EVALUATION OF CHANGES OF THE LEVEL OF POLYCHLORINATED BIPHENYLS (PCB) IN HUMAN TISSUE

Final Report on FDA Contract 223-73-2209

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Harold E. B. Humphrey, Ph.D.
Project Director
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EVALUATION OF CHANGES OF THE LEVEL OF POLYCHLORINATED BIPHENYL IN HUMAN TISSUE

SUMMARY OF FINDINGS

A two year study was made of persons who regularly consumed Lake Michigan sport fish and randomly selected persons who did not consume such fish. A total of 161 adults from the shoreline communities of Traverse City, Manistee, Ludington, and South Haven participated. 105 of these participants consumed more fish than recommended by the Michigan Department of Public Health (no more than one meal per week or 24 pounds per year) and constituted the PCB "exposed" group. The 37 participants eating six pounds or less per year, 19 eating an intermediate amount, and 19 fish eaters from Algonac where sport caught fish are low in PCB were used for comparison groups. A short medical history, a dietary record, and blood specimens were obtained for all participants. The following conclusions were reached from these data:

1. PCB blood levels ranged from 0.007 ppm in persons who ate no fish to a maximum of 0.366 ppm for a person eating Lake Michigan fish.

2. There was a direct relationship between the size and quantity of sport species of fish eaten and the PCB levels found in human blood.

3. In 1973, those who annually consumed 24 or more pounds of sport fish from Lake Michigan had a mean blood PCB value of 0.073 ppm; persons annually eating 6 pounds or less had a mean level of 0.020 ppm; persons who ate no fish averaged 0.017 ppm; and persons eating 24 or more pounds annually from Lake St. Clair had an average blood level of 0.023 ppm. The PCB blood levels observed for the Lake Michigan study groups were similar in 1974.

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4. The level of PCB found in the blood of participants did not change significantly from year to year, nor did it diminish significantly when fish consumption was eliminated for up to nine months.

5. The PCB levels observed in cooked fish were lower than expected from reported levels in raw fish.

6. Eighty-two percent of those who exceeded the state's recommended maximum intake (no more than one meal per week or 24 pounds per year) of Lake Michigan fish received an estimated annual dose of PCB which was greater than that cited by the Food and Drug Administration as the maximum annual dose of PCB which should be received over a protracted period of time. This estimated intake ranged from 0.49 µg PCB/Kg body weight/day to 3.94 µg PCB/Kg body weight/day and averaged 1.7 µg/Kg body weight/day. The Food and Drug Administration recommends that PCB intake not exceed 1 µg/Kg body weight/day for long term exposure.

7. As a group, the exposed participants had no health problems or medical conditions that could be correlated with PCB blood levels, exposure to Lake Michigan fish, or known symptoms of PCB poisoning.

CONCLUSION:

Consumption of Lake Michigan fish contributed substantially to the PCB levels in the blood of humans. The dose received is insufficient to produce a detectable effect on human health at present. It has not been determined whether long term exposure to PCB contaminated fish will result in a continuing accumulation of PCB's or eventually produce identifiable health effects in humans. The data gathered to date appear to justify continued surveillance of this situation in Michigan. The data also justify a continued recommendation that intake of Lake Michigan salmon and lake trout be limited to less than one meal per week or 24 pounds per year.

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EVALUATION OF CHANGES OF THE LEVEL OF POLYCHLORINATED BIPHENYL IN HUMAN TISSUE

INTRODUCTION

Polychlorinated biphenyls (PCB) have been manufactured and used for over forty years in a wide variety of industrial applications which require a substance with chemical and thermal stability. Approximately 40% of these uses may have resulted in loss of PCB to the environment. PCB residues began to be identified in animal and environmental samples in the late 1960's and it was soon confirmed that this chemical was a persistent and a ubiquitous world wide environmental contaminant (1, 2). PCB's have been detected in manufactured products, air, water, snow and sediment samples as well as aquatic biota and terrestrial animals and birds. A consequence of this situation has been concern about the indirect contamination of some foods destined for human consumption and the resulting exposure of humans to PCB. Reports of the detection of low levels of PCB in tissues from the general population (3, 4) have confirmed that human exposure is a reality.

The human health effects from PCB exposure, especially long term low level exposure, are not clearly understood. Information on PCB exposure for humans has been chiefly confined to acute effects from industrial exposure and an extensive food contamination episode in Japan where a disease called Yusho has been described (7). Although reports on the toxic symptoms observed with Yusho have generally been accepted as attributable to PCB poisoning, the suspected existence of other toxic contaminants in Japanese PCB preparations has raised questions on the cause of some of these observed effects.

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Scientific information on the characteristics and toxicity of PCB's was reviewed in 1972 (2), and currently by the Food and Drug Administration (FDA) with respect to the adequacy of the temporary tolerances for PCB (9). The body of data reported to date indicates that the toxicity of PCB varies with the extent of chlorination of the biphenyl molecule. These compounds are poorly metabolized and tend to accumulate and be retained in the lipid portion of animal tissues for prolonged periods (5, 10, 11). The accumulation and storage of a chemical would theoretically make it available, under appropriate conditions, for recirculation within the body allowing continuous or repeated exposure of target organs long after the original dose has ceased or when multiple low doses are received and accumulated to a critical level. The significance of the observed accumulation and storage of PCB in tissue is not fully known. However, recent reports of the continued presence of some clinical signs in Yusho patients years after the incident (5, 12) and the detection of significant levels of PCB in rat tissues ten months after exposure (11) tend to support the storage - continued exposure contention. Moreover, recent studies reporting acute health effects including reproductive failure in primates fed low levels of PCB (13, 14), the induction of liver tumors in rats from PCB ingestion over prolonged periods (15), and the partial conversion of tetrachlorobiphenyl to a more acutely toxic monohydroxy-metabolite in rats (16) suggests that long term or low level exposure to PCB or its metabolic byproducts is not fully understood and may be of significance.

The existing body of toxicity data for PCB has been sufficient for the FDA to regard these compounds as potentially serious health hazards in food. Temporary tolerances for PCB's were established by the FDA in 1973 (8). The determination of tolerance levels was predicated on the assumption that PCB exposure from food was sporadic and would diminish with time. Subsequent surveillance data has confirmed this to be true

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except for fresh water fish found in certain areas of the nation (9). It has been concluded that frequent consumption of fish containing PCB in excess of 5 parts per million (ppm) poses a risk to public health. Data for the evaluation of this risk to humans has not been available. Concern about the risk and the need to obtain information on humans exposed to PCB's from consumption of contaminated fish was the basis for establishing the research contract reported below.

THE PCB PROBLEM IN MICHIGAN

The Great Lakes surrounding Michigan represent one of the areas of the nation contaminated with PCB. The Michigan Water Resources Commission has reported that many surface water samples contained PCB at concentrations above the detection limit of 10 parts per trillion (ppt). Significant levels of PCB have been found in rivers and streams discharging into the Great Lakes. Effluents from wastewater treatment plants servicing industrialized communities have been found to be highly contaminated. Although efforts have been made to eliminate point source industrial losses of PCB, recent monitoring reveals that PCB contamination continues to be a problem. It has been suggested that highly contaminated bottom sediments in sewers and receiving streams may represent a reservoir for the continued release of PCB. It has been concluded that PCB continues to be discharged into the Great Lakes from many small but diffuse sources including atmospheric fallout.

PCB's were first detected in Great Lakes fish in 1969 when substances interfering with the analysis of DDT in Coho salmon samples were determined to be PCB (3). Subsequent environmental monitoring has identified

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PCB contamination in fish from all of the Great Lakes. The problem is most severe in Lake Michigan and least severe in lakes Huron (except for Saginaw Bay) and Lake St. Clair. Concern for PCB contamination has focused on Lake Michigan because of the large investment in the rejuvenation of this lake for sport fishing through fish stocking programs.

Statistical sampling surveys of contaminants in Great Lakes fish began in 1972. This program has shown that most species tested contained detectable levels of PCB's and that contamination levels were generally proportional to fish size (age) and highest in the predator species. Except for whitefish, the species of commercial or sport interest (trouts and salmons) from Lake Michigan were found to be most highly contaminated with PCB. Moderate and larger sized specimens have been found to be well in excess of the FDA tolerance level of 5 ppm. A portion of the data obtained for fillets of lake trout from Lake Michigan during the 1974 Great Lakes Environmental Contaminants Survey is exemplified below:

Lake Zone	(Size) Pounds	No. Fish	Mean PCB (ppm)
MM4	5-10	3	3.06
MM5	5-10	7	9.01
MM6	5-10	20	9.08
MM7	5-10	11	11.86
MM8	5-10	6	11.93

The lake zones refer to the statistical sampling areas of Lake Michigan from which the specimens were taken and are identified in Figure 1. The values shown indicate a trend of increasing PCB levels as samples are obtained further south in the lake along more heavily populated and industrialized areas of the State.

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Unfortunately PCB contamination of fish in the Great Lakes has not decreased to date. Table 1 shows data from a three-year study of two species of Lake Michigan fish by the U.S. Fish and Wildlife Service Laboratory. As shown, the PCB levels in lake trout appear to have risen and have not declined in Coho salmon over the study period.

TABLE 1. PCB CONTAMINATION IN WHOLE FISH*

Species & Location	Collection Year	Length (inches)	Sample Size	Mean PCB Value (ppm)
Lake Trout near South Haven	1972	20 - 28	9	12.86 ± 4.75
	1973	20 - 28	30	18.93 ± 2.08
	1974	20 - 28	30	22.91 ± 3.75
Coho Salmon near Ludington	1972	20 - 32	10	10.93 ± 2.12
	1973	20 - 32	29	12.17 ± 0.77
	1974	20 - 32	30	10.45 ± 0.92

*Data from the Great Lakes Fishery Laboratory, U.S. Bureau of Sport Fisheries and Wildlife.

The continued discharge of PCB into the water and trend analyses such as these indicate that PCB contamination of Great Lakes fish is a long term problem.

Sport fishing represents an uncontrolled source of PCB contaminated fish for distribution and human consumption. The State and federal inspection system controls exposure to PCB from commercial sources by seizure of contaminated fish before it reaches the market. Sport fishermen and those who consume sport caught Great Lakes trout and salmon represent the population most likely to be at risk to significant PCB exposure from fish. The Michigan Department

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TABLE 2. 1974 CATCH AND EFFORT REPORT FOR LAKE MICHIGAN*

	SPECIES					
	Lake Trout	Rainbow - Steelhead	Brown Trout	Coho Salmon	Chinook Salmon	TOTAL
No. Caught/ Year	739,260	271,980	96,480	502,200	264,420	1,874,320
Mean Weight/ Fish	5-6	8-10	5	6	15	-
Pounds of Fish Caught/ Year	4,065,930	2,447,820	482,400	3,013,200	3,966,300	13,975,650
No. Pounds/ Fisherman/ Year	10.6	6.4	1.3	7.9	10.4	35.6

* Data from the Michigan Department of Natural Resources 1974 Annual Sport Fishing Survey. Information obtained from statistical quarterly census of the 381,600 licensed fishermen in the 18 Michigan counties bordering Lake Michigan.

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Natural Resources indicates that 381,000 licensed fishermen reside in the 18 counties bordering Lake Michigan. That department's 1974 sport fishing survey (Table 2) shows that this group catches about 14 million pounds of trout and salmon from Lake Michigan annually. As indicated, the average size of the fish being caught fall into the range which is significantly contaminated with PCB. Statistically, each of these fishermen obtains 36 pounds per year (3/4 pounds per week) of Lake Michigan fish for consumption. This is over three times the reported national per capita consumption of fish from commercial sources (11.8 pounds) but about half that reported for the Japanese (67.6 pounds) (Source: Production Yearbook, 1970, vol. 24, Food and Agriculture Organization of the United Nations). Although the habits of individuals will vary it appears that as a group these sport fishermen consume more fish than the average and are successfully catching the PCB contaminated species from Lake Michigan.

THE MICHIGAN PCB STUDY

The Food and Drug Administration Contract 223-73-2209 with the Michigan Department of Public Health represents an attempt to evaluate human exposure to PCB from consumption of sport caught Lake Michigan fish. The study was principally designed to provide information on the levels and changes in the level of PCB's in humans. It was not intended to be a full toxicological evaluation of the human health effects of PCB exposure. The major objectives of the study were:

1. To conduct research on the analysis of PCB's in order to develop a sensitive laboratory method for detecting PCB concentrations in human blood.

2. To identify exposed and control population groups in selected geographical locations where PCB levels in fish are excessive.

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3. To select participants for the study and collect suitable blood specimens using accepted epidemiologic techniques.

4. To evaluate the concentration and variation of PCB's in representative groups of humans.

5. To estimate the fish consumption characteristics of the selected exposed group.

6. To determine the PCB levels in fish being consumed by humans.

7. To determine by laboratory analysis the concentration of PCB's in participants' blood specimens in order to evaluate:

   A. The PCB ingestion from fish

   B. The PCB levels in the blood of humans who eat fish and who do not eat fish

   C. The variation of PCB levels in blood due to seasonal fish consumption habits

   D. The metabolic half-life of PCB's present in the blood of humans

8. To attempt to correlate levels of PCB in tissues with levels of PCB ingestion.

FIELD SURVEY DESIGN:

The greatest opportunity for exposure to PCB's, as discussed above, was believed to lie in the consumption of certain sport caught species of Lake Michigan fish. Persons from four Michigan communities, South Haven, Ludington, Manistee, and Traverse City, all on the shoreline of Lake Michigan (see Figure 1) were selected for the study. These communities are points of origin for Great Lakes sport fishing and span the principal areas of Lake Michigan where PCB contaminated

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FIGURE 1. LOCATION OF PCB EXPOSED & CONTROL PARTICIPANTS

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fish have been identified. In addition, Algonac, a shoreline community on Lake St. Clair where PCB levels in fish are not excessive was included for a comparison of fishermen from a different geographical location.

Exposed and control subjects for the study were personally selected by field workers following introductory publicity in the local news media of each community. Adults (age 18 and above) who caught and regularly ate sport fish from Lake Michigan were sought and encouraged to participate. Exposed participants, those consuming at least 24-26 pounds of Great Lakes fish per year (an annual average of at least one 8 oz. meal per week) were identified through a voluntary and referral system. Control participants, those consuming less than six pounds of Great Lakes fish per year (an annual average of zero to no more than one 8 oz. meal per month) were identified by contacting households randomly selected from the directory for each community. All potential participants, whether voluntary or randomly selected, were visited and personally interviewed in order to determine their eligibility for the study utilizing the above fish consumption criteria and a questionnaire developed for the study. Those judged eligible by the interviewer, as determined by the responses to the fish consumption questions, were invited to participate in the study. Persons in agreement were then briefed on the purpose and extent of the study, were fully interviewed, given a bound log for recording their subsequent consumption of Great Lakes fish, and were asked to freeze portions of their fish meals. In each case the interviewer explained the importance and method for these procedures.

Periodic contacts were made in order to maintain participant interest in the project and to schedule blood sample collections. Specimen collections for laboratory analysis were scheduled at the local health department offices at times convenient for the participants. Whole blood samples (20 cc) were collected by venipuncture by the

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Michigan Department of Public Health staff. During these appointments, questionnaire information was updated and an informed consent statement was signed by the participant.

Exposed and control populations in South Haven, Ludington, Manistee and the Traverse City area were identified and selected for the study as described above. Blood specimens were collected from 152 persons during the Fall of 1973 at the end of the fishing season on the Great Lakes. This sampling provided a baseline for evaluation of PCB values after consuming sport fish through a whole fishing season. The classification and location of these participants are shown in Table 3. The representative number of randomly selected unexposed controls to be sought from each community was determined by consultation with statisticians. The group classified as "intermediate" represents persons who qualified as fish eaters when initially interviewed, but failed to actually consume a sufficient quantity of Great Lakes fish during the 1973 season or the 1974-75 season to be classified as exposed fish eaters.

Blood specimens were collected during the Spring of 1974 (April sample, Table 4) from seventeen of the Traverse City area fish eaters who had been sampled the previous Fall. These collections were made prior to the resumption of sport fishing for the 1974 season and represent an attempt to evaluate the seasonal variation in the level of PCB's in exposed persons. Consumption of frozen or canned Great Lakes fish during the winter months represents a problem for the evaluation of seasonal variation. It was originally believed that consumption of sport fish would cease shortly after the fresh supply was exhausted at the end of the fishing season. However, work with the study participants revealed that fresh caught sport fish are preserved, frozen or canned, to a much greater extent than expected. Thus, the cessation of fish consumption is not

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TABLE 3. PCB STUDY, PARTICIPATION BY CITY

CITY	Number Participants 1973				Number Participants 1974-75				Total Number Participants Over Life of Study			
	Total	Control	Inter-mediate	Exposed	Total	Control	Inter-mediate	Exposed	# Indi-viduals	Sex M	Sex F	Media Age
Traverse City	53	19	5	29	60	13	10	37	74	32	42	49.5
Manistee	21	7	2	12	21	5	3	13	25	13	12	45.9
Ludington	28	10	8	10	20	7	5	8	33	15	18	41.0
South Haven	31	2	4	25					31	21	10	42.5
Algonac	19	0	5	14*					19	13	6	51.3
TOTALS	152	38	24	90	101	25	18	58	182	94	88	45.3

*Exposure here constitutes consumption of fish from Lake St. Clair where PCB levels are relatively low.

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abrupt but instead tapers off slowly as the preserved supply is exhausted or continues at a reduced level until the following fishing season.

The 101 participants for the second (1974-75) phase of the study are listed in Table 3 by location. The July 1974 specimen collection (Tables 4, 5, 6) provided a second baseline sample for the study. A portion of these participants are persons who were included in the Fall screening from the previous year (1973). This provided for a year to year comparison of PCB levels in certain individuals. The balance of the 58 fish eaters were recruited during the Spring of 1974. Emphasis was placed on recruiting persons with a history and expectation of catching and consuming an amount of fresh fish well in excess of the required 24-26 pounds per year. This effort was in response to the realization that the quantity of fish consumption among Great Lakes fishermen is not consistent from year to year. Fish consumption appears to be dependent on the weather (number of trips onto the lake) and on success once at the fishing grounds. One of the problems encountered during this study was the inability of some exposed participants to catch and consume the anticipated quantity of fresh fish throughout the study. In some cases this necessitated a downward reclassification of the participant.

The 1974-75 phase of the PCB Project provided a second year comparison, a close monitoring of individual fish consumption over an entire fishing season, and an evaluation of the change in level of PCB's in blood through a series of specimen collections after the voluntary termination of fish consumption at the end of the season. Completion of the abstinence study was complicated by the staggered dates when individuals concluded one fishing season and began the next. In addition, the request for participants to cease eating sport fish represented a

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break in their normal habit of consuming frozen fish through the winter. These problems resulted in the elimination of some participants from this portion of the study, because they failed to abstain from eating fish for a sufficient period of time.

STUDY FINDINGS:

The study was designed to include 140 to 160 participants. This goal was achieved as 182 persons participated during the 2 years of the study. Table 3 shows the classification of participants in each community for the 1973 and 1974-75 phases of the study. The size of the control group was based on the number needed to be statistically acceptable for data evaluation. The intermediate exposure classification was necessitated by the realization that a difference existed between estimated fish consumption based on recall responses to the questionnaire and actual consumption of fish during the study period. As explained previously some persons who were alleged to consume over 24-26 pounds of Lake Michigan fish annually failed to do so and were reclassified from the exposed to an intermediate (7 to 23 pounds per year) group.

Many of the first year participants continued in the study to its conclusion. Those who elected to drop out and those who were reclassified as intermediate exposure after the first year were replaced by additional exposed participants for the second year of the study. Table 3 also shows that the distribution of males and females was nearly equal and that the median participant age was about 46 years. The age, sex, height, and weight data for each participant is provided in Appendix C.

