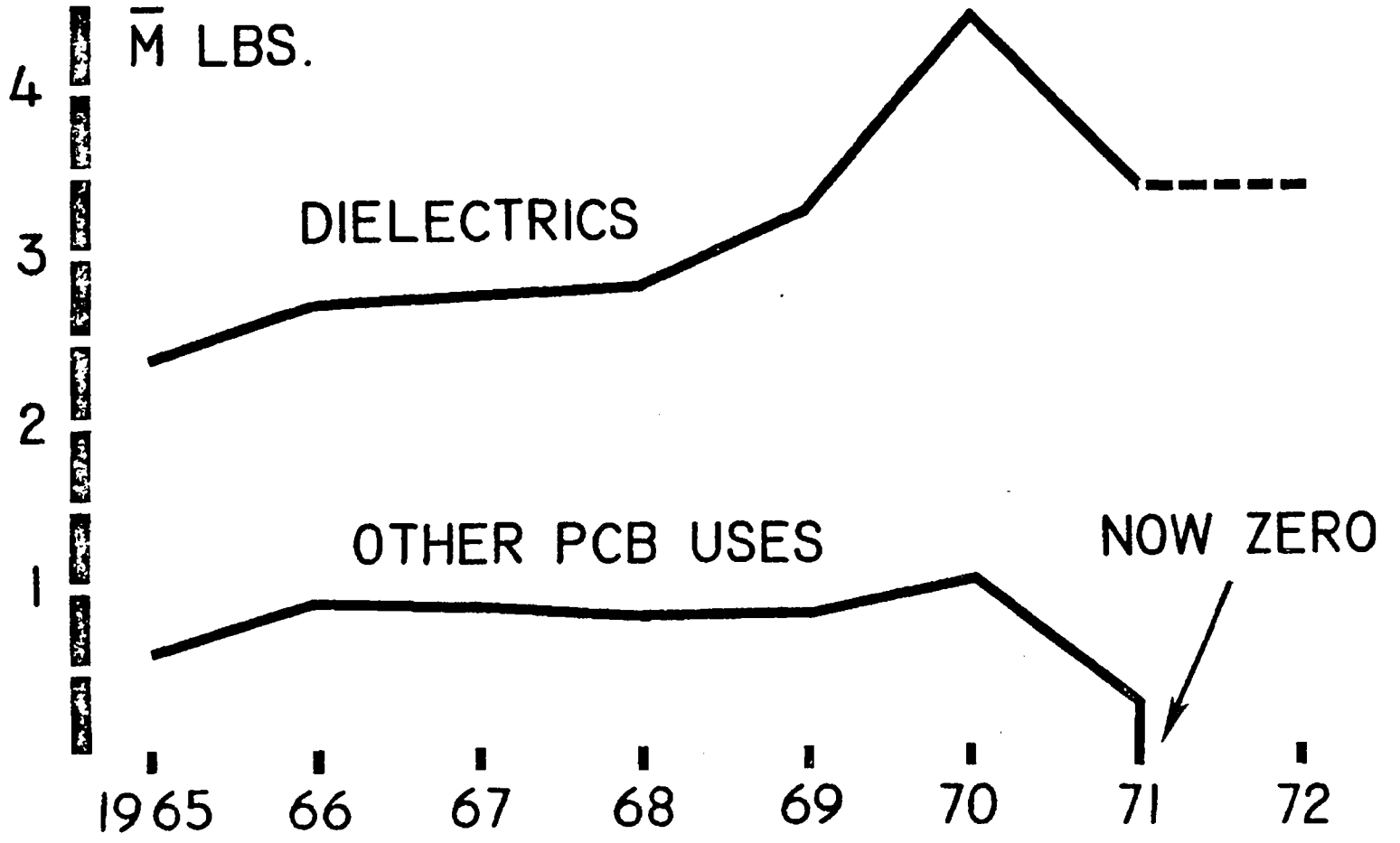
[1] POLYCHLORINATED BIPHENYLS

[2] NO SALES IN CANADA

DSM 020003

STLCOPCB4007936

MONSANTO PCB SALES IN CANADA



DSM 020004

STLCOPCB4007937

MONSANTO PCB ACTIONS

- PHASE-OUT OF PCB SALES WORLDWIDE IN ALL APPLICATIONS EXCEPT DIELECTRICS
- CONVERSION OF DIELECTRIC FLUIDS TO MORE BIODEGRADABLE PCB'S

MSD 020005

STLCOPCB4007938

MONSANTO PCB SALES

NORTH AMERICA

DIELECTRIC APPLICATIONS

	CANADA	U.S.A.	SALES IN CANADA
	(IN MILLIONS OF POUNDS)		%
1969	3.24	37.0	8
1970	4.44	40.5	10
1971	3.36	28.4	10
1972 EST	3.30	33.0	9

DSM 020006

STLCOPCB4007939

MONSANTO PCB SALES

NORTH AMERICA

NON-DIELECTRIC APPLICATIONS

	CANADA	U.S.A.	SALES IN CANADA
	(IN MILLIONS OF POUNDS)		%
1969	0.83	30.0	2.6
1970	0.96	33.5	2.8
1971	0.22	~ 3.7	~ 5.0
1972 EST	-	-	-

DSW 020007

STLCOPCB4007940

MONSANTO PCB SALES

NORTH AMERICA

CONCLUSIONS

- MONSANTO SALES FOR NON-DIELECTRIC USES IN CANADA ALWAYS WERE UNDER 3% NORTH AMERICA TOTAL
- MONSANTO SALES DIELECTRIC USES IN CANADA ARE ONLY ~10% NORTH AMERICA TOTAL

DSW 020008

STLCOPCB4007941

EFFECT OF
PHASE-OUT POLICY

MONSANTO PCB SALES REDUCED:

- IN NORTH AMERICA BY 31 TO 34 $\bar{M}$ POUNDS
- IN CANADA BY 0.8 TO 1.0 $\bar{M}$ POUNDS

DSM 020009

STLCOPCB4007942

PCB CHANGES IN DIELECTRICS

By

Dr. C. Paton

I respectfully submit we have achieved a significant reduction in PCB output by our actions. Turning to the second phase of our actions, viz, the product changes in PCBs for dielectric use, I will first take a moment to explain the variation in biodegradability of PCBs.

Slide 1: Degree of Biodegradation of PCBs.

The product changes made in dielectrics are shown on Slide 2: PCB Product Changes in Dielectrics.

Dealing first with capacitors:

Slide 3: PCBs used in capacitors

Note:
(a) Penta-chlorobiphenyl percentages include hexa- and higher homologs. Do not add both percentages together.

(b) This slide shows a substantial decrease in production of homologs of penta-chloro and higher over the years.

Slide 4: Why convert to Aroclor 1016?

Reasons were:

(a) 9-fold reduction in penta-chloro and higher homologs.

(b) 10-fold reduction in hexa-chloro and higher homologs.

(c) Aroclor 1016 was the PCB product that could be introduced into the capacitor industry while still meeting Underwriters Laboratory's requirement on flammability.

(d) Aroclor 1016 was selected because its electrical properties and in-plant processing performance most closely met the capacitor industry's requirements.

Note: Our choice of Aroclor 1016 has since been borne out by industry experience which to date has shown no problems.

STLCOPCB4007943

Slide 5: Capacitor Fluids: What is Effect of Aroclor 1016?

We have tried to show amounts of penta-chloro and higher and hexa-chloro and higher homologs which would have been produced (not entering the environment) for each of three possible capacitor fluids in 1972. Aroclor 1016 is obviously the PCB involving least penta and higher chloro biphenyl production.

Of obvious interest is the possible amount of PCBs entering the environment from capacitor failures.

Slide 6: What is the Capacitor Failure Rate?

Slide 7:

Using the worst case (0.2% per year failure) we see that no more than one pound of hexa-chloro and higher homologs of PCB are likely to enter the environment if Aroclor 1016 is used at a rate of 0.6M lb./year.