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The quantity of fish consumed by individuals in the exposed classification was as a group unimpressive but correlated with the calculated mean catch as reported in the sport fishing survey (Table 2). The reported popularity and catch success of sport fishing on Lake Michigan and the deliberate effort to enlist reputed fishing enthusiasts in the study led to expectations that the exposed group would consume large quantities of fish. However, a plot of the distribution of mean annual fish consumption over the two fishing seasons of the study shows that the most frequently recorded quantity of fish actually consumed was in the 24-35 pounds per year range (Figure 2). The number of participants reporting a consumption of greater than 53 pounds was low. The highest reported consumption over the two year period was 180 pounds per year and the highest single season consumption was 260 pounds per year (data for annual consumption from Tables 4, 5, 6 & 7). The annual consumption for each fisherman based on a two year average was lower than that based on a single season because of the aforementioned inconsistency in fishing success from year to year. Although the reported size and species of fish being consumed indicates a significantly contaminated raw food source is being obtained, the average Michigan fisherman apparently does not consume high quantities of fish. The study did confirm that these people eat more fish than the reported national per capita average of 11 pounds per year and that some individuals consume significant amounts of contaminated fish.

PCB's were found in 500 blood and one breast milk specimens collected from participants during the study. The values ranged from a low of 0.007 ppm in the control group to a high of 0.366 ppm in the exposed group. A baseline sample for 1973 (November) and for 1974 (July), a spring sample in 1974, and a series of samples commencing in 1974 and ending in 1975 represent the planned collection schedule for the study. The annual fish consumption and the concentrations of PCB detected in blood collected from participants at the specified times during the study are shown in Tables 4 (Traverse City),

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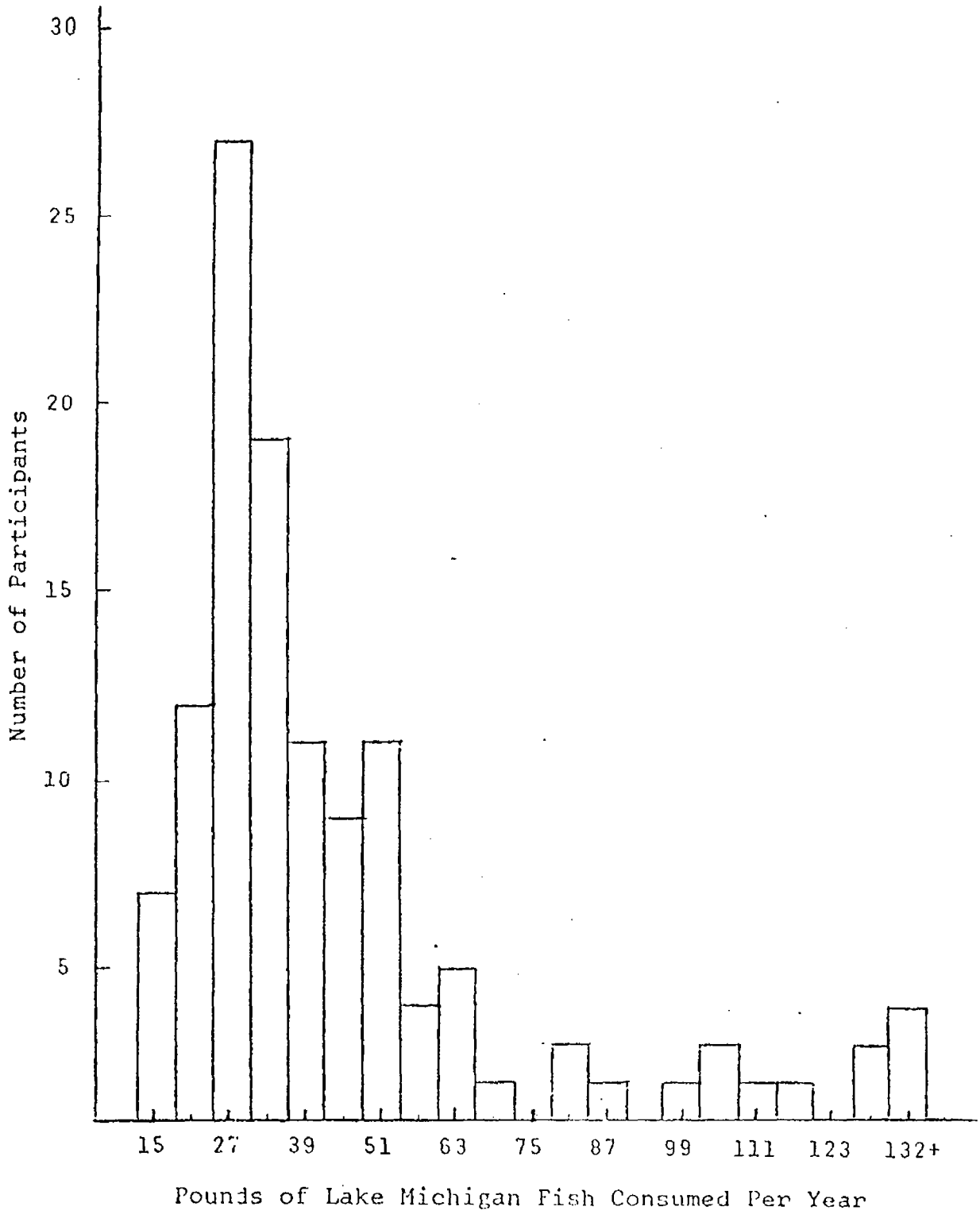

FIGURE 2. FREQUENCY DISTRIBUTION OF REPORTED GREAT LAKES FISH CONSUMPTION, EXPOSED GROUP, TRAVERSE CITY, MANISTEE & LUDINGTON

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5 (Manistee), 6 (Ludington), and 7 (South Haven and Algonac). The participants are listed in these tables by ascending order of annual fish consumption as reported for the 1974 baseline year. The raw laboratory data for all PCB tests run are recorded in Appendices A and B. The 35 test results shown in Appendix B are for specimens which were depleted during the development of the final analytical test procedure. These results have been segregated and are not presented in Tables 4, 5, 6 & 7 because it was not possible to retest these specimens with the more precise procedure which was adopted for use in the study.

There was a highly significant correlation between the reported quantity of Lake Michigan fish consumed and the concentration of PCB in the blood of participants in the study. Examination of the blood level and fish consumption data for persons from four communities bordering Lake Michigan (Tables 4, 5, 6 & 7) revealed 117 participants who reported eating fish from the lake in 1973. A plot of the levels of PCB in blood vs pounds of fish consumed for this group (Figure 3) indicates a wide range of blood values for each quantity consumed. Using a natural log transformation* of PCB values the data was again plotted (Figure 4) and the correlation between these variables determined to be 0.51 which is highly significant ($t = 6.24$, $p<<.001$). Thus higher reported fish consumption was associated with more PCB. In addition, a regression analysis of other variables (from Appendix C) showed that being older and male (height and weight correlated significantly with PCB and with being male) was significantly associated with higher PCB levels ($p<<.001$).

The direct relationship between the concentration of PCB in blood and increasing quantities of Lake Michigan fish consumed was observed in all four of the study communities

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*A log transformation is used when variance increases as values increase (18).

Statistical computations were provided by the Office of Vital and Health Statistics, Michigan Department of Public Health.

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TABLE 4. CORRELATION OF FISH EXPOSURE WITH PCB VALUES IN BLOOD OVER A TWO YEAR PERIOD, TRAVERSE CITY GROUP.

I.D.#	1973 Fish Consumed	1974 Fish Consumed	BLOOD SPECIMENS - Total PCB in parts per million						
			Nov.'73	Apr.'74	Jul.'74	Jan.'75	Feb.'75	Apr.'75	May '75
)354	0 lbs.	0 lbs.	0.033		0.027				
9345*	0 lbs.		0.019						
0340*	0 lbs.		0.041						
3341*	0 lbs.		0.027						
.0314*	0 lbs.		0.011						
0316	0 lbs.	0 lbs.	0.016		0.011				
0318	0 lbs.	0 lbs.	0.010		0.012				
0319	0 lbs.	0 lbs.	0.013		0.015				
0320	0 lbs.	0 lbs.	0.014		0.015				
.0368	0 lbs.	0 lbs.			0.023				
0321*	1 lbs.		0.032						
0344*	1 lbs.		0.015						
0342	1 lbs.	1 lbs.	0.018		0.022				
0343	0 lbs.	1 lbs.	0.014		0.019				
0329*	2 lbs.		0.022						
0315	2 lbs.	2 lbs.	0.039		0.041				
0346	0 lbs.	2 lbs.	0.017		0.019				
0347	2 lbs.	2 lbs.	0.015		0.022				
0317	4 lbs.	3 lbs.	0.024		0.029				
0313	4 lbs.	5 lbs.	0.007		0.010				
0333	28 lbs.	8 lbs.	**	**	**	0.038		0.032	0.031
.0332	32 lbs.	8 lbs.	**	**	**	0.051		0.040	0.061
0366	29 lbs.	9 lbs.		0.018	0.023	0.021	0.016	0.019	
.0371		12 lbs.			0.025	0.036	0.025	0.026	0.037
0335	45 lbs.	16 lbs.	0.043		0.041		0.056	0.066	0.077
0360	18 lbs.	16 lbs.		0.019	0.023				
0348*	17 lbs.		0.045						
0349*	17 lbs.		0.020						
.0327*	18 lbs.		0.022						
0355	37 lbs.	18 lbs.		0.041	0.043	0.052	0.044	0.043	
0308*	22 lbs.								
0334	40 lbs.	22 lbs.	0.040		0.053		0.051		0.052
0310	17 lbs.	22 lbs.	0.020		0.023	0.026			0.021
0324	35 lbs.	22 lbs.	0.041		0.058	0.053			0.039
0337	29 lbs.	24 lbs.	0.028		0.041		0.040	0.042	0.039
0306*	25 lbs.		0.040						
0363	27 lbs.	25 lbs.		0.036	0.061		0.039	0.032	0.040
0353	27 lbs.	30 lbs.	0.048		0.063	0.074	0.070	0.054	0.066
0352		30 lbs.	0.093		0.103	0.090	0.097	0.086	0.130
0365	40 lbs.	30 lbs.		0.014	0.015	0.012	0.012	0.013	0.013
0325	32 lbs.	31 lbs.	0.075		0.065	0.058	0.052	0.074	0.065
0301	57 lbs.	32 lbs.	0.038	0.028	***	0.033	0.026		
0369	33 lbs.	33 lbs.			0.036	0.036	0.034		
0305*	34 lbs.		***	**	**	0.013	0.019	0.013	0.029
0372	67 lbs.	34 lbs.	0.055		0.080	0.077			
0370		36 lbs.			0.034	0.036	0.041	0.056	0.032
0359	56 lbs.	39 lbs.		0.033	0.033				
0309	33 lbs.	40 lbs.	0.038		0.058	0.058			0.069
0302	51 lbs.	41 lbs.	0.085	**	**	0.056	0.050	0.058	0.044
0336	29 lbs.	41 lbs.	0.037		0.037		0.058	0.029	0.036

CONTINUED . . .

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(TABLE 4 - Continued)

I.D.#	1973 Fish Consumed	1974 Fish Consumed	BLOOD SPECIMENS - Total PCB in parts per million						
			Nov.'73	Apr.'74	Jul.'74	Jan.'75	Feb.'75	Apr.'75	May '75
0326	32 lbs.	44 lbs.	0.044		0.059	0.069	0.057	0.049	0.074
0362	48 lbs.	44 lbs.		0.034	0.034	0.031	0.036	0.027	0.032
0372		45 lbs.			0.045				
0312	48 lbs.	47 lbs.	0.065		0.064	0.062	0.047	0.045	0.061
0300*	51 lbs.		0.060		**				
0303*	51 lbs.		**	**	**	0.043			
0304*	51 lbs.		0.057						
0361	53 lbs.	53 lbs.		0.043	0.065	0.040	0.042		
0328	62 lbs.	53 lbs.	0.047	0.037	0.048	0.058	0.056	0.037	0.042
0330	68 lbs.	56 lbs.	0.030	0.044	0.042	0.040	0.045	0.036	0.045
0351	24 lbs.	60 lbs.	0.081		**	0.080			0.092
0323	67 lbs.	68 lbs.	0.050		0.058	0.078			0.071
0358		79 lbs.		0.142	0.131	0.177	0.152	0.135	0.147
0331	162 lbs.	90 lbs.	0.152	0.115	0.134	0.101	0.140	0.121	0.172
0357	260 lbs.	98 lbs.		0.022	0.026	0.021			0.028
0311	130 lbs.	111 lbs.	0.096	0.083	0.068				
0356	75 lbs.	120 lbs.		0.071	0.064	0.067	0.073	0.059	0.068
0350	93 lbs.	120 lbs.	**		**	0.106			0.121
0373	90 lbs.	131 lbs.			0.064	0.076	0.059	0.064	0.068
0367	162 lbs.	140 lbs.			0.093	0.123			0.086
0364	60 lbs.	147 lbs.		0.007	0.011				0.014
0339	85 lbs.	152 lbs.	0.083	***	0.072	0.086	0.088		0.082
0338	156 lbs.	162 lbs.	0.114		0.120	0.078	0.081	0.095	0.088

* Chronological order of fish consumed is based on 1973 data. The 1974 questionnaire was not completed.

** Sample was depleted during initial analysis, using decachlorobiphenyl techniques. See Appendix (B) for decachlorobiphenyl blood values.

*** Sample lost (broken, not received, etc.)

DSW 038385

STLCOPCB4022209

TABLE 5. CORRELATION OF FISH EXPOSURE WITH PCB VALUES IN BLOOD OVER A TWO YEAR PERIOD, LUDINGTON GROUP.

I.D.#	1973 Fish Consumed	1974 Fish Consumed	BLOOD SPECIMENS - Total PCB in parts per million Nov.'73	Jul.'74	Dec.'74	Jan.'75	Mar.'75	Apr.'75	May '7
00203	0 lbs.	0 lbs.	0.011	0.014					
00204*	0 lbs.		0.017						
00206	1 lbs.	0 lbs.	0.021	0.021					
00207*	1 lbs.		0.018						
00200	3 lbs.	1 lbs.	0.037	0.042					
00201	3 lbs.	1 lbs.	0.029	0.031					
00209	2 lbs.	1 lbs.	0.016	0.016					
00202	3 lbs.	2 lbs.	0.015	0.018					
00205	2 lbs.	4 lbs.	0.020	0.029					
00208*	6 lbs.		0.030						
00219*	8 lbs.		0.046						
00220*	8 lbs.		0.016						
00221*	8 lbs.		0.023						
00212*	9 lbs.		0.026						
00218	22 lbs.	10 lbs.	0.023	0.022	0.026	0.029	0.026		0.023
00214	31 lbs.	12 lbs.	0.089	0.066	0.069				
00225*	14 lbs.		0.054						
00215	26 lbs.	15 lbs.	0.062	0.078	0.063	0.059	0.064		0.055
00227*	18 lbs.		0.079						
00230	18 lbs.	18 lbs.		0.055					
00217	29 lbs.	19 lbs.	0.060	0.071	0.048	0.047	0.052		0.064
00224*	19 lbs.		0.118						
00222*	26 lbs.		0.063						
00223*	26 lbs.		0.036						
00229	29 lbs.	26 lbs.		0.021	0.019	0.021	0.017	0.021	0.023
00216*	27 lbs.		0.031						
00228	27 lbs.	27 lbs.		0.031	0.033	0.022	0.017	0.021	***
00231	28 lbs.	28 lbs.		0.031	0.026	0.025	0.053	0.046	0.025
00210	24 lbs.	33 lbs.	0.065	0.076	0.085	0.070	0.070	0.084	0.084
00211	24 lbs.	39 lbs.	0.065	0.077	***	0.066	0.066	0.065	0.066
00213	205 lbs.	60 lbs.	0.100	0.109	0.084	0.090			0.069
00226	205 lbs.	60 lbs.	0.045	0.045	0.035				
00232		60 lbs.		0.050	0.053	0.079	0.030	0.069	0.052

* Chronological order of fish consumed is based on 1973 data. The 1974 questionnaire was not completed.

** Sample was depleted during initial analysis, using decachlorobiphenyl techniques. See Appendix (B) for decachlorobiphenyl blood values.

*** Sample lost (broken, not received, etc.)

DSW 038386

STLCOPCB4022210

TABLE 6 . CORRELATION OF FISH EXPOSURE WITH PCB VALUES IN BLOOD OVER A TWO YEAR PERIOD, MANISTEE GROUP

I.D.#	1973 Fish Consumed	1974 Fish Consumed	BLOOD SPECIMENS - Total PCB in parts per million									
			Nov.'73	Jul.'74	10-2-74	10-22-74	Nov.'74	Dec.'74	Jan.'75	Feb.'75	Mar.'75	Jun.'7
0252	0 lbs.	0 lbs.	0.014	0.035								
0251	0 lbs.	0 lbs.	0.011	0.010								
0256	5 lbs.	1 lbs.	0.028	0.026								
0250	<6 lbs.	1 lbs.	0.039									
0253	<6 lbs.	2 lbs.	0.025									
0255	1 lbs.	2 lbs.	0.033	0.041								
0254	5 lbs.	2 lbs.	0.027	0.029								
0262	17 lbs.	13 lbs.	0.047	0.041	**	**		0.048	0.057	0.060	0.042	0.047
0264	24 lbs.	15 lbs.	0.037	0.024				0.025	0.036	0.024	0.021	0.035
0269	40 lbs.	23 lbs.	0.025	0.023	**	0.019	0.020	0.023	0.020	0.020	0.018	0.020
0267	22 lbs.	24 lbs.	0.090	0.083				0.082	0.091	***	0.094	0.093
0273		24 lbs.		0.022				0.027				0.026
0271		24 lbs.		0.019						***		0.016
0268	55 lbs.	25 lbs.	0.062	0.064	0.069	**	**	0.070	0.070	0.077	0.056	0.070
0260*	26 lbs.		0.094									
0261	32 lbs.	28 lbs.	0.050	0.117	0.062			0.072	0.074	0.059	0.063	0.089
0270*	29 lbs.		0.038									
0259	53 lbs.	29 lbs.	0.249	0.259					0.227	0.331	0.244	0.264
0266	27 lbs.	30 lbs.	0.124	0.110				0.097	0.144	0.138	0.128	0.102
0257	30 lbs.	32 lbs.	0.105	0.096	0.133	0.128	**	0.127		0.123	0.133	
0272	35 lbs.	35 lbs.		0.089						0.099		0.085
0265	48 lbs.	45 lbs.	0.151	0.123				0.165	0.145	0.125	0.180	0.127
0274	48 lbs.	48 lbs.		0.239				0.206				0.229
0263	79 lbs.	51 lbs.	0.247	0.167				**	0.185	0.133	0.218	0.162
0258	44 lbs.	64 lbs.	0.128	0.169	**	0.153	0.166	0.151		0.131	0.173	0.148

* Chronological order of fish consumed is based on 1973 data. The 1974 questionnaire was not completed.

** Sample was depleted during initial analysis, using decachlorobiphenyl techniques. See Appendix (B) for decachlorobiphenyl blood values.

** Sample lost (broken, not received, etc.)

DSW 038387

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TABLE 7. CORRELATION OF FISH EXPOSURE WITH PCB VALUES IN BLOOD, SOUTH HAVEN AND ALGONAC GROUPS.