Turning now to Transformers.

Slide 8:

Note: Higher chlorinated PCBs are needed in transformers than in capacitors because the correct Hydrogen/Chlorine ratio is vital in preventing formation of flammable, explosive arc-form gases.

Slide 9: What is the Failure Rate in Liquid Transformers?

Slide 10: How Much PCB is Affected?

In Summary, Slide 11:

We will continue our voluntary policy of no more sales world-wide except to dielectric users. We will restrict over 97% capacitor fluid sales to Aroclor 1016 only. This means penta-chloro and high production will be no more than 1.1%. Hexa-chloro biphenyl and higher will be even lower at 0.1%. We will eliminate Aroclor 1260 from transformer fluids and continue incineration facilities for scrap PCBs. We will encourage the dielectric industry through ANSI C-107, which represents both capacitor and transformer manufacturers and users, to enforce strict environmental control over PCBs.

DSW 020011

DEGREE OF BIODEGRADATION OF PCB'S

BASED ON DATA PRESENTED

- TRANSITION IN BIODEGRADATION OCCURS AROUND PENTA-/HEXA-CHLOROBIPHENYL
- DISAPPEARANCE OF ALL HOMOLOGS BELOW HEXA-CHLOROBIPHENYL OBSERVED
- PENTA- AND HIGHER PCB DETERMINED BY SPECIFIC GLC/MS TEST METHOD

DSW 020012

STLCOPCB4007945

PCB PRODUCT
CHANGES IN DIELECTRICS

CAPACITORS

97% CONVERSION TO AROCLOR 1016

TRANSFORMERS

ELIMINATION OF AROCLOR 1260

DSM 020013

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PCB'S USED IN CAPACITORS

PCB	MAJOR USE PERIOD	% PCB (PENTA-CHLORO- AND HIGHER	% PCB (HEXA-CHLORO- AND HIGHER
AROCLOR 1254	1930-1952	77.0	29.0
AROCLOR 1242	1952-SEPT. 1971	9.0	1.0
AROCLOR 1016	OCT. 1971	1.1	0.1

DSM 020014

STLCOPCB4007947

CAPACITOR FLUIDS
WHY CONVERT TO AROCLOR 1016?

- 9-FOLD REDUCTION IN PCB'S OF PENTACHLORO- AND HIGHER
- 10-FOLD REDUCTION IN PCB'S OF HEXACHLORO- AND HIGHER
- MINIMUM INDUSTRY TESTING REQUIRED

DSW 020015

STLCOPCB4007948

CAPACITOR FLUIDS

WHAT IS THE EFFECT OF AROCLOR 1016?

CANADIAN CAPACITOR FLUID SALES

0.6 $\bar{M}$ LBS/YEAR (AVERAGE)

IF AROCLOR WAS	% PENTACHLORO- AND HIGHER PCBs WOULD BE*	% HEXA CHLORO- AND HIGHER PCBs WOULD BE*
1254	462,000 POUNDS	174,000 POUNDS
1242	54,000	6,000
1016	6,600	600

*THIS DOES NOT MEAN AMOUNTS OF PCB ENTERING THE ENVIRONMENT -- REFERS TO PCB MANUFACTURE.

DSW 020016

STLCOPCB4007949

WHAT IS CAPACITOR FAILURE RATE ?

INDUSTRY SOURCES CITE : 0.02-0.2% PER YEAR

DSW 020017

STLCOPCB4007950

IF CAPACITOR FAILURE RATE

IS 0.2% PER YEAR (WORST CASE)

PCB ESCAPE TO THE ENVIRONMENT* IS --

	AROCLOR 1242	AROCLOR 1016
ALL PCB HOMOLOGS	1,200 POUNDS	1,200 POUNDS
PENTACHLORO- AND HIGHER	108	13
HEXA CHLORO- AND HIGHER	12	1

* ASSUMES CANADIAN FLUID SALES OF 0.6 M POUNDS/YEAR

DSM 020018

STLCOPCB4007951

PCB CHANGES IN

TRANSFORMER FLUID APPLICATIONS

- AROCLOR 1260 BEING PHASED-OUT NOW
- INCINERATION OF SCRAP PCB'S - 1971

NOTE: ASKAREL (PCB) TRANSFORMERS ARE HERMETICALLY SEALED UNITS

DSW 020019

STLCOPCB4007952

WHAT IS FAILURE RATE IN LIQUID TRANSFORMERS?