SOUTH HAVEN				ALGONAC			
I.D.#	1972 Fish Consumed	1973 Fish Consumed	1973 Blood Specimens Total PCB(ppm)	I.D.#	1972 Fish Consumed	1973 Fish Consumed	1973 Blood Specimens Total PCB(ppm)
)0071	28 lbs.	<3 lbs.	0.027	10029	26 lbs.	11 lbs.	0.023
'0072	38 lbs.	<6 lbs.	0.029	11029	26 lbs.	11 lbs.	0.026
:0073	26 lbs.	<10 lbs.	0.053	10166	13 lbs.	13 lbs.	0.025
)0065	51 lbs.	13 lbs.	0.026	10033	26 lbs.	16 lbs.	0.030
:0066	31 lbs.	17 lbs.	0.035	10130	31 lbs.	20 lbs.	0.019
)0106	35 lbs.	17 lbs.	0.031	10013	26 lbs.	24 lbs.	0.011
)0121	26 lbs.	24 lbs.	0.064	10111	52 lbs.	26 lbs.	0.021
)0105	70 lbs.	24 lbs.	0.045	10171		>26 lbs.	0.017
:0115	23 lbs.	26 lbs.	0.025	10172		≥26 lbs.	0.033
)0070	26 lbs.	26 lbs.	0.068	10129	39 lbs.	28 lbs.	0.030
)0126	42 lbs.	26 lbs.	0.059	10118	52 lbs.	34 lbs.	0.021
)0067	68 lbs.	26 lbs.	0.037	10100	36 lbs.	38 lbs.	0.038
)0111*	26 lbs.		0.040	10035	26 lbs.	42 lbs.	0.012
:0130	30 lbs.	26 lbs.	0.034	10150	48 lbs.	26 lbs.	0.013
:0036	26 lbs.	28 lbs.	0.025	10085*	45 lbs.		0.017
)0124	50 lbs.	28 lbs.	0.056	10110	77 lbs.	57 lbs.	0.020
)0119*	30 lbs.		0.164	10138		52 lbs.	0.032
)0053	50 lbs.	30 lbs.	0.034	10084*	126 lbs.		0.042
:0139*	36 lbs.		0.032	10168		135 lbs.	0.026
:0140*	36 lbs.		0.018				
)0120	24 lbs.	39 lbs.	0.048				
:0055	32 lbs.	40 lbs.	0.326				
)0035	26 lbs.	42 lbs.	0.043				
)0064	43 lbs.	45 lbs.	0.123				
)0104*	48 lbs.		0.056				
:0114	45 lbs.	55 lbs.	0.029				
)0122	60 lbs.	58 lbs.	0.150				
:0100*	63 lbs.		0.035				
)0128	55 lbs.	64 lbs.	0.082				
'0062	98 lbs.	69 lbs.	0.366				
:0116*	80 lbs.		0.118				

* Chronological order of fish consumed is based on 1972 data. The 1973 questionnaire was not completed.

DSW 038388

STLCOPCB4022212

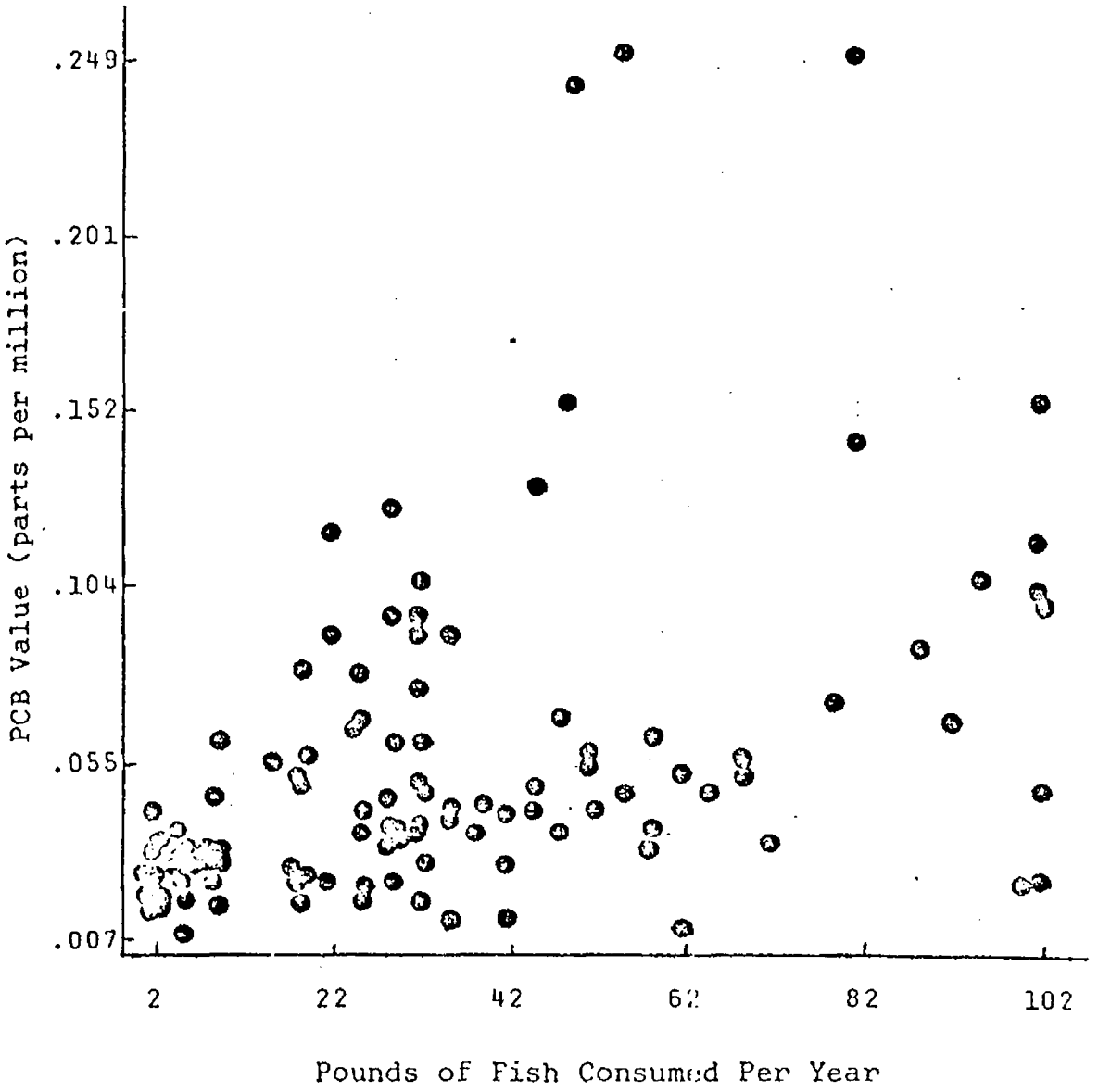

FIGURE 3. CORRELATION OF PCB LEVELS IN HUMAN BLOOD WITH FISH CONSUMPTION

DSW 038389

STLCOPCB4022213

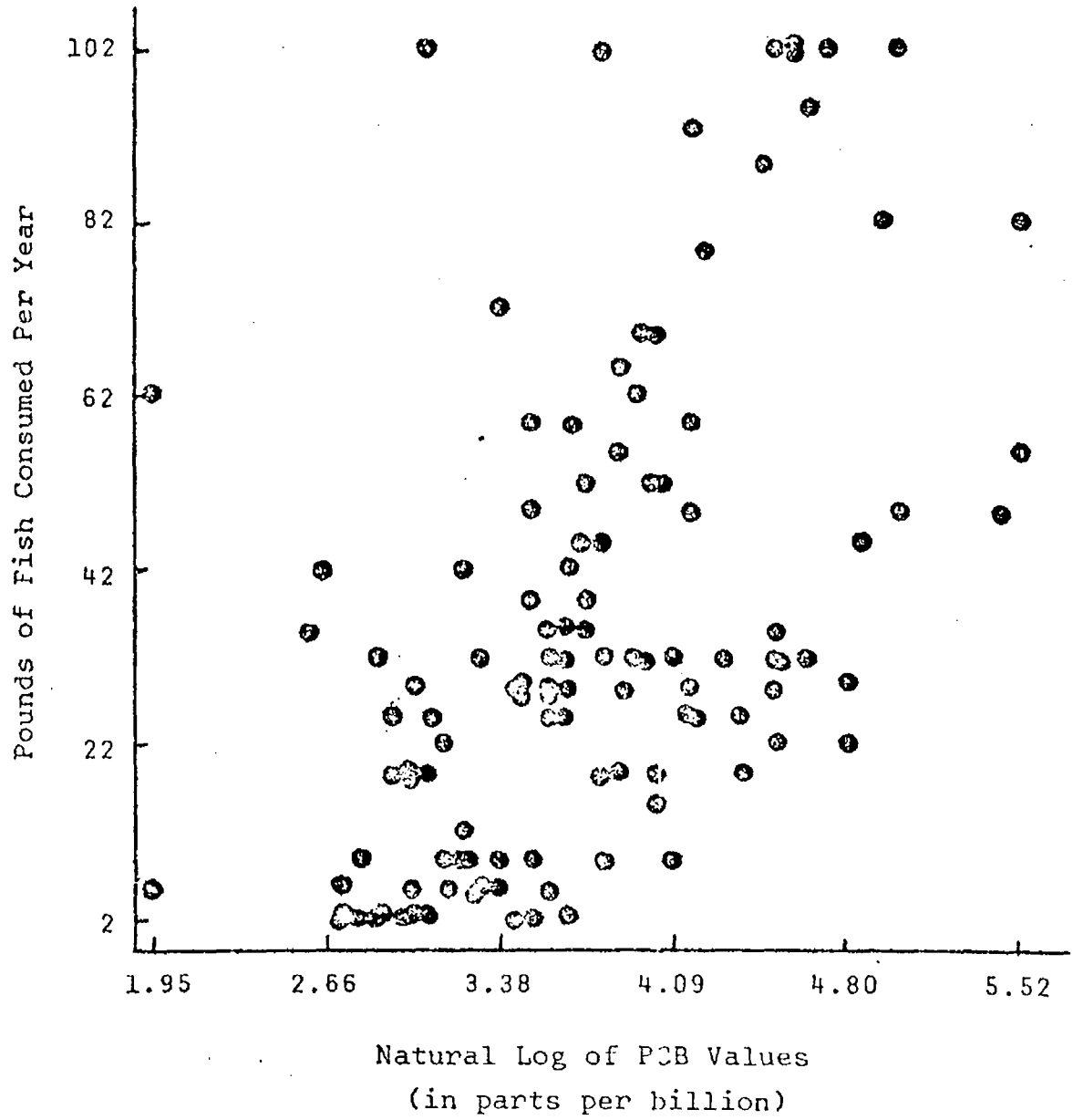

FIGURE 4. SCATTER PLOT OF POUNDS OF FISH CONSUMED v_s THE NATURAL LOG OF PCB LEVELS IN HUMAN BLOOD

DSW 038390

STLCOPCB4022214

bordering Lake Michigan. The mean level of PCB for participants grouped in the major fish consumption categories is shown for each community in Table 8. These data clearly show that the presence of PCB in human blood increases significantly for persons in each ascending consumption category regardless of geographic location.

Apparently any exposure to contaminated fish causes an elevation of PCB blood levels. The control group included persons who ate no fish and those who ate up to six pounds per year. A comparison of control participants who ate no fish from Lake Michigan with those who ate an occasional fish revealed significantly higher ($p<<.002$) PCB levels for the latter group (Table 9). It has been reported that the general population is exposed to PCB from a variety of sources and this is reflected in detectable levels in blood (17) and adipose (3, 4). The study confirms such a conclusion as shown by the values found in the control subjects. It appears that an additional exposure through consumption of contaminated fish, even in small amounts, contributes to the existing body burden of PCB in humans.

A substantial exposure to contaminated fish makes a highly significant contribution to the PCB body burden. A comparison of PCB blood values for exposed persons (those who consume 24 or more pounds of Lake Michigan fish per year) in the four communities bordering the Lake were compared to the blood values for the zero consumption controls. Using the 1973 baseline data from Tables 4, 5, 6 & 7 the mean PCB values for these two groups were found to be 0.077 ppm ($n = 71$, range 0.025 to 0.366 ppm) and 0.017 ppm ($n = 16$, range 0.007 to 0.042 ppm) respectively. The difference between these mean values is highly significant ($p<<.001$)* indicating a positive correlation between exposure to contaminated fish and the accumulation of PCB in the human body.

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*A Cochran adjustment to the t-test was used because of the large difference in the variances of the PCB values for the two groups (18).

DSW 038391

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The significantly higher PCB levels found in humans is the direct result of an additional exposure to PCB from eating contaminated fish from Lake Michigan. Participants from Algonac, a community bordering Lake St. Clair on the opposite side of the State, who consumed fish from Lake St. Clair, had a mean PCB blood level of 0.023 ppm (n=14, range 0.011 to 0.042 ppm)(1973 data from Tables 4, 5, 6 & 7). The difference between the mean PCB values for these two exposed groups is highly significant ($p<<.001$).* The mean PCB value for the Algonac fish eaters compares closely with that of the Lake Michigan control group (Table 8). Fish in Lake St. Clair do not contain the high levels of PCB reported for Lake Michigan sport fish. Thus, fish eating per se does not cause the observed elevation of PCB in humans but consumption of the more highly contaminated species in Lake Michigan does.

No annual variation in PCB levels in humans could be demonstrated. The mean PCB values for the control and exposed groups did not appear to change markedly from year to year (1973 baseline v_s 1974 baseline, Table 8). The exposed group included individuals reporting many combinations of size, species (contamination level) and quantities of fish consumed. Considering these individual variations in PCB exposure the similarity of the annual mean values strongly suggest that PCB levels in exposed persons as a group do not change significantly from year to year. The PCB blood values for a selection of participants who maintained their usual fish consumption habits during the study period are individually illustrated in Figures 10 and 11 (Appendix D).

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*A Cochran adjustment of the t-test was used because of the large difference in the variances of the PCB values for the two groups (18).

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STLCOPCB4022216

TABLE 8. YEAR TO YEAR COMPARISON OF MEAN PCB VALUES BY CITY

City	Mean Total PCB Value (ppm) 1973			Mean Total PCB Value (ppm) 1974		
	Participant Group			Participant Group		
	Control	Inter-mediate	Exposed	Control	Inter-mediate	Exposed
Traverse City	0.017	0.026	0.060	0.019	0.036	0.061
Manistee	0.025	0.068	0.109	0.028	0.029	0.120
Ludington	0.021	0.048	0.062	0.024	0.058	0.055
South Haven	0.028	0.036	0.083			
Algonac	-	0.024	0.023			
Group Mean First 3 Cities	0.020	0.044	0.073	0.023	0.041	0.075

DSW 038393

STLCOPCB4022217

TABLE 9 . EVALUATION OF MEAN PCB VALUES, CONTROL GROUP

FISH CONSUMPTION	MEAN PCB VALUE (ppm) 1973	MEAN PCB VALUE (ppm) 1974
Ate No Fish 0 lbs./year	0.017 n=16	0.016 n=10
Ate Some Fish 1-6 lbs./year	0.024 n=21	0.026 n=15

DSW 038394

STLCOPCB4022218

No seasonal variation in the level of PCB in humans was observed. Initially it was believed that exposure from fish consumption would follow the seasonal pattern of summer fishing and winter lay off. Examination of the dietary data collected during the study shows that this was not the case. Instead, as discussed previously, fish are consumed throughout the year with the higher rates during the active fishing period and lower rates during the winter when preserved fish from the previous season are eaten. The absence of a seasonal consumption pattern was reflected by the absence of statistically significant changes in PCB blood levels during the year (Tables 4, 5, 6 and Appendix D). The April 1974, November 1973, and July 1974 specimen collections were intended to illustrate blood levels just prior to the resumption of fishing, near the end of fishing, and in the middle of a fishing season respectively. The PCB levels determined for these collections were not significantly different. To test this further an artificially created seasonal comparison was established by comparing blood values for a selection of participants who reportedly ate eight more fish meals over the three month period prior to one specimen collection then in a like period prior to another specimen collection. Fifteen subjects met this arbitrary criteria. A paired t-test of the differences in blood PCB for the high and low consumption periods was not significant ($t = 0.99$).

Abstinence from Lake Michigan fish consumption did not significantly change the level of PCB in the blood of persons in the exposed group. Forty-four participants from Traverse City, Manistee, and Ludington were selected and asked to abstain from consumption of Lake Michigan fish at the conclusion of the 1974 fishing season. Thirty-six persons were able to maintain an abstinence period of 90 days or more. The 1974 annual consumption, length of abstinence, and PCB blood levels at various times during abstinence for these participants are shown in Table 10. The length of abstinence

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STLCOPCB4022219

Table 10. Correlation of PCB Levels in Humans and Length of Abstinence from Fish Consumption

Participant ID#	Annual Fish Consumption lbs/year *	Period of Abstinence Dates	Period of Abstinence #Days	Total PCB Concentrations in Blood (ppm) Number of Days After Termination of Fish Consumption 0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270
Ludington																						
00218	10	12-74/3-75	85	.026		.029				.026												
00215	15	11-74/3-75	127				.063		.059			.064										
00217	19	12-74/3-75	85	.045		.047				.052												
00229	26	11-74/4-75	158				.019		.021			.017			.021							
00228	27	12-74/4-75	126	.033			.022			.017		.021										
00210	33	12-74/4-75	121	.085		.070				.070		.084										
00211	39	12-74/4-75	121	lost		.066				.066		.065										
Manistee																						
00262	13	12-74/3-75	108	.048		.057			.060		.042											
00264	15	10-75/3-75	147					.025		.036		.024		.021								
00269	23	10-75/3-75	176	**		.020			.023		.020		.020			.018						
00267	24	12-74/6-75	176	.082		.091		**			.094					.093						
00263	25	10-74/3-75	176	.069		**			.070		.070		.077			.056						
00261	28	12-74/3-75	108	.072		.074			.059		.063											
00266	30	12-74/6-75	176	.097		.144			.138		.128					.102						
00257	32	10-74/3-75	148	**			.127				.123			.133								
00265	45	11-74/2-75	87		.165			.145		.125												
00263	51	11-74/3-75	124		**			.185		.133		.218										
Traverse City																						
00332	8	1-75/5-75	131	.051						.040			.061									
00333	8	1-75/5-75	131	.038						.032			.031									
00336	9	11-74/4-75	152					.021		.016				.019								
00355	18	11-74/5-75	160					.052		.044					.043							
00352	30	1-75/5-75	138	.090			.097			.086			.130									
00353	30	1-75/5-75	138	.074			.070			.054			.066									
00325	31	1-75/4-75	90	.058		.052				.074												
00305	34	12-74/5-75	153		.013		.019				.013			.025								
00370	36	9-74/5-75	249								.036		.041					.056			.032	
00302	41	12-74/5-75	153		.056		.050				.058			.044								
00326	44	1-75/4-75	90	.069		.057				.049												
00362	44	8-74/5-75	278										.031			.036			.027			.032
00312	47	1-75/5-75	139	.062		.047				.045			.061									
00330	56	12-74/4-75	104		.040		.045				.036											
00358	79	12-74/5-75	153		.177		.152				.135			.147								
00331	90	12-74/5-75	104		.101		.140				.121											
00355	120	11-74/5-75	193					.067		.073				.059				.068				
00339	152	12-75/5-75	151		.086		.088							.082								
00338	162	1-75/5-75	141	.078		.081				.095			.088									

* Based on 1974 report

** Sample was depleted using decachlorobiphenyl techniques. See Appendix (B) for decachlorobiphenyl values.

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ranged from 85 days to 278 days. The date of initiation of abstinence was staggered because of the individuality of the end of the fishing season. In the same manner the end of the abstinence period was staggered and determined by the beginning of the 1975 fishing season or the desire of individuals to avoid wasting their store of frozen catch from the previous season. As discussed previously, this portion of the study represented a change in the normal habits of most of these subjects, a matter which took considerable self restraint.

An examination of the blood levels over the abstaining period (Table 10) shows variation but no pronounced decline in PCB for the group. In fact, more subjects showed no change or a rise than showed a decline in PCB level over time. PCB blood values for selected subjects who abstained from eating fish for part of the study period are individually illustrated in Figures 12 and 13 (Appendix E). An analysis of variance for 24 subjects with a beginning blood PCB level of at least 0.040 ppm showed no significant decline in levels over time. A paired t-test using the initial and final abstaining blood values showed an average net increase in PCB and no statistical significance in the recorded change during abstinence from Lake Michigan fish. It must be concluded that abstinence from eating contaminated fish did not reduce the PCB blood levels in these subjects. Thus, an evaluation of the half-life of the concentration of PCB's in humans could not be made within an abstinence period of 90 to 278 days.

Cooked Lake Michigan fish consumed by study participants contained PCB's but at levels lower than those reported for raw whole fish. Participants were asked to record their fish consumption in dietary logs and save a portion of their fish meals for analysis. Questionnaire and dietary log data were used to estimate the annual fish consumption reported in Tables 4, 5, 6 & 7. This data also

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indicated that Lake Trout, Steelhead and Salmon (Coho or Chinook) represented the perferred and most frequently consumed species of fish for most of the participants. An exception was found in South Haven where chubs and perch were eaten more frequently. The PCB levels found in cooked fish collected from participants during 1973 and 1974 are shown in Table 11. This data has been averaged and arranged by fish category and community in Table 12. These results represent tests on composites of collected samples of Lake Michigan fish eaten by individuals during the study. The PCB level in cooked Lake Trout ranged from 1.03 to 4.67 ppm, in cooked salmon from 0.48 to 5.38 ppm, and in other cooked fish from 0.36 to 2.06 ppm. These levels are decidedly lower than the level of PCB contamination generally reported for raw whole Trout and Salmon (Table 1). This is not unexpected since preparation (trimming away fatty tissue) and cooking (loss of fat drippings)* have been shown to decrease the concentration of PCB's (19). The results indicate that actual human exposure to PCB is less than that expected from data for raw whole fish.

The calculated quantity of PCB ingested by eating Lake Michigan fish averaged 46.5 mg/year and ranged from 14.17 to 114.31 mg/year for 91 of the exposed group participants (Table 13). PCB ingestion for each individual was determined by proportioning the reported annual fish consumption by frequency of species eaten and the cooked fish PCB levels (Table 11) for these fish. The community average (Table 12) was used for instances where cooked fish determinations were not available for a participant. Because fish consumption was found to vary from year to year the average annual consumption for the two baseline years of the study was used in each case.

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*Tests on two samples of cooking oil used for deep fat frying of fish showed 0.84 and 0.76 ppm PCB.

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TABLE 11. PCB LEVELS IN COOKED FISH CONSUMED BY HUMANS

PARTICIPANT I.D.#	PCB 1254 CONCENTRATION (parts per million)					
	LAKE TROUT		SALMON		OTHER*	
	1973	1974	1973	1974	1973	1974
00210	4.51	3.24		1.39		
00213			0.48	0.96		
00214		5.17	1.85			
00217	2.83		3.86	3.66		
00223	3.53		3.01		0.76	
00225	1.63		2.96		1.46	
00227	4.00		3.48			
00231		3.65		4.63		0.86
00219	3.68		1.87		0.98	
00257	3.75	2.84		2.81		
00259	1.03	1.48	2.99			
00261	1.87	4.38	3.34			
00263			4.89		0.90	0.62
00266	2.48	2.07		1.32		
00268		1.97		3.18		0.56
00270	5.13				1.05	
00273		1.69		1.49		
00300	3.66	4.17			1.81	1.66
00308	3.44				1.69	
00309	1.58	2.35	3.18			1.17
00311			2.54			
00312	3.17	2.43		2.84		0.36
00323	2.23	1.69			0.73	
00325	1.63	1.63	2.64	4.11	0.73	
00327						
00328	4.67	1.66		2.75	1.56	
00330	2.84	2.31		1.29		0.97
00332	1.04	1.83		4.63		0.63
00334	3.47					
00336	3.18				2.06	1.52
00339		2.32				1.98
00350				3.45		0.56
00365		1.85		5.38		
00035	3.28		2.18		1.87	
00062	3.48					
00104			3.33			
00105			2.99			
00114						
00119	5.63		1.45			
00120	4.81		2.72		0.47	
00121	5.62		2.39			
00130	1.84					

*Includes: Pike, Whitefish, Smelt, Chubs, Menominee and Perch

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TABLE 12. COOKED FISH SURVEY, MEAN PCB CONCENTRATIONS BY COMMUNITY

LOCATION	FISH SPECIES								
	LAKE TROUT			SALMON			OTHER*		
	PCB 1254 (ppm)			PCB 1254 (ppm)			PCB 1254 (ppm)		
	1973	1974	1973-74	1973	1974	1973-74	1973	1974	1973-74
Traverse City:									
Mean	2.80	2.22	2.52	2.78	3.49	3.28	1.43	1.11	1.25
No. Samples	11	10	21	3	7	10	6	8	14
Manistee:									
Mean	2.85	2.40	2.60	3.74	2.20	2.86	0.98	0.59	0.78
No. Samples	5	6	11	3	4	7	2	2	4
Ludington:									
Mean	3.36	4.02	3.58	2.50	2.65	2.55	1.06	0.86	0.99
No. Samples	6	3	9	7	4	11	3	1	4
South Haven:									
Mean	4.11			2.51			1.17		
No. Samples	6			6			2		

*Includes: Pike, Whitefish, Smelt, Chubs, Menominee and Perch

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Table 13 shows that PCB ingestion depends not only on the quantity of fish eaten but also on the species and contamination level of the fish which compose the meals. Thus a person consuming a given quantity of fish could receive a varying amount of PCB depending on the species and the size of fish eaten. In general, PCB ingestion corresponded with the quantity of fish consumed.

The correlation between PCB ingestion from fish and human PCB blood levels was significant. An annual PCB dose was determined for each participant listed in Table 13 and compared to the corresponding mean (1973-74 baseline) PCB blood levels as illustrated in Figures 5 (Traverse City group) and 6 (Manistee, Ludington and South Haven groups). The correlation coefficients for these plots are 0.347 and 0.316 respectively, indicating significance at the 5% probability level. The dose-blood level relationship confirms the pounds of fish consumed - blood level relationship shown previously in Figure 3 and Table 8. Interpretation of the meaning of these correlations requires caution because of the number of uncontrolled variables which complicates accurate estimation of PCB ingestion. The PCB level in each fish eaten, the exact number of pounds consumed annually, the species and quantity of fish consumed in previous years, and the conditions controlling the appearance and level of PCB in human blood are all factors which contribute to the high degree of scatter seen in the data plots.

The maximum allowable ingestion recommended for protracted exposure to PCB is being exceeded by the majority of the exposed group participants. It has been estimated that 1 µg/Kg body weight/day represents the maximum allowable dose for protracted ingestion of PCB's (8). This was based on extrapolation from the lowest total dose (500 mg) reported to produce an effect in man and the assumption that PCB exposure may be tolerated over a long period if daily exposure is held to minimal levels. The calculated mean daily dose

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TABLE 13. ESTIMATED PCB INGESTION FROM FISH, ANNUAL DOSE AND MEAN BLOOD VALUES FOR PERSONS CONSUMING 24 OR MORE POUNDS PER YEAR

I.D.#	Body Weight Kg	1973-75 Mean Annual Fish Consumption Kg/yr.	Calculated Annual* PCB Ingestion From Fish mg PCB/yr.	Annual PCB Dose mg/Kg/yr.	Mean Blood** PCB Value (ppm)
TRAVERSE CITY:					
00306	79	11.3	14.17	0.18	0.040
00363	77	11.8	23.85	0.30	0.040
00337	97	12.2	24.77	0.26	0.041
00324	82	12.7	18.65	0.23	0.050
00355	75	12.7	22.33	0.28	0.043
00353	64	13.2	37.14	0.59	0.056
00352	74	13.6	38.43	0.52	0.098
00334	79	14.1	36.31†	0.48	0.047
00325	64	14.5	33.82†	0.53	0.070
00335	61	14.5	37.48	0.61	0.042
00369	57	15.0	30.01	0.53	0.036
00336	77	15.9	31.09†	0.40	0.037
00365	75	15.9	23.66†	0.32	0.015
00370	82	16.3	46.11	0.68	0.034
00309	100	17.0	28.01†	0.28	0.048
00326	71	17.2	40.16	0.57	0.052
00351	61	19.1	26.97	0.44	0.081
00301	70	20.4	35.57	0.51	0.038
00372	54	20.4	35.57	0.67	0.045
00362	70	20.8	69.30	0.99	0.034
00312	59	21.8	29.09†	0.49	0.065
00359	136	21.8	38.28	0.28	0.033
00300	64	23.1	40.65†	0.64	0.060
00304	57	23.1	40.65	0.71	0.057
00322	66	23.1	65.33	0.99	0.068
00361	70	24.0	48.37	0.68	0.065
00328	64	26.3	78.98†	1.24	0.048
00330	54	28.1	45.39†	0.83	0.036
00323	75	30.8	44.65†	0.60	0.054
00358	73	35.8	44.79	0.62	0.131
00356	100	44.5	78.15	0.78	0.064
00364	77	47.2	94.91	1.23	0.009

* Values for PCB concentrations in fish provided from tests on cooked composite samples provided by participants or from community averages for such samples.

† Determined from tests on fish samples provided by the participant

** Average of the November 1973 and July 1974 blood values

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TABLE 13. (continued)

I.D.#	Body Weight Kg	1973-75 Mean Annual Fish Consumption Kg/yr.	Calculated Annual* PCB Ingestion From Fish mg PCB/yr.	Annual PCB Dose mg/Kg/yr.	Mean Blood** PCB Value (ppm)
TRAVERSE CITY (continued)					
00350	84	48.5	75.23†	0.90	0.106
00373	68	50.8	89.22	1.31	0.064
00339	63	53.9	90.57†	1.44	0.078
00311	102	57.2	100.47†	0.99	0.072
00331	82	57.2	92.27	1.13	0.143
00338	81	36.1	102.80	1.25	0.117
MANISTEE					
00273	82	10.9	17.53†	0.22	0.022
00271	69	10.9	29.43	0.42	0.019
00268	75	11.1	44.53†	0.60	0.062
00260	65	11.8	23.02	0.35	0.094
00261	91	13.6	35.68†	0.39	0.084
00270	73	13.2	45.52†	0.63	0.038
00266	76	13.2	25.00†	0.33	0.110
00257	66	14.1	43.64†	0.66	0.096
00269	104	14.5	35.62	0.34	0.023
00272	84	15.9	42.93	0.51	0.089
00259	94	18.6	36.29†	0.38	0.259
00265	104	21.3	74.42	0.71	0.137
00274	70	21.8	35.05	0.50	0.239
00263	106	29.5	103.67†	0.98	0.207
00258	82	24.5	76.03	0.93	0.148
LUDINGTON					
00217	94	10.9	36.88†	0.39	0.071
00223	79	11.8	29.65†	0.37	0.036
00229	57	12.5	24.02	0.42	0.021
00216	67	12.3	30.60	0.46	0.031
00228	102	12.3	23.79	0.23	0.031
00231	64	12.7	51.34†	0.81	0.031
00210	68	12.9	37.18†	0.54	0.076

* Values for PCB concentrations in fish provided from tests on cooked composite samples provided by participants or from community averages for such samples.

† Determined from tests on fish samples provided by the participant

** Average of the November 1973 and July 1974 blood values

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TABLE 13. (continued)

I.D.#	Body Weight Kg	1973-75 Mean Annual Fish Consumption Kg/yr.	Calculated Annual* PCB Ingestion From Fish mg PCB/yr.	Annual PCB Dose mg/Kg/yr.	Mean Blood** PCB Value (ppm)
LUDINGTON (continued)					
00211	64	14.3	40.99	0.64	0.077
00232	93	27.2	109.01	1.18	0.107
00226	70	60.1	49.76	0.70	0.045
00213	81	60.1	78.29†	0.96	0.050
SOUTH HAVEN					
00066	52	10.9	18.56	0.36	0.035
00115	52	11.3	35.72	0.69	0.025
00121	61	11.3	41.75†	0.68	0.064
00070	74	11.8	29.16	0.40	0.068
00106	73	11.8	31.87	0.44	0.031
00111	91	11.8	27.66	0.31	0.040
00036	57	12.2	29.80	0.53	0.025
00130	73	12.7	28.48†	0.39	0.034
00119	84	13.6	42.49†	0.51	0.164
00065	75	14.5	24.75	0.33	0.026
00120	61	14.5	57.68†	0.94	0.048
00035	75	15.4	37.53†	0.50	0.043
00126	61	15.4	26.31	0.43	0.059
00055	74	16.3	56.66	0.76	0.326
00140	68	16.3	38.36	0.56	0.018
00139	55	17.2	40.44	0.73	0.032
00124	57	17.7	41.50	0.73	0.056
00053	89	18.1	42.56	0.48	0.034
00064	79	19.9	46.82	0.59	0.123
00067	82	21.3	36.37	0.46	0.037
00105	95	21.3	57.61†	0.61	0.045
00104	79	21.8	44.29†	0.56	0.056
00114	82	22.7	71.45†	0.88	0.029
00122	101	26.8	45.66	0.45	0.150
00128	86	27.2	46.44	0.54	0.082
00116	79	36.3	114.31	1.44	0.118
00062	84	38.1	84.58†	1.01	0.366

* Values for PCB concentrations in fish provided from tests on cooked composite samples provided by participants or from community averages for such samples.

† Determined from tests on fish samples provided by the participant

** Average of the November 1973 and July 1974 blood values

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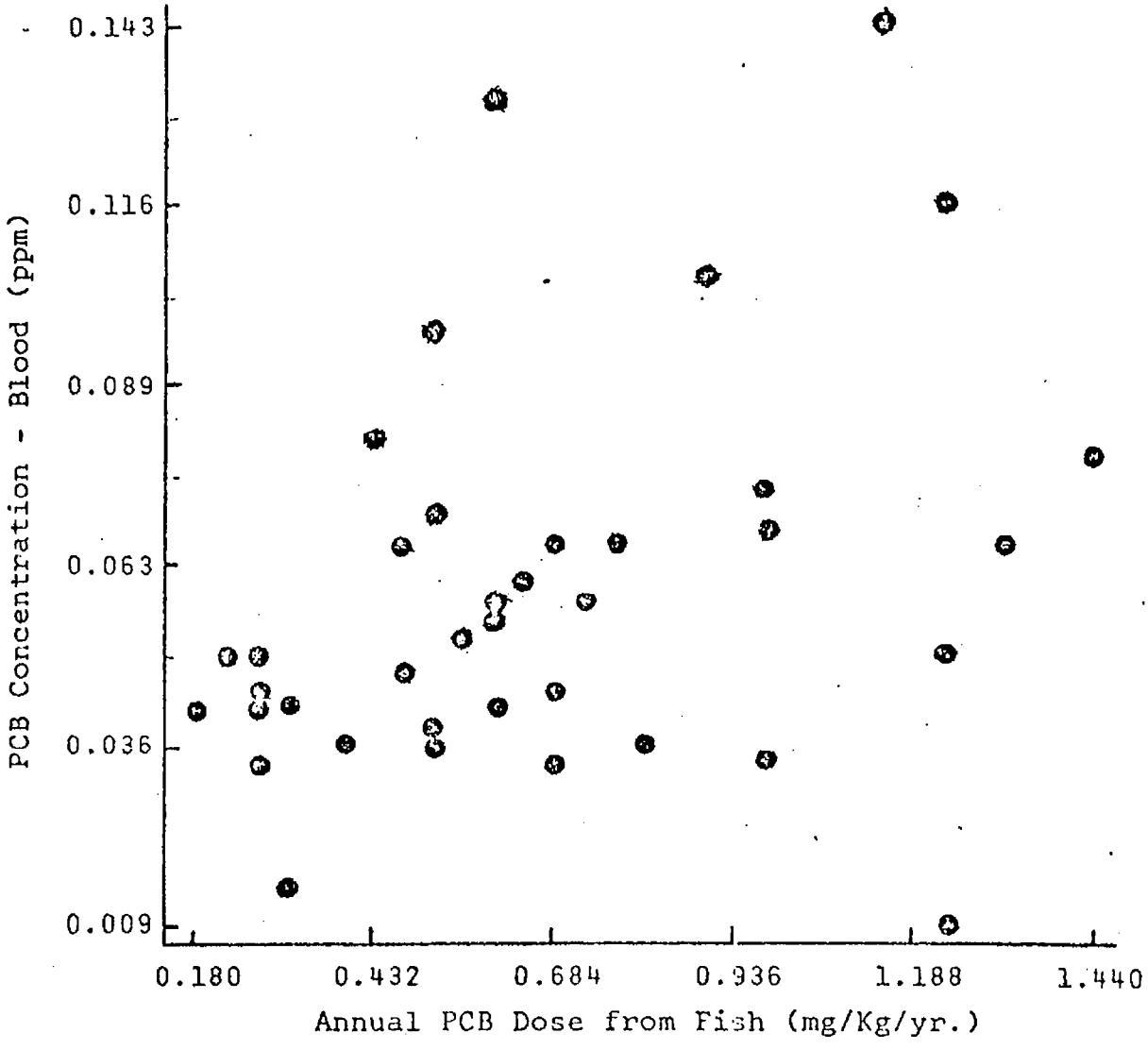

FIGURE 5. CORRELATION OF PCB LEVELS IN HUMAN BLOOD WITH PCB INGESTION FROM FISH, TRAVERSE CITY GROUP

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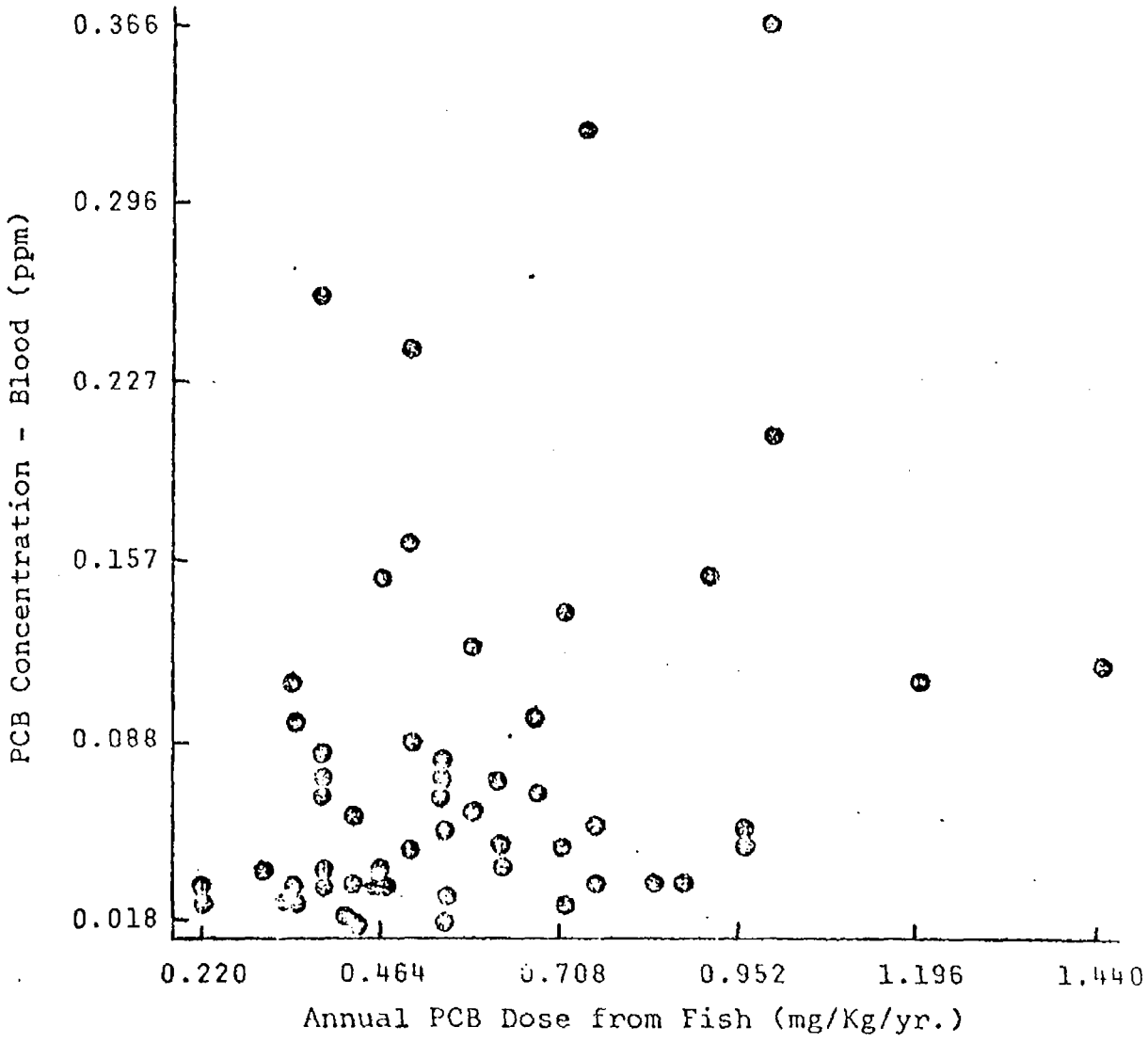

FIGURE 6. CORRELATION OF PCB LEVELS IN HUMAN BLOOD WITH PCB INGESTION FROM FISH, MANISTEE, LUDINGTON, AND SOUTH HAVEN GROUPS

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received by the exposed group listed in Table 13 is 1.70 µg/Kg/day and ranges from 0.49 to 3.94 µg/Kg/day (Table 14). Except for those in the lower range these levels clearly exceed the recommended dose established for long term continuous exposure.