INDUSTRY SOURCES CITE: UNDER 0.2% PER YEAR*

*ALL LIQUID TYPES - MINERAL OIL AND PCB.

DSM 020020

STLCOPCB4007953

IF ASKAREL (PCB)

TRANSFORMERS FAIL AT 0.2%/YEAR

HOW MUCH PCB IS AFFECTED*?

ALL PCB HOMOLOGS 6,000 POUNDS

(ESTIMATED MONSANTO PCB TRANSFORMER FLUID SALES IN CANADA 3 M POUNDS/YEAR)

*WITH INCINERATION FACILITIES AVAILABLE, NOT ALL THESE AMOUNTS WILL ENTER ENVIRONMENT.

DSW 020021

STLCOPCB4007954

MONSANTO'S PRESENT PROGRAM TO PREVENT ENVIRONMENTAL POLLUTION BY PCB'S

- NO MORE SALES WORLD-WIDE EXCEPT DIELECTRIC USERS
- RESTRICT OVER 97% CAPACITOR FLUID SALES TO AROCLOR 1016 ONLY
- ELIMINATE AROCLOR 1266 FROM TRANSFORMER FLUIDS
- CONTINUE INCINERATION FACILITIES FOR SCRAP PCB'S
- ENCOURAGE DIELECTRIC INDUSTRY THROUGH ANSI C-107 TO ENFORCE STRICT ENVIRONMENTAL CONTROL OVER PCB'S

DSM 020022

STLCOPCB4007955

ANSI C-107

COMMITTEE ACTIVITIES

By

P. G. BENIGNUS

DSW 020023

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PERSONNEL
OF
AMERICAN NATIONAL
STANDARDS INSTITUTE

COMMITTEE C107

DSM 020024

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ADMINISTRATIVE

STEERING COMMITTEE, CHAIRMAN ----------	PAUL G. BENIGNUS MONSANTO COMPANY
COMMITTEE C107, CHAIRMAN ----------	W. B. PAPAGEORGE MONSANTO COMPANY
COMMITTEE C107, SECRETARY ----------	AL M. SALAZAR NEMA
CAPACITOR SUB COMMITTEE, CHAIRMAN -----	DR. AL POZEFSKY GENERAL ELECTRIC
TRANSFORMER SUB COMMITTEE, CHAIRMAN ---	EDW. L. RAAB GENERAL ELECTRIC

DSM 020025

STLCOPCB4007958

CAPACITOR SUBCOMMITTEE MEMBERS

NAME	BUSINESS AFFILIATION	ORGANIZATION REPRESENTED
N. R. CLARK	UNIVERSAL MFG.	CERTIFIED BALLAST MFRS. ASSOC.
ARNOLD S. DOTY	P. R. MALLORY	ELECTRONICS INDUSTRIES ASSOC. (EIA)
R. D. McCLAIN	WESTINGHOUSE	NATIONAL ELECTRICAL MFG. ASSOC.
KEN McGEE	SANGAMO	NEMA
DR. E. M. MOORE	ELECTRICAL UTILITIES	--
E. G. HAMMER	McGRAW EDISON	NEMA
R. L. ROLLINS	JARD CO.	EIA