Lake Michigan fish consumption has been shown to be intermittently continuous through the year. This provides repeated doses of PCB which appear sufficient to maintain a PCB equilibrium within humans. Sport fishing has become increasingly popular in the past eight years and activity is expected to continue. Consumption of salmonids from the Great Lakes is and will continue to represent a source of prolonged exposure to PCB. If the average annual rate of PCB ingestion from fish shown in Table 14 is continued over the years, and if net accumulation occurs, the average fish eater could receive a total PCB dose equal to the 200 mg safety limit in 4.3 years. The lowest total dose reported to produce an overt effect in humans (500 mg) would be reached in 10.7 years. An individual who habitually consumed large quantities of contaminated fish would reach these total dose levels sooner, 1.75 years and 4.3 years respectively if the top range value is used. Such a person would reach the average total dose received by those with Yusho symptoms (2,000 mg) in 17.5 years. If it is proven that such total dose accumulations actually occur in persons who consume significant quantities of contaminated Great Lakes fish, then the long term exposure to PCB contaminated fish could prove important.

Segregation of exposed participants on the basis of reported prior history of fish consumption revealed that PCB blood levels rise with the length of time fish have been consumed (Table 15). All of the groups received comparable PCB doses during 1973-74 yet the mean blood PCB levels for this period were directly related to the extent of prior fish consumption. Higher blood levels were associated with a longer history of consuming Lake Michigan fish. Although the details and quantities of prior fish consumption are not

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TABLE 14. CALCULATED PCB INGESTION AND DOSE FROM CONSUMPTION OF GREAT LAKES FISH*

PCB Ingestion			PCB Dose		
Annual mg/year		Daily µg/day	Annual mg/Kg/year		Daily µg/Kg/day
Mean	46.500	0.130	Mean	0.620	1.700
Range: low	14.170	0.038	Range: low	0.180	0.490
high	114.310	0.313	high	1.440	3.940

*Calculated from data on 91 exposed subjects in Table 13.

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TABLE 15. CORRELATION OF BLOOD PCB LEVELS WITH NUMBER OF YEARS OF FISH CONSUMPTION

No. Years Lake Michigan Fish Eaten	Mean PCB Dose mg/Kg/year	Mean Blood PCB (ppm)	No. Subjects*
1 - 3	0.58	0.046	3
4 - 6	0.62	0.055	35
7 - 9	0.53	0.068	6
10 or more	0.59	0.082	43

*From Traverse City, Manistee, Ludington and South Haven

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known the data strongly suggest that long term exposure to PCB contaminated fish results in a net accumulation of PCB in human tissue. Furthermore, the absence of any data indicating a decline in PCB levels suggests that a PCB equilibrium may exist and that recirculation of PCB may be occurring in humans. This would cause target organs to be continuously exposed to PCB for years.

Exposed and control participants were asked if they had experienced any of 17 health conditions. Many of the conditions described the signs and symptoms reported for Yusho disease. There was no significant difference between the number of exposed and control persons responding "yes" to any condition (Table 16). No health conditions or group of symptoms could be identified that were clearly related to PCB exposure. This implies that exposure to PCB from eating contaminated fish and the presence of PCB in exposed persons had not caused an observable acute effect in humans at the time of the study. This does not exclude the possibility that effects too subtle for detection by our survey are occurring.

The blood PCB levels for those responding "yes" to a health condition were not significantly different from those responding "no" to the condition (Table 17). Standard t-tests and a Behrens-Fisher technique for unequal variances were used to evaluate the data. A significant number of exposed subjects or subjects with high PCB levels would be expected to report a given health condition if such a condition was a manifestation of the presence of PCB in humans. The failure of this to occur suggests that there was no common illness related to PCB exposure or that PCB blood levels were not related to the appearance of any of the conditions investigated.

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TABLE 16. EXPOSED AND CONTROL PARTICIPANT RESPONSES TO HEALTH CONDITIONS

Health Conditions	Fish Eater		Non-Fish Eater		Fisher's Probability
	Yes	No	Yes	No	
1. Stomach pains or vomitting for more than one week.	1	75	1	37	0.56
2. Kidney and/or bladder problems.	4	72	2	36	0.68
3. Stroke.	0	76	0	38	--
4. General Fatigue	7	69	2	36	0.37
5. Persistent headaches.	5	71	1	37	0.35
6. Weakness or loss of movement in any part of body.	1	75	1	37	0.56
7. Difficulty with coordination.	2	74	0	38	0.44
8. Fainting, dizzy spells or loss of consciousness.	5	71	1	37	0.35
9. Numbness or tingling in arms or legs.	5	71	0	38	0.13
10. Loss of memory (for names or numbers).	0	76	0	38	--
11. Shaking, unsteadiness, especially of hands and arms.	1	75	0	38	0.67
12. Problems with speech or writing.	0	76	0	38	--
13. Convulsions or a seizure	0	76	0	38	--
14. Persistent blurred vision or unusual sensitivity to light.	3	73	0	38	0.29
15. Discharge from eyes or swelling of the eyelids.	1	75	1	37	0.56
16. Persistent skin eruptions or unusual skin pigmentation or itching.	1	75	0	38	0.67
17. Increased perspiration of palms.	1	75	0	38	0.67
18. Other	7	69	0	38	0.05
Any of the above (at least one).	24	52	7	31	0.10

*Fisher's exact test of the difference between "yes" proportions for the two groups.

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TABLE 17. MEAN AND STANDARD DEVIATIONS OF PCB VALUES AND SAMPLE SIZES FOR EACH CONDITION BY REPORTING STATUS

Condition	Reported Having Condition			Reported Not Having Condition		
	Mean of PCB Values (ppm)	Standard Deviation of PCB Values (ppm)	Sample Size	Mean of PCB Values (ppm)	Standard Deviation of PCB Values (ppm)	Sample Size
1. Stomach	0.058	0.055	7	0.049	0.043	123
2. Kidney/Bladder	0.036	0.020	14	0.051	0.045	116
3. Stroke	--	--	1*	--	00	129
4. Fatigue	0.042**	0.026	14	0.051	0.045	116
5. Headaches	0.047	0.051	19	0.050	0.042	111
6. Weakness/Loss of Movement	0.056	0.034	8	0.049	0.044	122
7. Coordination	0.041	0.048	2	0.050	0.044	128
8. Fainting/Dizziness	0.036	0.029	12	0.051	0.045	118
9. Numbness/Tingling	0.047**	0.028	15	0.050	0.045	115
10. Loss of Memory	0.015**	0.006	4	0.051	0.044	126
11. Shaking/Unsteadiness	0.051	0.036	4	0.050	0.044	126
12. Speech/Writing	--	--	1*	--	--	129
13. Convulsions	--	--	0*	--	--	130
14. Blurred Vision	0.088**	0.102	4	0.049	0.041	126
15. Eye Discharge	0.047	0.024	6	0.050	0.044	124
16. Skin	0.057	0.032	8	0.049	0.044	122
17. Palm Perspiration	0.028	0.009	2	0.050	0.044	128
18. Other	0.067**	0.077	14	0.048	0.038	116
19. At Least One of Above	0.051	0.046	64	0.049	0.041	66

* No test possible; only one or no cases.

** Unequal variances. These were tested using a standard F-ratio test.

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RESIDUE ANALYTICAL METHODOLOGY:

The development of a suitable method for detection and quantitation of PCB's in human blood involved the following investigations: (1) extraction, (2) separation from organochlorine pesticides, (3) derivation, and (4) gas chromatography. Practicality of the analytical scheme, time involved per sample, and reliability of data obtained were important factors in the choice of procedures. Extraction, separation by silica gel chromatography and direct GLC determination of Aroclors (PCB's) requires about half as much laboratory time as the combination of extraction, separation by chemical degradation, perchlorination, and GLC determination of decachlorobiphenyl. At best, either scheme can provide only a good estimate of the degree of exposure of the individual to the PCB compounds actually present in the sample. Accumulation of PCB's in the biological system appears to be higher in the case of pentachlorobiphenyl and more highly chlorinated biphenyls (20).

An extraction procedure for pesticide residue analysis of blood developed specifically for Community Pesticide Study programs (21) was investigated initially. Burke (22) questioned whether the two-hour extraction with hexane on the rotary mixer is efficient. Trial runs indicated less than 45% of Aroclor 1260 was recovered from sheep plasma fortified at the 100 ppb level. Some residue analysts had pretreated blood samples with 60% sulfuric acid to release pesticide residues bound to protein sites (23). Our preliminary investigation of this method produced about 55% recovery of Aroclor 1260 from spiked sheep plasma.

The procedure currently used for extracting PCB's from blood samples incorporates a triple solvent system (i.e., methanol, ethyl ether and hexane), is highly reproducible, and is more quantitative. Since PCB's are fat soluble chemicals

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and the lipids in blood exist mainly as conjugates with protein (24), a method designed to disrupt lipoprotein complexes was required for efficient extraction of blood lipids and, hence, PCB's. Plasma proteins are denatured with methanol, and lipids are extracted with a mixture of ethyl ether and hexane. Recoveries of PCB's (as Aroclors) greater than 88% have been achieved, and a better match of the profiles for extracted Aroclors with those for reference standards have been observed with this method.

Separation of PCB's from organochlorine pesticides is necessary with either direct analysis or derivation in order to reduce or eliminate interference by DDT and its isomers. Although numerous separation techniques have been reported in scientific journals, efforts were focused on charcoal column chromatography, chemical degradation of organochlorine pesticides, and silica gel column chromatography. These are more suited to detecting the small quantities of PCB found in human blood samples than macro methods such as the silicic acid-Celite column chromatography (25).

The charcoal column technique described by Berg et al. (26) appeared to meet our requirement for handling micro quantities of PCB's (5 micrograms or less). A 6 mm i.d. Chromaflex column (Kontes) is plugged with glass wool and filled with 1.1 gram Fisher No. 5-690 charcoal as an acetone slurry. An acetone solution of the sample is added on the column. The DDT group pesticides are eluted with 90 ml of Solvent A (25% acetone in ethyl ether) and PCB's with 60 ml of benzene. Under these conditons, some PCB's eluted in the first fraction but increasing the weight of charcoal from 1.1 gram to 2.5 grams reduced this effect. Although the separation of PCB's appeared to be satisfactory (80%), the elution required as much as three hours per sample, probably due to the formation of vapor pockets.

A micro scale procedure for the quantitative separation of PCB's from DDT and its analogs was studied in a cooperative effort by Dr. Trotter (27). Certain organochlorine pesticides

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are dehydrochlorinated with ethanolic potassium hydroxide to their respective olefins (28) which are then oxidized by chromic acid in acetic acid to dichlorobenzophenone (29). The latter is separated from PCB's by Florisil column chromatography. Trotter (30) achieved recoveries greater than 80% in the ppm range (based on a 5-gram sample) and recoveries of 60% or more in the ppb range for Aroclor 1254 and 1260. Chemical degradation has little effect on certain pesticides such as dieldrin, oxychlordane and Mirex which may not be at levels sufficient to interfere with the quantitation of PCB's in human blood. Our chemical degradation experiments with 0.5 µg to 1.0 µg amounts of Arochlor 1254 and 1260 indicated that recoveries of 65-90% can be achieved.

In an effort to seek a more simplified and less time consuming technique, attention was turned to the use of a micro column of silica gel (31). Woelm silica gel, activity grade I, deactivated with 3% (v/w) distilled water, was sandwiched between layers of anhydrous sodium sulfate in a 7 mm i.d. Chromaflex column. This column was tested with standard solutions of Aroclor 1254 (2.0 µg) and organochlorine pesticides by elution with hexane. With the exception of p,p' DDE, pesticides were found to be completely separated from Aroclor 1254 (about 95% recovery). However, the presence of DDE did not interfere with direct analysis of PCB's. Elution of the PCB fraction can be accomplished in 20-25 minutes.

Perchlorination of PCB's to decachlorobiphenyl (DCB) with antimony pentachloride (32) was evaluated for improved sensitivity of PCB analysis. Conversion of a multicomponent residue to a single compound offered several advantages. This procedure would provide a qualitative and quantitative confirmatory method for PCB's. Also, it would minimize the necessary analytical judgments involved in the measurement of gas chromatographic tracings of a multicomponent residue. Considerable effort was devoted to adapting this procedure for

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routine analysis of PCB's in human blood samples, and several problems became evident. At less than 50 ppb PCB levels, conversions were less reproducible and reagent blanks became significant, e.g., 2-10 ppb DCB for a 5-gram sample. Antimony pentachloride has been found to contain a bromide contaminant which produced bromononachlorobiphenyl during perchlorination (33), but several lots of a high purity grade (99.99%) received in this laboratory did not show any evidence of this contaminant.

The suggestion that PCB levels in blood samples can be determined directly (27) appeared to be more practical for this survey because the gas chromatograph response can be adjusted to permit detection levels as low as 10 ppb total PCB's (Aroclor 1254 and 1260) and fewer steps would be involved in preparing samples for gas chromatographic analysis. The GLC column used for the determination of individual Aroclors was 4%SE-30/6%OV-210. Estimation of PCB residue levels in sample extracts was based on the heights of five peaks in comparison with respective peaks derived from reference Aroclors. The GLC peak having a relative retention time of 1.26 (p,p' DDE=1.00; T-203°C) on this column was distinct and was selected for the estimation of Aroclor 1254 levels.

The analytical procedure incorporating extraction, separation by silica gel chromatography, and direct determination by gas chromatography was the final method of choice primarily because of its superior analytical productivity rate. The output by this procedure was approximately 4 samples per man-day, whereas only 2 samples per man-day could be processed according to the analytical scheme comprising extraction, spearation by chemical degradation, perchlorination, and GLC determination of decachlorobiphenyl. The analyst had less confidence in the latter procedure as yields of the derivative were variable, particularly at the low PCB levels often found

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in blood samples. Also at low residue levels, reagent blanks contributed a significant proportion of the decachlorobiphenyl product and were not always dependable.

CHOSEN ANALYTICAL PROCEDURE:

I. Reagents:

A. Solvents: Hexane, ethyl ether and methanol suitable for use in pesticide residue analysis or distilled-in-glass (Burdick and Jackson Laboratories, Inc. 1953 S. Harvey St., Muskegon, Mi. 49442).

B. Silica gel: Woelm, activity grade I (ICN Pharmaceuticals, Inc.). Deactivate with 3% (v/w) distilled water and store in tightly sealed glass container.

C. Sodium sulfate: Anhydrous, granular (Mallinckrodt No. 8024 or equivalent). Store at 130° in glass stoppered bottle.

D. Antimony pentachloride: Anhydrous, 99.99% (Research Organic/Inorganic Chemical Corp., No. SB-03).

E. Reference standards: Aroclor 1254 (FDA 370) and decachlorobiphenyl (FDA 1056) obtained from Division of Chemical Technology, Bureau of Foods, FDA, Washington, D.C.; Aroclor 1260 from P.T.S.E.L., U.S.E.P.A., Research Triagle Park, N.C.

II. Apparatus:

A. Chromatographic column; Chromaflex glass column, 7 mm i.d. (Kontes No. K-420100-0022). Prepare columns by plugging with small wad of clean glass wool, filling to depth of 1 cm with granular anhydrous Na_2SO_4, adding 3.0 grams absorbent, and topping with another 2-3 cm layer of Na_2SO_4.

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B. Concentrating apparatus: Evaporative concentrator complete with modified micro Snyder column, joint 19/22 (Kontes No. K-569250); concentrator tubes sizes 1025 and 2525 (Kontes No. K-570050).

C. Gas chromatograph: Tracor Model MT220 with tritium foil parallel-plate design electron capture detectors; glass, U-shaped columns, 6' x 4 mm i.d.

1. Pack first column with 4%SE-30/6%OV-210 on 80-100 mesh Gas Chrom Q.

2. Pack second column with 5%OV-210 on 80-100 mesh Supelcoport.

3. Pack third column with 1%OV-101 on 100-120 mesh Gas Chrom Q.

4. Columns 1 and 2 are used for direct analysis of PCB's and Column 3 for decachlorobiphenyl.

5. Operating conditions: Nitrogen flow, 100 ml/min. (Columns 1 and 3) and 40 ml/min. (Column 2); column and detector temperatures, 203°C; injector temperature, 225°C.

III. Extraction:

Transfer 5.0 ml plasma or serum into clean culture tube (20 x 150 mm) having Teflon-lined screw cap. Add 4 ml methanol and swirl on Vortex mixer about 10 seconds. Add 5 ml hexane-ethyl ether (1:1) and attach screw cap securely. Mix contents 10 minutes, using rotary mixer at 50-55 rpm. Centrifuge for 2-5 minutes at 2000 rpm. Transfer upper layer to 25 ml concentrator tube. Repeat extraction twice with 5 ml hexane-ethyl ether. Add carborundum chip, attach micro Snyder column and concentrate extract to about 0.5 ml using a water bath at 80-90°C.

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IV. Separation on Silica Gel:

Wash silica gel chromatographic column with 5 ml hexane. Just as the last of the hexane enters sodium sulfate layer, quantitatively transfer concentrated extract to the top of the column using a disposable glass pipet. Elute PCB's from column with 19 ml hexane. Collect a first fraction, 4 ml, and a second fraction, 15 ml, in graduated centrifuge tubes. Discard the first fraction. The second fraction contains PCB's and p,p' DDE. Reduce volume to 1.0 ml with a slight stream of nitrogen directed upon hexane solution. If transferred to a 10-ml concentrator tube, the extract may be reduced to 0.5 ml.

V. Gas Chromatographic Analysis:

Inject a 5-8 µl aliquot of concentrated eluate, and, if necessary, adjust to suitable volume. Heights of peaks having the following relative retention times (p,p' DDE=1.00) are measured and compared with respective peaks for reference standards of Aroclor 1254 and 1260: 1.26; 1.42; 1.69; 1.85 and 2.62 (4%SE-30/6%OV-210 column at 203°C). Aroclor 1254 is calculated on the basis of peak 1.26. Peak 1.86 is considered to be derived from Aroclor 1260. After subtracting apparent Aroclor 1254 portions, i.e., peak heights, of peaks 1.42, 1.69 and 2.62, the mean Aroclor 1260 level of these peaks is then calculated. No corrections were made to reflect 100% recovery of PCB's. The limit of detection is 10 ppb Aroclor 1254 and 6 ppb Aroclor 1260.