DSW 020026

STLCOPCB4007959

TRANSFORMER SUBCOMMITTEE MEMBERS

NAME	BUSINESS AFFILIATION	ORGANIZATION REPRESENTED
F. R. LENGEFELD	UNION ELECTRIC CO.	ELECTRIC LIGHT & POWER
H. A. ONISHI	COMMONWEALTH EDISON	ELECTRIC LIGHT & POWER
J. P. MARKEY	EDISON ELECTRIC INST.	ELECTRIC LIGHT & POWER
W. S. GROGAN	ALLIS CHALMERS	NEMA
W. C. REINHARDT	MOLONEY	NEMA
H. R. ROWE	McGRAW EDISON	NEMA
A. L. RICKLEY	DOBLE ENGINEERING	DOBLE CLIENTS
DR. T. K. SLOAT	WESTINGHOUSE ELECTRIC	IEEE AND ASTM

DSW 020027

STLCOPCB4007960

GOVERNMENT REPRESENTATIVES
SERVING BOTH COMMITTEES

NAME	ORGANIZATION REPRESENTED
D. M. CRABTREE	DEPARTMENT OF THE ARMY
DR. KENNETH J. HOOD	ENVIRONMENTAL PROTECTION AGENCY - R+M
CHARLES C. TRAVIS	GENERAL SERVICES ADMINISTRATION
AARON J. WOLOSHIN	OFFICE OF ENVIRONMENTAL AFFAIRS
DR. STANLEY P. WASIK	NATIONAL BUREAU OF STANDARDS
DR. JOHN DEUTRITZ, JR.	RURAL ELECTRIFICATION ADMINISTRATION
WM. R. NICHOLAS	DIRECTOR ENVIRONMENTAL RESEARCH TENNESSEE VALLEY AUTHORITY

DSM 020028

STLCOPCB4007961

INDIVIDUALS
SERVING BOTH COMMITTEES

NAME	COMPANY
AL O. HAUSER	ELECTRICAL UTILITIES
H. A. ALSENTZER	ROLLINS-PURLE, INC.
C. W. HART	ROLLINS-PURLE, INC.
JULES S. LAPIDES	GILBERT ASSOCIATES, INC.
LOUIS E. WAGNER	CHEM-TROL POLLUTION SERVICE
P. WILLIAMSON	ROLLINS-PURLE, INC.

DSW 020029

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OTHER AGENCIES

NAME	ORGANIZATION REPRESENTED
ALEX RODIN	AMERICAN PUBLIC POWER ASSOC.
THOMAS GOODFELLOW	ASSOC. AMERICAN RAILROADS
W. FLOYD-JONES	ASSOC. OF EDISON ILLUMINATING COMPANIES
T. C. MANN	AMERICAN AUTOMOBILE MFG. ASSOC.
C. S. MORGAN	NATIONAL FIRE PROTECTION ASSOC.
B. WHITAKER	UNDERWRITERS LABORATORIES
B. A. CANHAM	WATER POLLUTION CONTROL FEDERATION
C. C. EDWARDS	FOOD AND DRUG ADMINISTRATION
	DEPARTMENT OF INTERIOR
R. SMITH	WATER AND POWER DEVELOPMENT
E. L. ARMSTRONG	COMM. OF RECLAMATION
H. R. RICHMOND	BONNEVILLE POWER ADMINISTRATION
C. L. KLEIN	WATER QUALITY AND RESEARCH

DSW 020030

STLCOPCB4007963

OBJECTIVES OF ANSI C107

- SOURCE OF TECHNICAL INFORMATION AND ADVICE FOR FEDERAL, STATE, LOCAL AUTHORITIES AND ALL OTHERS CONCERNED.
- ENCOURAGE DEVELOPMENT OF SUITABLE DISPOSAL FACILITIES AND KEEP ALL CONCERNED INFORMED.
- SERVE AS THE ADVISORY GROUP FOR U.S. PARTICIPATION IN INTERNATIONAL ORGANIZATIONS: CEE, IEC, SIGRE.

DSW 020031

STLCOPCB4007964

SCOPE OF ANSI C107

PROCEDURES AND GUIDES FOR SAFE USE MAINTENANCE AND DISPOSAL OF ASKAREL AND ASKAREL-SOAKED MATERIALS USED IN ELECTRICAL EQUIPMENT.