VI. Controls and Reagent Blanks:

Each batch of 12 samples consists of one control and one reagent blank. Quality control samples are prepared by fortifying sheep plasma with ethyl acetate solutions of Aroclor 1254 (66-132 ppb) and Aroclor 1260 (16-30 ppb). Recoveries were 91% Aroclor 1254 (range 80-105%) and 85% Aroclor 1260 (range 75-96%). PCB's were not detected in sheep plasma blanks used in this study.

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VII. Confirmation by Perchlorination:

The procedure by Armour (32) was followed for qualitative confirmation of PCB's in certain blood samples.

VIII. Precision:

Sixty-seven blood samples were analyzed in duplicates by the direct analysis procedure. The total levels for the first reading were correlated with those of the second reading as a test of reliability (Figure 7). The correlation coefficient was 0.972 which indicates a highly significant agreement for the replicate tests and a high degree of reliability of analytical data obtained in this study.

SPECIAL TESTS:

I. Figures 8 and 9 are illustrations of the chromatograms of hexane extracts following chemical degradation of samples containing Aroclor 1254 and 1260 respectively. Plot B in Figure 8 represents a sample of cooking oil used by one of the study subjects for fish preparation. As shown the PCB found in the cooking oil closely resembles the GLC tracing for the Aroclor 1254 standard (plot A Figure 8). The absence of pronounced peaks indicative of Aroclor 1260 in the oil used to cook Lake Michigan fish and the Aroclor concentrations found in the blood of participants (Appendix A) indicate that those who consume Lake Michigan fish are primarily exposed to the Aroclor 1254 form of PCB.

II. Best Specimen:

Fasting and nonfasting blood specimens were collected from subjects in the PCB Study and an investigation involving a related chemical, polybrominated biphenyl (PBB). There

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was no significant difference in the chlorinated or brominated biphenyl concentrations for the two types of blood specimens (Table 18). Thus either type of sample would be satisfactory for the detection of PCB.

III. Breast Milk Specimen:

Traverse City participant 00324 who consumed an average of 28 pounds of Lake Michigan fish during 1973-74 gave birth to a child in January of 1975. A breast milk specimen collected during January contained 4 ppm PCB, Aroclor 1254 (fat basis - the specimen had 2% fat content). In contrast, a blood specimen collected in January contained 0.053 ppm total PCB. This shows that body tissues with a significant lipid content will contain PCB's which are fat soluble at levels greater than those found in blood. It also suggests that pregnant or nursing women should consume Lake Michigan fish with caution.

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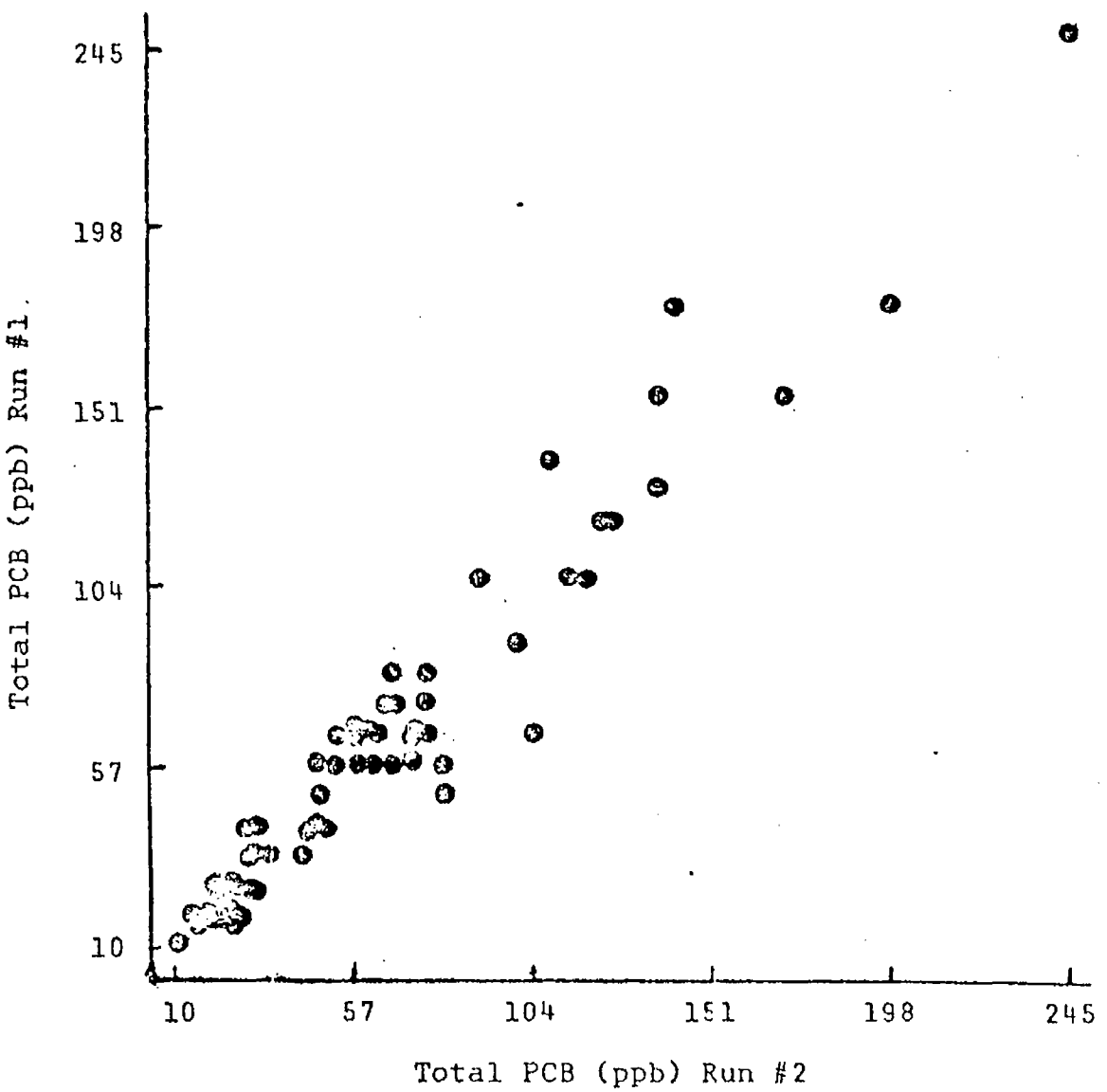

FIGURE 7. ANALYTICAL PRECISION, PLOT OF PCB VALUES FOR REPLICATE TESTS.

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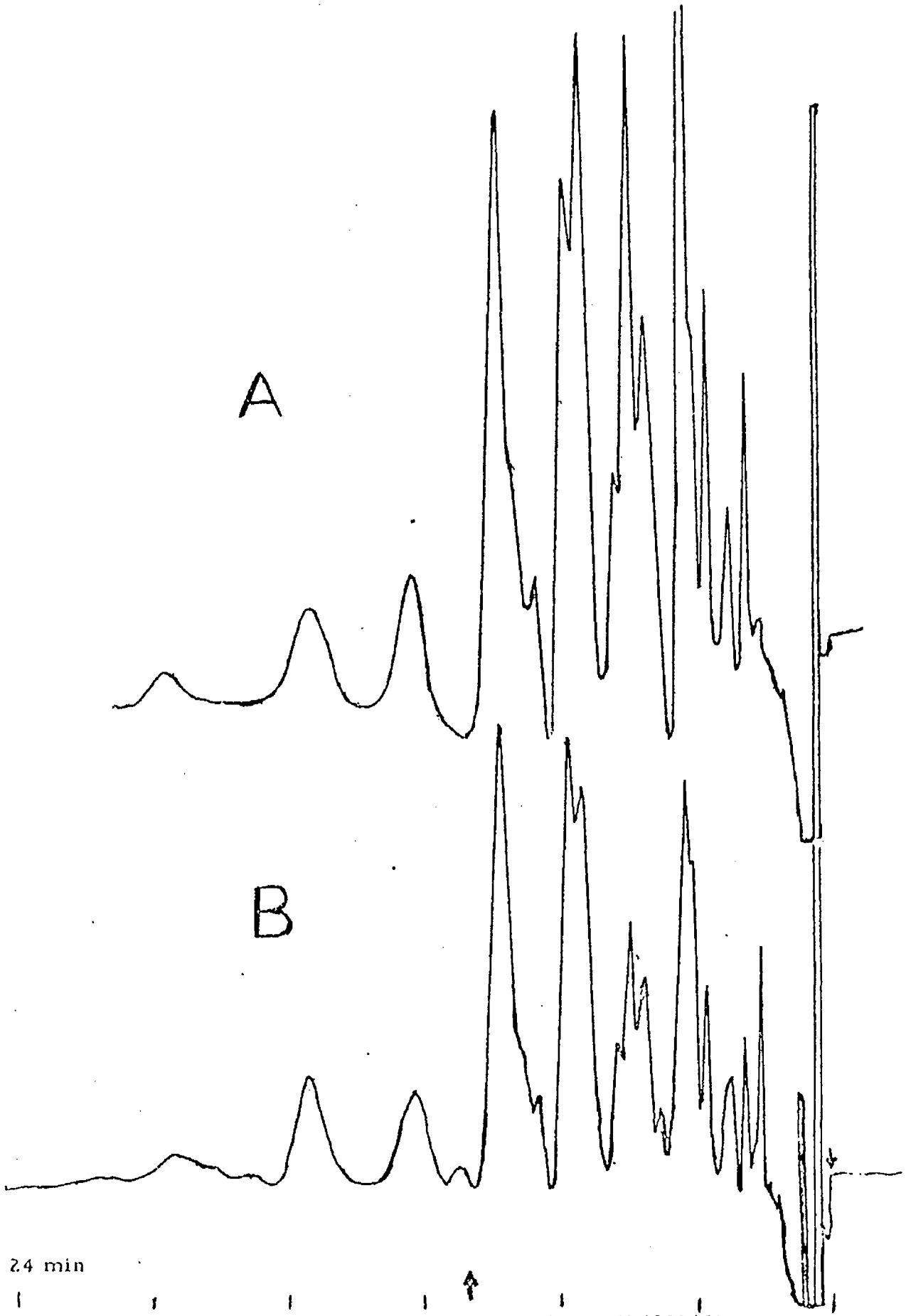

Fig. 8. A, 1.5ng Aroclor 1254. B, 1.34mg cooking oil (00268).
GLC parameters: see Fig. 9.

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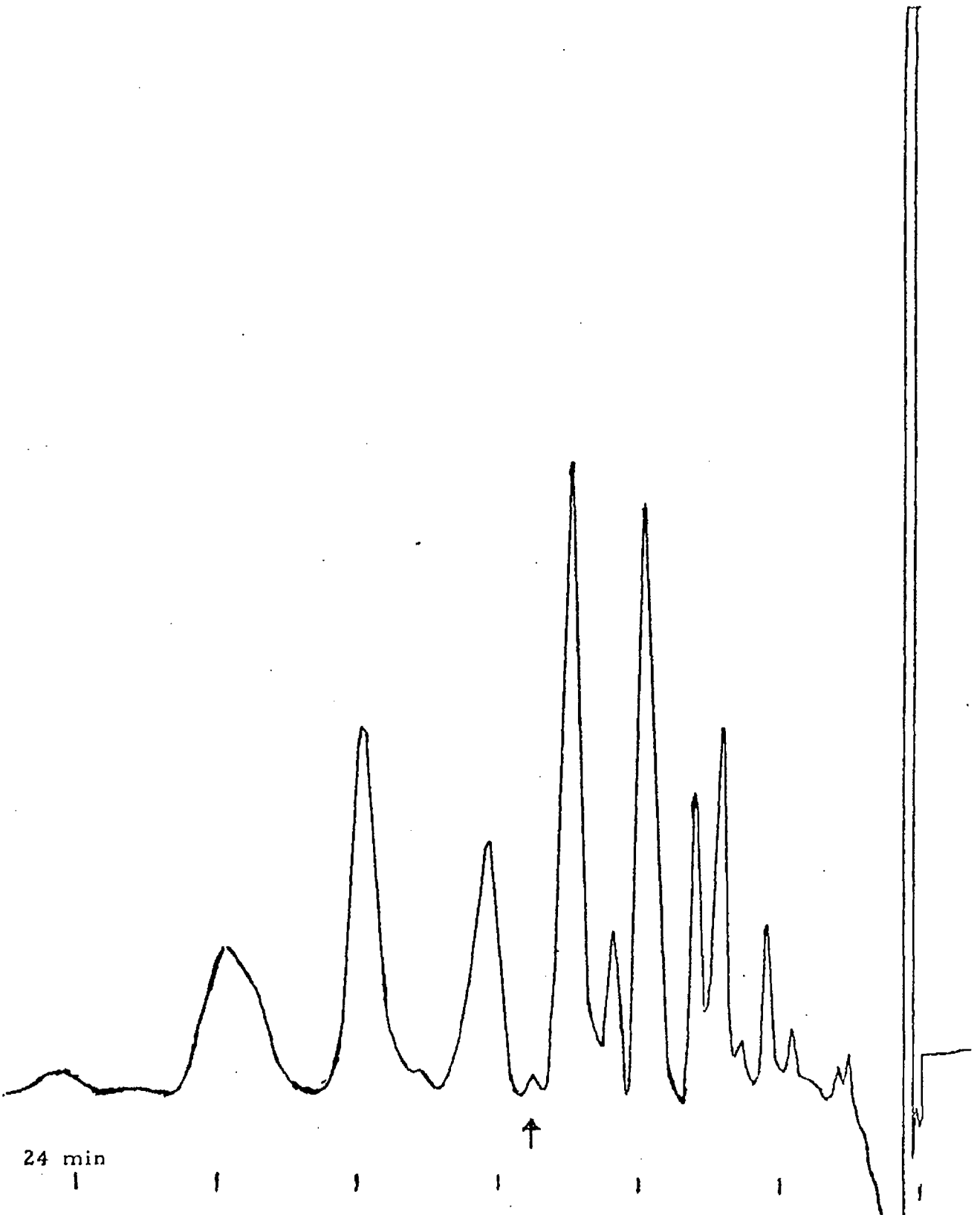

Fig. 9. Aroclor 1260 (0.6 ng). GLC parameters. --column: 6'x4mm i.d., 5% OV-210; col. T.: 168°C. Arrow: p,p' DDT elution position. Flow: 70ml N_2/min.

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TABLE 18. BEST SPECIMEN COMPARISON

HALOGENATED BIPHENYL VALUE (ppm)	
Fasting Blood	Nonfasting Blood
0.015	0.017
0.051	0.050
0.001	0.001
0.001	0.001
0.066	0.065
0.035	0.038
0.088	0.102
0.005	0.005
0.022	0.025
0.042	0.040
0.025	0.025

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A P P E N D I X A

FINAL LABORATORY DATA FOR PCB TESTS ON BLOOD SPECIMENS COLLECTED DURING THE STUDY

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ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00035	29-10-73	0.030	0.013	0.043
00036	29-10-73	0.020	0.005	0.025
00053	29-10-73	0.024	0.010	0.034
00055	29-10-73	0.218	0.108	0.326
00062	27-10-73	0.255	0.111	0.366
00064	27-10-73	0.091	0.032	0.123
00065	29-10-73	0.018	0.008	0.026
00066	29-10-73	0.027	0.008	0.035
00067	29-10-73	0.027	0.010	0.037
00070	29-10-73	0.045	0.023	0.068
00071	27-10-73	0.022	0.005	0.027
00072	29-10-73	0.022	0.007	0.029
00073	29-10-73	0.038	0.015	0.053
00100	29-10-73	0.027	0.008	0.035
00104	29-10-73	0.042	0.014	0.056
00105	29-10-73	0.032	0.013	0.045
00106	29-10-73	0.025	0.006	0.031
00111	29-10-73	0.033	0.007	0.040
00114	29-10-73	0.019	0.010	0.029
00115	29-10-73	0.018	0.007	0.025
00116	29-10-73	0.075	0.043	0.118
00119	29-10-73	0.126	0.038	0.164
00120	29-10-73	0.040	0.008	0.048
00121	29-10-73	0.049	0.015	0.064
00122	29-10-73	0.116	0.034	0.150
00124	29-10-73	0.036	0.020	0.056
00126	29-10-73	0.048	0.011	0.059
00128	29-10-73	0.064	0.018	0.082
00130	29-10-73	0.025	0.009	0.034
00139	29-10-73	0.023	0.009	0.032
00140	29-10-73	0.012	0.006	0.018
00200	01-11-73	0.027	0.010	0.037
00200	11-07-74	0.033	0.009	0.042
00201	01-11-73	0.023	0.006	0.029
00201	11-07-74	0.026	0.005	0.031
00202	01-11-73	0.012	0.003	0.015
00202	29-07-74	0.015	0.003	0.018
00203	01-11-73	0.009	0.002	0.011
00203	11-07-74	0.011	0.003	0.014
00204	01-11-73	0.015	0.002	0.017
00205	01-11-73	0.015	0.005	0.020
00205	11-07-74	0.022	0.007	0.029
00206	01-11-73	0.016	0.005	0.021
00206	11-07-74	0.016	0.005	0.021
00207	01-11-73	0.014	0.004	0.018
00208	01-11-73	0.022	0.008	0.030
00209	01-11-73	0.012	0.004	0.016
00209	29-07-74	0.012	0.004	0.016
00210	01-11-73	0.048	0.017	0.065
00210	11-07-74	0.057	0.019	0.076
00210	18-12-74	0.065	0.020	0.085
00210	21-01-75	0.052	0.018	0.070
00210	10-03-75	0.053	0.017	0.070
00210	15-04-75	0.064	0.020	0.084
00210	21-05-75	0.063	0.021	0.084
00211	01-11-73	0.050	0.015	0.065
00211	11-07-74	0.060	0.017	0.077
00211	21-01-75	0.052	0.014	0.066
00211	10-03-75	0.050	0.016	0.066
00211	15-04-75	0.049	0.016	0.065
00211	21-05-75	0.048	0.018	0.066
00212	01-11-73	0.022	0.004	0.026
00213	01-11-73	0.068	0.032	0.100
00213	11-07-74	0.081	0.028	0.109
00213	18-12-74	0.062	0.022	0.084
00213	22-01-75	0.066	0.024	0.090
00213	21-05-75	0.047	0.019	0.066
00214	01-11-73	0.066	0.023	0.089
00214	30-07-74	0.050	0.016	0.066
00214	19-12-74	0.051	0.018	0.069
00215	21-11-73	0.050	0.012	0.062
00215	11-07-74	0.066	0.012	0.078
00215	19-12-74	0.052	0.011	0.063
00215	21-01-75	0.047	0.012	0.059
00215	12-03-75	0.052	0.012	0.064
00215	20-05-75	0.045	0.010	0.055
00216	01-11-73	0.023	0.008	0.031
00217	01-11-73	0.042	0.018	0.060
00217	29-07-74	0.047	0.024	0.071
00217	18-12-74	0.034	0.014	0.048
00217	21-01-75	0.029	0.018	0.047
00217	10-03-75	0.035	0.017	0.052
00217	20-05-75	0.043	0.021	0.064
00218	01-11-75	0.015	0.008	0.023
00218	29-07-74	0.015	0.007	0.022
00218	18-12-74	0.017	0.009	0.026
00218	21-01-75	0.021	0.008	0.029
00218	10-03-75	0.018	0.008	0.026
00218	20-05-75	0.015	0.008	0.023
00219	01-11-73	0.038	0.008	0.046
00220	01-11-73	0.012	0.004	0.016
00221	01-11-73	0.017	0.006	0.023
00222	01-11-73	0.047	0.016	0.063
00223	01-11-73	0.026	0.010	0.036
00224	01-11-73	0.088	0.030	0.118
00225	01-11-73	0.039	0.015	0.054
00226	01-11-73	0.035	0.010	0.045
00226	11-07-74	0.036	0.009	0.045
00226	18-12-74	0.027	0.008	0.035
00227	01-11-73	0.055	0.024	0.079

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ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00228	11-07-74	0.025	0.006	0.031
00228	18-12-74	0.027	0.006	0.033
00228	22-01-75	0.019	0.003	0.022
00228	12-03-75	0.014	0.003	0.017
00228	21-04-75	0.016	0.005	0.021
00229	11-07-74	0.016	0.005	0.021
00229	18-12-74	0.015	0.004	0.019
00229	22-01-75	0.016	0.005	0.021
00229	12-03-75	0.012	0.005	0.017
00229	15-04-75	0.016	0.005	0.021
00229	21-05-75	0.017	0.006	0.023
00230	11-07-74	0.040	0.015	0.055
00231	11-07-74	0.023	0.008	0.031
00231	17-12-74	0.020	0.006	0.026
00231	21-01-75	0.019	0.006	0.025
00231	12-03-75	0.043	0.010	0.053
00231	16-04-75	0.033	0.013	0.046
00231	20-05-75	0.018	0.007	0.025
00232	11-07-74	0.039	0.011	0.050
00232	17-12-74	0.042	0.011	0.053
00232	21-01-75	0.062	0.017	0.079
00232	12-03-75	0.022	0.008	0.030
00232	16-04-75	0.052	0.017	0.069
00232	20-05-75	0.039	0.013	0.052
00250	02-11-73	0.029	0.010	0.039
00251	02-11-73	0.009	0.002	0.011
00251	15-07-74	0.007	0.003	0.010
00252	02-11-73	0.009	0.005	0.014
00252	15-07-74	0.023	0.012	0.035
00253	02-11-73	0.020	0.005	0.025
00254	02-11-73	0.023	0.004	0.027
00254	15-07-74	0.025	0.004	0.029
00255	02-11-73	0.026	0.007	0.033
00255	31-07-74	0.031	0.010	0.041
00256	02-11-73	0.018	0.010	0.028
00256	15-07-74	0.015	0.011	0.026
00257	02-11-73	0.087	0.018	0.105
00257	15-07-74	0.075	0.021	0.096
00257	02-10-74	0.107	0.026	0.133
00257	22-10-74	0.103	0.025	0.128
00257	13-12-74	0.105	0.022	0.127
00257	19-02-75	0.102	0.021	0.123
00257	26-03-75	0.107	0.026	0.133
00258	02-11-73	0.100	0.028	0.128
00258	15-07-74	0.130	0.039	0.169
00258	22-10-74	0.116	0.037	0.153
00258	05-11-74	0.130	0.036	0.166
00258	19-02-75	0.104	0.027	0.131
00258	26-03-75	0.138	0.035	0.173
00258	04-06-75	0.108	0.040	0.148
00259	02-11-73	0.179	0.070	0.249
00259	15-07-74	0.193	0.066	0.259
00259	15-01-75	0.153	0.074	0.227
00259	19-02-75	0.244	0.087	0.331
00259	26-03-75	0.164	0.080	0.244
00259	04-06-75	0.170	0.094	0.264
00260	02-11-73	0.067	0.027	0.094
00261	02-11-73	0.036	0.014	0.050
00261	15-07-74	0.081	0.036	0.117
00261	02-10-74	0.043	0.019	0.062
00261	13-12-74	0.053	0.019	0.072
00261	15-01-75	0.054	0.020	0.074
00261	19-02-75	0.042	0.017	0.059
00261	26-03-75	0.045	0.018	0.063
00261	04-06-75	0.066	0.023	0.089
00262	02-11-73	0.035	0.012	0.047
00262	15-07-74	0.030	0.011	0.041
00262	13-12-74	0.036	0.012	0.048
00262	15-01-75	0.045	0.012	0.057
00262	19-02-75	0.044	0.016	0.060
00262	26-03-75	0.032	0.010	0.042
00262	04-06-75	0.036	0.011	0.047
00263	02-11-73	0.185	0.062	0.247
00263	15-07-74	0.121	0.046	0.167
00263	15-01-75	0.139	0.046	0.185
00263	19-02-75	0.095	0.038	0.133
00263	26-03-75	0.152	0.066	0.218
00263	04-06-75	0.115	0.047	0 162
00264	02-11-73	0.027	0.010	0 037
00264	15-07-74	0.016	0.008	0 024
00264	11-12-74	0.018	0.007	0.025
00264	15-01-75	0.028	0.008	0.036
00264	19-02-75	0.016	0.008	0 024
00264	26-03-75	0.014	0.007	0.021
00264	04-06-75	0.022	0.013	0.035
00265	02-11-73	0.119	0.032	0.151
00265	15-07-74	0.091	0.032	0.123
00265	13-12-74	0.128	0.037	0.165
00265	15-01-75	0.112	0.033	0.145
00265	19-02-75	0.096	0.029	0.125
00265	26-03-75	0.140	0.040	0.180
00265	04-06-75	0.096	0.031	0.127
00266	02-11-73	0.092	0.032	0.124
00266	31-07-74	0.081	0.029	0.110
00266	13-12-74	0.076	0.021	0.097
00266	15-01-75	0.111	0.033	0.144
00266	19-02-75	0.104	0.034	0.138
00266	26-03-75	0.094	0.034	0.128
00266	04-06-75	0.074	0.028	0.102
00267	02-11-73	0.065	0.025	0.090

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ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00267	31-07-74	0.062	0.021	0.083
00267	11-12-74	0.058	0.024	0.082
00267	15-01-75	0.063	0.028	0.091
00267	26-03-75	0.069	0.025	0.094
00267	04-06-75	0.068	0.025	0.093
00268	02-11-73	0.050	0.012	0.062
00268	15-07-74	0.048	0.016	0.064
00268	02-10-74	0.053	0.016	0.069
00268	11-12-74	0.054	0.016	0.070
00268	15-01-75	0.055	0.015	0.070
00268	19-02-75	0.062	0.015	0.077
00268	26-03-75	0.044	0.012	0.056
00268	04-06-75	0.057	0.013	0.070
00269	02-11-73	0.023	0.002	0.025
00269	15-07-74	0.020	0.003	0.023
00269	22-10-74	0.017	0.002	0.019
00269	05-11-74	0.018	0.002	0.020
00269	11-12-74	0.020	0.003	0.023
00269	15-01-75	0.018	0.002	0.020
00269	19-02-75	0.018	0.002	0.020
00269	26-03-75	0.016	0.002	0.018
00269	04-06-75	0.016	0.004	0.020
00270	02-11-73	0.026	0.012	0.038
00271	15-07-74	0.015	0.004	0.019
00271	04-06-75	0.012	0.004	0.016
00272	31-07-74	0.072	0.017	0.089
00272	19-02-75	0.077	0.022	0.099
00272	04-06-75	0.060	0.025	0.085
00273	15-07-74	0.016	0.006	0.022
00273	11-12-74	0.021	0.006	0.027
00273	04-06-75	0.019	0.007	0.026
00274	15-07-74	0.142	0.097	0.239
00274	11-12-74	0.120	0.086	0.206
00274	04-06-75	0.130	0.099	0.229
00300	13-11-73	0.051	0.009	0.060
00301	13-11-73	0.034	0.004	0.038
00301	24-04-74	0.023	0.005	0.028
00301	10-01-75	0.028	0.005	0.033
00301	12-02-75	0.023	0.003	0.026
00302	13-11-73	0.071	0.014	0.085
00302	10-01-75	0.043	0.013	0.056
00302	12-02-75	0.039	0.011	0.050
00302	09-04-75	0.044	0.014	0.058
00302	28-05-75	0.034	0.010	0.044
00303	10-01-75	0.032	0.011	0.043
00304	13-11-73	0.045	0.012	0.057
00305	10-01-75	0.011	0.002	0.013
00305	12-02-75	0.016	0.003	0.019
00305	09-04-75	0.010	0.003	0.013
00305	28-05-75	0.014	0.011	0.025
00306	13-11-73	0.031	0.009	0.040
00307	13-11-73	0.018	0.004	0.022
00309	13-11-73	0.029	0.009	0.038
00309	16-07-74	0.046	0.012	0.058
00309	09-01-75	0.046	0.012	0.058
00309	27-05-75	0.055	0.014	0.069
00310	13-11-73	0.017	0.003	0.020
00310	16-07-74	0.019	0.004	0.023
00310	10-01-75	0.022	0.004	0.026
00310	27-05-75	0.017	0.004	0.021
00311	13-11-73	0.073	0.023	0.096
00311	24-04-74	0.062	0.021	0.083
00311	16-07-74	0.050	0.018	0.068
00312	13-11-73	0.046	0.019	0.065
00312	01-08-74	0.046	0.018	0.064
00312	09-01-75	0.048	0.014	0.062
00312	12-02-75	0.029	0.018	0.047
00312	28-05-75	0.038	0.023	0.061
00312	09-04-75	0.029	0.016	0.045
00313	13-11-73	0.006	0.001	0.007
00313	01-08-74	0.009	0.001	0.010
00314	13-11-73	0.010	0.001	0.011
00315	13-11-73	0.028	0.011	0.039
00315	01-08-74	0.030	0.011	0.041
00316	13-11-73	0.013	0.003	0.016
00316	16-07-74	0.008	0.003	0.011
00317	13-11-73	0.020	0.004	0.024
00317	16-07-74	0.023	0.006	0.029
00318	13-11-73	0.006	0.004	0.010
00318	16-07-74	0.008	0.004	0.012
00319	13-11-73	0.009	0.004	0.013
00319	16-07-74	0.010	0.005	0.015
00320	13-11-73	0.010	0.004	0.014
00320	16-07-74	0.010	0.005	0.015
00321	13-11-73	0.027	0.005	0.032
00322	13-11-73	0.040	0.015	0.055
00322	16-07-74	0.061	0.019	0.080
00322	09-01-75	0.060	0.017	0.077
00323	13-11-73	0.035	0.015	0.050
00323	01-08-74	0.040	0.018	0.058
00323	09-01-75	0.055	0.023	0.078
00323	27-05-75	0.054	0.017	0.071
00324	13-11-73	0.033	0.008	0.041
00324	01-08-74	0.046	0.012	0.058
00324	09-01-75	0.044	0.009	0.053
00324	27-05-75	0.029	0.010	0.039
00325	13-11-75	0.058	0.017	0.075
00325	01-08-74	0.049	0.016	0.065
00325	09-01-75	0.044	0.014	0.058
00325	12-02-75	0.034	0.018	0.052

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ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00355	16-07-74	0.032	0.011	0.043
00355	09-01-75	0.040	0.012	0.052
00355	12-02-75	0.033	0.011	0.044
00355	09-04-75	0.033	0.010	0.043
00355	28-05-75	0.135	0.038	0.173
00356	16-07-74	0.047	0.017	0.064
00356	09-01-75	0.048	0.019	0.067
00356	12-02-75	0.053	0.020	0.073
00356	24-04-74	0.051	0.020	0.071
00356	09-04-75	0.043	0.016	0.059
00356	28-05-75	0.049	0.019	0.068
00357	24-04-74	0.015	0.007	0.022
00357	16-07-74	0.018	0.008	0.026
00357	09-01-75	0.013	0.008	0.021
00357	20-05-75	0.019	0.009	0.028
00358	24-04-74	0.100	0.042	0.142
00358	16-07-74	0.091	0.040	0.131
00358	09-01-75	0.119	0.058	0.177
00358	12-02-75	0.108	0.044	0.152
00358	09-04-75	0.097	0.038	0.135
00358	28-05-75	0.106	0.041	0.147
00359	24-04-74	0.026	0.007	0.033
00359	01-08-74	0.025	0.008	0.033
00360	24-04-74	0.017	0.002	0.019
00360	01-08-74	0.020	0.003	0.023
00361	24-04-74	0.031	0.012	0.043
00361	24-04-74	0.028	0.011	0.039
00361	17-07-74	0.045	0.020	0.065
00361	10-01-75	0.028	0.012	0.040
00361	12-02-75	0.029	0.013	0.042
00362	24-04-74	0.025	0.009	0.034
00362	16-07-74	0.025	0.009	0.034
00362	09-01-75	0.024	0.007	0.031
00362	12-02-75	0.027	0.009	0.036
00362	09-04-75	0.019	0.008	0.027
00362	28-05-75	0.025	0.007	0.032
00363	24-04-74	0.026	0.010	0.036
00363	01-08-74	0.040	0.021	0.061
00363	12-02-75	0.025	0.014	0.039
00363	09-04-75	0.021	0.011	0.032
00363	27-05-75	0.025	0.015	0.040
00364	24-04-74	0.006	0.001	0.007
00364	01-08-74	0.008	0.003	0.011
00364	28-05-75	0.012	0.002	0.014
00365	24-04-74	0.011	0.003	0.014
00365	16-07-74	0.011	0.004	0.015
00365	10-01-75	0.008	0.004	0.012
00365	12-02-75	0.007	0.005	0.012
00365	09-04-75	0.010	0.003	0.013
00365	28-05-75	0.009	0.004	0.013
00366	24-04-74	0.015	0.003	0.018
00366	16-07-74	0.020	0.003	0.023
00366	10-01-75	0.016	0.005	0.021
00366	12-02-75	0.014	0.002	0.016
00366	09-04-75	0.016	0.003	0.019
00367	16-07-74	0.057	0.036	0.093
00367	10-01-75	0.074	0.049	0.123
00367	28-05-75	0.057	0.029	0.086
00368	16-07-74	0.013	0.010	0.023
00369	17-07-74	0.028	0.008	0.036
00369	10-01-75	0.027	0.009	0.036
00369	12-02-75	0.027	0.007	0.034
00370	01-08-74	0.023	0.011	0.034
00370	10-01-75	0.023	0.013	0.036
00370	11-02-75	0.030	0.011	0.041
00370	08-01-75	0.036	0.020	0.056
00370	27-05-75	0.022	0.010	0.032
00371	01-08-74	0.018	0.007	0.025
00371	10-01-75	0.028	0.008	0.036
00371	11-02-75	0.019	0.006	0.025
00371	08-04-75	0.019	0.007	0.026
00371	27-05-75	0.028	0.009	0.037
00372	01-08-74	0.031	0.014	0.045
00373	01-08-74	0.040	0.024	0.064
00373	09-01-75	0.049	0.027	0.076
00373	12-02-75	0.036	0.023	0.059
00373	09-04-75	0.041	0.023	0.064
00373	28-05-75	0.044	0.024	0.068
00374	10-01-75	0.040	0.005	0.045
00374	12-02-75	0.037	0.004	0.041
00374	09-04-75	0.039	0.004	0.043
10013	07-11-73	0.007	0.004	0.011
10029	07-11-73	0.020	0.003	0.023
10033	07-11-73	0.023	0.007	0.030
10035	07-11-73	0.009	0.003	0.012
10084	07-11-73	0.032	0.010	0.042
10085	07-11-73	0.013	0.004	0.017
10100	07-11-73	0.029	0.009	0.038
10110	07-11-73	0.016	0.004	0.020
10111	07-11-73	0.018	0.003	0.021
10118	07-11-73	0.016	0.005	0.021
10129	07-11-73	0.022	0.008	0.030
10130	07-11-73	0.012	0.007	0.019
10138	07-11-73	0.024	0.008	0.032
10150	07-11-73	0.009	0.004	0.013
10166	07-11-73	0.021	0.004	0.025
10168	07-11-73	0.020	0.006	0.026
10171	07-11-73	0.014	0.003	0.017
10172	07-11-73	0.024	0.009	0.033
11029	07-11-73	0.018	0.008	0.026

DSW 038430

STLCOPCB4022254

ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00325	09-04-75	0.056	0.018	0.074
00325	28-05-75	0.051	0.014	0.065
00326	13-11-73	0.033	0.011	0.044
00326	01-08-74	0.044	0.015	0.059
00326	09-01-75	0.053	0.016	0.069
00326	12-02-75	0.041	0.016	0.057
00326	09-04-75	0.035	0.014	0.049
00326	28-05-75	0.056	0.018	0.074
00327	13-11-73	0.017	0.005	0.022
00328	13-11-73	0.032	0.015	0.047
00328	24-04-74	0.025	0.012	0.037
00328	16-07-74	0.033	0.015	0.048
00328	09-01-75	0.042	0.016	0.058
00328	12-02-75	0.039	0.017	0.056
00328	27-05-75	0.027	0.015	0.042
00329	13-11-73	0.017	0.005	0.022
00330	13-11-73	0.020	0.010	0.030
00330	24-04-74	0.031	0.013	0.044
00330	16-07-74	0.030	0.012	0.042
00330	10-01-75	0.028	0.012	0.040
00330	12-02-75	0.034	0.011	0.045
00330	09-04-75	0.025	0.011	0.036
00330	28-05-75	0.031	0.014	0.045
00331	13-11-73	0.108	0.044	0.152
00331	24-04-74	0.083	0.032	0.115
00331	16-07-74	0.098	0.036	0.134
00331	10-01-75	0.075	0.026	0.101
00331	12-02-75	0.098	0.042	0.140
00331	09-04-75	0.085	0.036	0.121
00331	28-05-75	0.121	0.051	0.172
00332	09-01-75	0.035	0.016	0.051
00332	09-04-75	0.027	0.013	0.040
00332	28-05-75	0.044	0.017	0.061
00333	09-01-75	0.029	0.009	0.038
00333	09-04-75	0.025	0.007	0.032
00333	28-05-75	0.024	0.007	0.031
00334	13-11-73	0.029	0.011	0.040
00334	01-08-74	0.039	0.014	0.053
00334	12-02-75	0.036	0.015	0.051
00334	27-05-75	0.038	0.014	0.052
00335	13-11-73	0.035	0.008	0.043
00335	01-08-74	0.033	0.008	0.041
00335	12-02-75	0.044	0.012	0.056
00335	09-04-75	0.053	0.013	0.066
00335	27-05-75	0.063	0.014	0.077
00336	13-11-73	0.025	0.012	0.037
00336	16-07-74	0.024	0.013	0.037
00336	12-02-75	0.041	0.017	0.058
00336	09-04-75	0.019	0.010	0.029
00336	27-05-75	0.024	0.010	0.034

ID#	Collection Date	parts per million PCB 1254	PCB 1260	PCB Total
00337	13-11-73	0.023	0.005	0.028
00337	16-07-74	0.031	0.010	0.041
00337	12-02-75	0.033	0.007	0.040
00337	09-04-75	0.032	0.010	0.042
00337	27-05-75	0.032	0.007	0.039
00338	13-11-73	0.081	0.033	0.114
00338	01-08-74	0.079	0.041	0.120
00038	09-01-75	0.052	0.026	0.078
00338	12-02-75	0.052	0.029	0.081
00338	09-04-75	0.061	0.034	0.095
00338	27-05-75	0.060	0.028	0.088
00339	13-11-73	0.058	0.025	0.083
00339	16-07-74	0.054	0.018	0.072
00339	09-01-75	0.061	0.025	0.086
00339	12-02-75	0.063	0.025	0.088
00339	28-05-75	0.061	0.021	0.082
00340	13-11-73	0.034	0.007	0.041
00341	13-11-73	0.024	0.003	0.027
00342	13-11-73	0.011	0.007	0.018
00342	01-08-74	0.013	0.009	0.022
00343	13-11-73	0.010	0.004	0.014
00343	16-07-74	0.014	0.005	0.019
00344	13-11-73	0.009	0.006	0.015
00345	13-11-73	0.015	0.004	0.019
00346	13-11-73	0.013	0.004	0.017
00346	16-07-74	0.014	0.005	0.019
00347	13-11-73	0.012	0.003	0.015
00347	16-07-74	0.018	0.004	0.022
00348	13-11-73	0.033	0.012	0.045
00349	13-11-73	0.016	0.004	0.020
00350	09-01-75	0.074	0.032	0.106
00350	28-05-75	0.088	0.033	0.121
00351	13-11-73	0.059	0.022	0.081
00351	09-01-75	0.061	0.019	0.080
00351	28-05-75	0.068	0.024	0.092
00352	13-11-73	0.070	0.023	0.093
00352	16-07-74	0.074	0.029	0.103
00352	10-01-75	0.068	0.022	0.090
00352	19-02-75	0.072	0.025	0.097
00352	16-04-75	0.062	0.024	0.086
00352	27-05-75	0.095	0.035	0.130
00353	13-11-73	0.038	0.010	0.048
00353	16-07-74	0.048	0.015	0.063
00353	10-01-75	0.058	0.016	0.074
00353	19-02-75	0.053	0.017	0.070
00353	16-04-75	0.043	0.011	0.054
00353	27-05-75	0.052	0.014	0.066
00354	13-11-73	0.030	0.003	0.033
00354	01-08-74	0.023	0.004	0.027
00355	24-04-74	0.033	0.008	0.041