DSW 020032

STLCOPCB4007965

USE AND DISPOSAL OF ASKAREL FLUID AND ASKAREL-SOAKED MATERIALS

DSM 020033

STLCOPCB4007966

CAPACITOR GUIDELINES

AROCLOR 1016

SPECIFIES EXCLUSIVE USE OF ASTM D 2233 TYPE D ASKAREL FOR CAPACITORS. LIMITS HIGHER BOILING HOMOLOGS TO 0.4% BY MONSANTO METHOD T-02302.

DSM 020034

STLCOPCB4007967

MINIMIZE
EFFLUENT STREAM CONTAMINATION

- ISOLATE ALL EFFLUENT STREAMS, USE SUMPS, CARBON ABSORPTION, LIMESTONE BEDS AND SOLVENT EXTRACTION TO REDUCE PCBs.
- CONSISTENT WITH EPA GOAL BELOW 0.01 PARTS PER BILLION IN LAKES AND RIVERS.

DSM 020035

STLCOPCB4007968

SMALL CAPACITORS

CONTAINING LESS THAN 2 POUNDS OF ASKAREL

NOT FITTED WITH PCB WARNING LABEL
DISPOSED AS HERETOFORE, INCLUDES
BALLAST AND MOTOR RUN TYPE UNITS

DSM 020036

STLCOPCB4007969

LARGE CAPACITORS

CONTAINING MORE THAN 2 POUNDS OF ASKAREL

LABELED CAUTION THIS CAPACITOR CONTAINS PCB.
TO AVOID POSSIBLE ENVIRONMENTAL CONTAMINATION,
IT SHOULD BE DISPOSED OF ONLY IN SUPERVISED
DRY LANDFILL AREAS MEETING STATE REQUIREMENTS
OR IN INCINERATION FACILITIES DESIGNED FOR
DISPOSAL OF PCBs.

DSW 020037

STLCOPCB4007970

SCRAP ASKAREL FLUID

TO BE COMPLETELY DESTROYED BY INCINERATION
AT LEAST 2,000°F AND HCL GAS NEUTRALIZED.

SCRAP SOLID WASTE

BURY IN SUPERVISED DRY LANDFILL.

DSW 020038

STLCOPCB4007971

CAUTION LABEL

FOR ASKAREL TRANSFORMERS

THE INSULATING LIQUID IN THIS TRANSFORMER CONTAINS POLYCHLORINATED BIPHENYLS (PCBs). CARE SHOULD BE TAKEN TO PREVENT ENTRY INTO THE ENVIRONMENT. IN CASE OF MALFUNCTION OR LEAKS, CONSULT THE INSTRUCTION MANUAL OR THE MANUFACTURER.

DSM 020040

STLCOPCB4007972

SUMMARY

By

W. B. Papageorge

In summary, our observations, admittedly limited, both from our laboratory data and from reports of other investigators, lead us to believe with considerable confidence that PCBs do degrade in the environment. The complexity of the commercial mixtures has, however, hampered the determination of the varying rates of degradation of all the possible isomers.

Monsanto's sales actions have definitely reduced the amount of PCBs that could be introduced into the environment.

In those applications in which the use of PCBs is considered essential, namely transformers and capacitors, further actions will assure strict environmental control on PCBs.

In transformers the elimination of the use of Aroclor 1260, along with proper handling during manufacture, use and repair and proper disposal of waste fluid by high temperature incineration, should result in acceptable control.

For the capacitor application the development of Aroclor 1016, which satisfied all of the industry's requirements relating to dielectric characteristics and handling properties, as well as having Underwriters Laboratory fire-resistance approval, permits the continued use of PCBs in this important hermetically-sealed application but with a fluid that has a significantly lower content of the slower degrading isomers. The use of this material, accompanied by proper handling and disposal of the scrap fluid by high temperature incineration, represents, in our considered opinion, a significant step forward in our efforts to control the impact of PCBs on the environment.

STLCOPCB4007973