DSW 038431

STLCOPCB4022255

A P P E N D I X B

LABORATORY DATA FOR PCB TESTS UTILIZING PRELIMINARY ANALYTICAL PROCEDURES

DSW 038432

STLCOPCB4022256

TABLE 19. BLOOD SAMPLES TESTED BY THE DEGRADATION-DERIVATIZATION TECHNIQUE†

Traverse City Sample ID#	Total PCB as Decachlorobiphenyl in Parts Per Million					
	Sample Date					
	Nov. 1973	Apr. 1974	May 1974	6-25-74	6-26-74	July 1974
00300*	0.015					
00302*		0.020				0.018
00303*	0.025	0.014				0.025
00305*		0.006				0.006
00332**	0.026	0.032	0.023	0.017	0.015	
00333**	0.015	0.008	0.017	0.014	0.005	
00350*	0.028					0.017

Manistee Sample ID#	Total PCB as Decachlorobiphenyl in Parts Per Million		
	Sample Date		
	10-2-74	10-2-74	Nov. 1974
00257	0.075	0.074	0.047
00258	0.060	0.072	0.079
00261	0.032		
00262	0.022	0.030	
00268	0.038	0.036	0.047
00269	0.008	0.034	0.014

† Recovery of decachlorobiphenyl by this technique was 65%

* Single extraction used

** Triple extraction used

*** Accuracy questionable

DSW 038433

STLCOPCB4022257

A P P E N D I X C

PHYSICAL DATA FOR STUDY PARTICIPANTS

DSW 038434

STLCOPCB4022258

TABLE 20. PARTICIPANT PHYSICAL DATA - LUDINGTON

I.D.#	Sex	Age	Height	Weight
00200	M	51	71	200
00201	F	44	61	155
00202	F	38	63	159
00203	F	28	66	135
00204	F	58	62	220
00205	M	27	68	158
00206	F	23	64	125
00207	F	64	66	165
00208	F	60	68	192
00209	F	53	63	147
00211	F	48	63	142
00210	M	50	66	150
00212	F	40	64	130
00213	M	38	72	178
00214	M	44	72	160
00215	F	43	62	120
00216	F	41	69	147
00217	M	43	74	208
00218	F	43	61	115
00219	M	50	72	194
00220	F	49	69	150
00221	M	18	73	170
00222	M			
00223	M	26	71	175
00224	M	53	71	210
00225	M	39	70	170
00226	F	36	65	155
00227	M	38	70	160
00228	M	37	67	225
00229	F	33	62	125
00230	F	29	64	102
00231	F	31		
00232	M	33	72	205
00233	M	42	72	213

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TABLE 20. PARTICIPANT PHYSICAL DATA - MANISTEE

I.D.#	Sex	Age	Height	Weight
00250	M	68	62	180
00251	F	38	70	152
00252	M	43	67	143
00253	F	43	65	138
00254	F	59	62	120
00255	F	54	63	148
00256	M	62	62	115
00257	F	53	65	140
00258	M	55	72	180
00259	M	66	73	208
00260	F	64	65	144
00261	M	56	69	200
00262	F	54	67	140
00263	M	51	76	234
00264	F	51	61	114
00265	M	23	75	230
00266	M	62	67	167
00267	F	59	63	123
00268	M	43	69	165
00269	F	36	65	230
00270	M	45	69	160
00271	F	42	64	153
00272	M	45	69	185
00273	F	49	64	180+
00274	M	48	68	155

DSW 038436

STLCOPCB4022260

TABLE 20. PARTICIPANT PHYSICAL DATA - TRAVERSE CITY

I.D.#	Sex	Age	Height	Weight
00300	F	78	58	140
00301	F	50	66	155
00302	F	63	70	165
00303	F	67	64	142
00304	F	73	60	125
00305	F	41	69	172
00306	M	56	68	175
00307	F	53		
00308	F	64	63	222
00309	M	38	75	220
00310	F	36	69	200
00311	M	53	70	225
00312	F	55	60	130
00313	F	21	57	
00314	F			
00315	M	58	71	176
00316	F	33	67	130
00317	F	56	67	145
00318	M	26	71	147
00319	M	43	72	165
00320	F	22	65	130
00321	F	56	62	120
00322	F	47	64	145
00323	M	31	69	165
00324	F	31	65	180
00325	F	58	61	140
00326	M	58	68	152
00327	F	52	61	
00328	F	41	62	140
00329	M	57	66	160
00330	F	47	62	120
00331	M	50	67	180
00332	M	58	69	175
00333	F	52	67	135
00334	M	41	69	175
00335	F	41	65	135
00336	M	63	70	170
00337	F	56	65	212
00338	M	57	72	179
00339	F	69	65	139
00340	M	60	70	170
00341	M	60	66	135
00342	M	27	71	160
00343	F	27	68	138
00344	M	23	72	170
00345	F	23	64	125
00346	M	53	65	140
00347	F	51	62	110
00348	M	29	71	160
00349	F	26	66	117
00350	M	42	70	185

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TABLE 20. (continued)

I.D.#	Sex	Age	Height	Weight
00351	F	40	65	135
00352	M	45	69	162
00353	F	44	67	140
00354	F	51	67	130
00355	F	48	66	165
00356	M	47	74	220
00357	F	54	66	180
00358	M	69	67	160
00359	M	36	74	300
00360	F	34	62	160
00361	M	62	68	155
00362	F	66	67	155
00363	M	28	69	170
00364	F	22	65	170
00365	M	64	68	165
00366	F	62	67	158
00367	M	58	67	180
00368	M	43	70	170
00369	F	58	63	125
00370	M	35	70	180
00371	F	35	64	120
00372	F	38	61	118
00373	M	58	70	150
00374	F	21	66	130

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TABLE 20. PARTICIPANT PHYSICAL DATA - SOUTH HAVEN

I.D.#	Sex	Age	Height	Weight
00035	M	28	72	165
00036	F	24	65	125
00053	M	23	72	195
00055	M	51	71	164
00062	M	53	73	185
00064	M	44	70	174
00065	M		72	165
00066	F	34	65	115
00067	M	39	72	180
00070	M	57	72	162
00071	F	29	63	120
00073	M	48	67	169
00106	F	36	66	160
00105	M	37	77	210
00114	M	45	72	
00115	F	47	63	110
00120	F	50	68	135
00122	M	46	70	222
00124	M	55	72	126
00126	F	39		
00128	M	62	71	192
00130	F	59	65	160
00116	M	41	71	175
00104	M	35	72	172
00140	F	61	66	140
00139	M	61	68	150
00119	M	45	70	185
00111	M	33	70	200
00121	M	38	70	165
00116	M	41	70	175
00072	F	48	67	140

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TABLE 20. PARTICIPANT PHYSICAL DATA - ALGONAC

I.D.#	Sex	Age	Height	Weight
10013	F	51	68	128
10029	F	59	68	185
11029	M	55	68	161
10033	M	72	70	176
10035	M	66	67	161
10100	M	52	74	220
10110	M	34	71	220
10111	F	31	66	125
10118	M	58	69	220
10129	M	64	65	155
10130	F	50	62	107
10138	M	73	68	193
10150	M	33	72	188
10166	F	48	67	146
10168	F	48	66	242
10169	M	56	66	170
10170	M	71	70	160
10084	M	69	68	150
10085	M	35	67	180

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A P P E N D I X D

SELECTED ILLUSTRATIONS OF THE CONCENTRATION OF PCB IN THE BLOOD OF PARTICIPANTS WHO CONSUMED GREAT LAKES FISH DURING THE STUDY

APPENDIX D

Illustrations of the correlation between PCB levels in blood and time for persons consuming 26 or more pounds of Great Lakes fish per year. PCB values from Tables 4, 5 & 6.

Legend for Figures 10 and 11.

Participant 00323: Male 31 years, 1974 weight 165 lbs., 1973-75 mean annual fish consumption 64 lbs./yr.

Participant 00328: Male 41 years, 1974 weight 140 lbs., 1973-75 mean annual fish consumption 58 lbs./yr.

Participant 00336: Male 63 years, 1974 weight 170 lbs., 1973-75 mean annual fish consumption 35 lbs./yr.

Participant 00213: Male 38 years, 1974 weight 178 lbs., 1973-75 mean annual fish consumption 132 lbs./yr.

Participant 00324: Female 31 years, 1974 weight 180 lbs., 1973-75 mean annual fish consumption 29 lbs./yr.

Participant 00226: Female 36 years, 1974 weight 155 lbs., 1973-75 mean annual fish consumption 132 lbs./yr.

Participant 00312: Female 55 years, 1974 weight 130 lbs., 1973-75 mean annual fish consumption 49 lbs./yr.

Participant 00363: Male 28 years, 1974 weight 170 lbs., 1973-75 mean annual fish consumption 65 lbs./yr.

Participant 00357: Female 54 years, 1974 weight 180 lbs., 1973-75 mean annual fish consumption 190 lbs./yr.

Participant 00309: Male 38 years, 1974 weight 220 lbs., 1973-75 mean annual fish consumption 42 lbs./yr.

Participant 00337: Female 56 years, 1974 weight 212 lbs., 1973-75 mean annual fish consumption 33 lbs./yr.

Participant 00310: Female 36 years, 1974 weight 200 lbs., 1973-75 mean annual fish consumption 22 lbs./yr.

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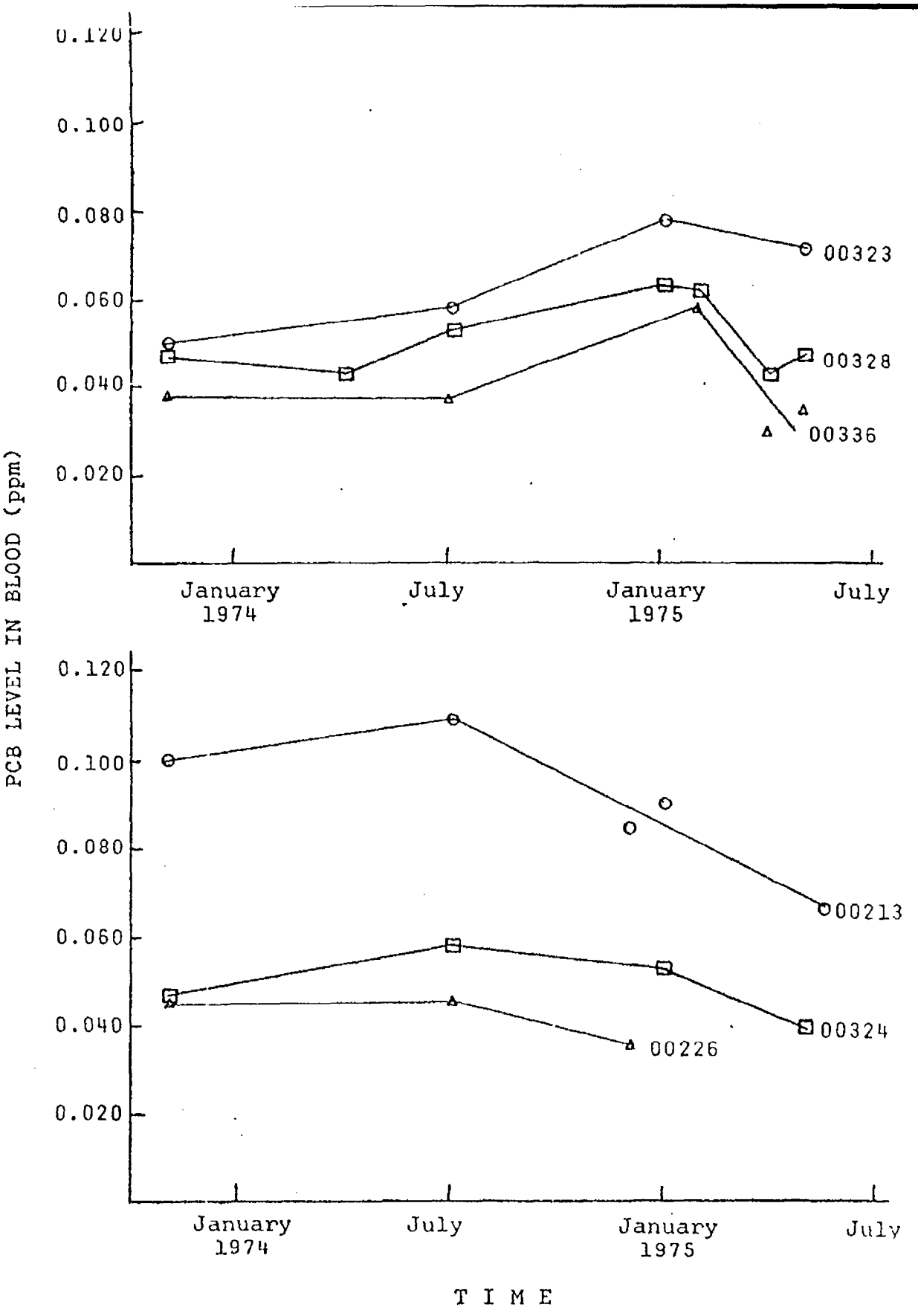

FIGURE 10. CHANGE IN BLOOD PCB LEVELS OVER TIME FOR PERSONS EXPOSED TO LAKE MICHIGAN FISH

DSW 038443

STLCOPCB4022267

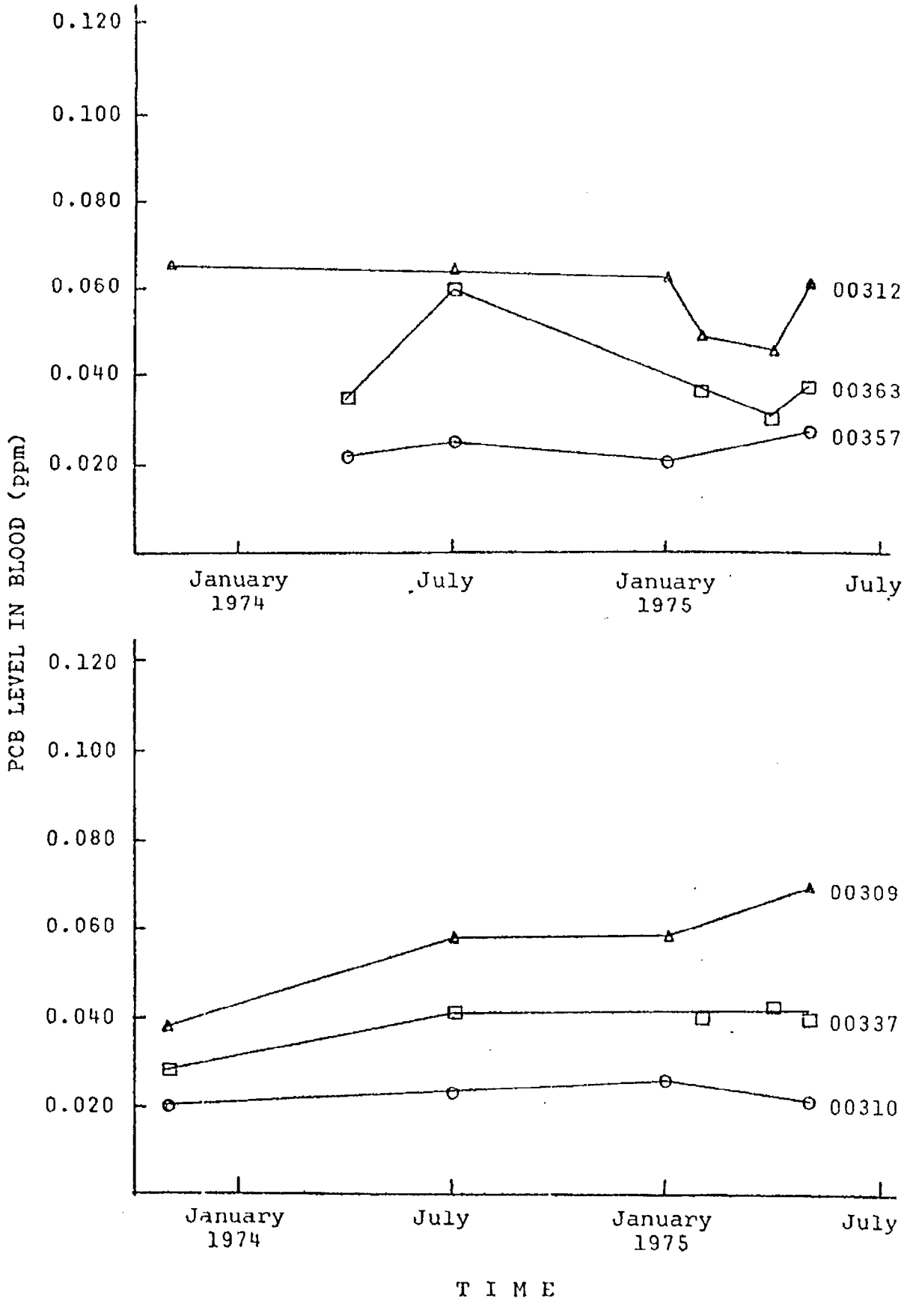

FIGURE 11. CHANGE IN BLOOD PCB LEVELS OVER TIME FOR PERSONS EXPOSED TO LAKE MICHIGAN FISH

DSW 038444

STLCOPCB4022268

A P P E N D I X E

SELECTED ILLUSTRATIONS OF THE CONCENTRATION OF PCB IN THE BLOOD OF PARTICIPANTS WHO ABSTAINED FROM EATING GREAT LAKES FISH DURING 1975

DSW 038445

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APPENDIX E

Illustrations of the correlation between PCB levels in blood and time for persons who abstained from consuming Great Lakes fish for various periods of time. PCB values from Tables 4, 5 & 6.

Legend for Figures 12 and 13.

Participant 00338: Male 57 years, 1974 weight 179 lbs., 1973-75 mean annual fish consumption 80 lbs./yr.

Participant 00312: Female 55 years, 1974 weight 130 lbs., 1973-75 mean annual fish consumption 49 lbs./yr.

Participant 00210: Male 50 years, 1974 weight 150 lbs., 1973-75 mean annual fish consumption 24 lbs./yr.

Participant 00330: Female 47 years, 1974 weight 120 lbs., 1973-75 mean annual fish consumption 62 lbs./yr.

Participant 00352: Male 45 years, 1974 weight 162 lbs., 1973-75 mean annual fish consumption 30 lbs./yr.

Participant 00356: Male 47 years, 1974 weight 220 lbs., 1973-75 mean annual fish consumption 100 lbs./yr.

Participant 00355: Female 48 years, 1974 weight 165 lbs., 1973-75 mean annual fish consumption 28 lbs./yr.

Participant 00267: Female 59 years, 1974 weight 123 lbs., 1973-75 mean annual fish consumption 24 lbs./yr.

Participant 00217: Male 43 years, 1974 weight 208 lbs., 1973-75 mean annual fish consumption 24 lbs./yr.

Participant 00218: Female 43 years, 1974 weight 115 lbs., 1973-75 mean annual fish consumption 10 lbs./yr.

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STLCOPCB4022270

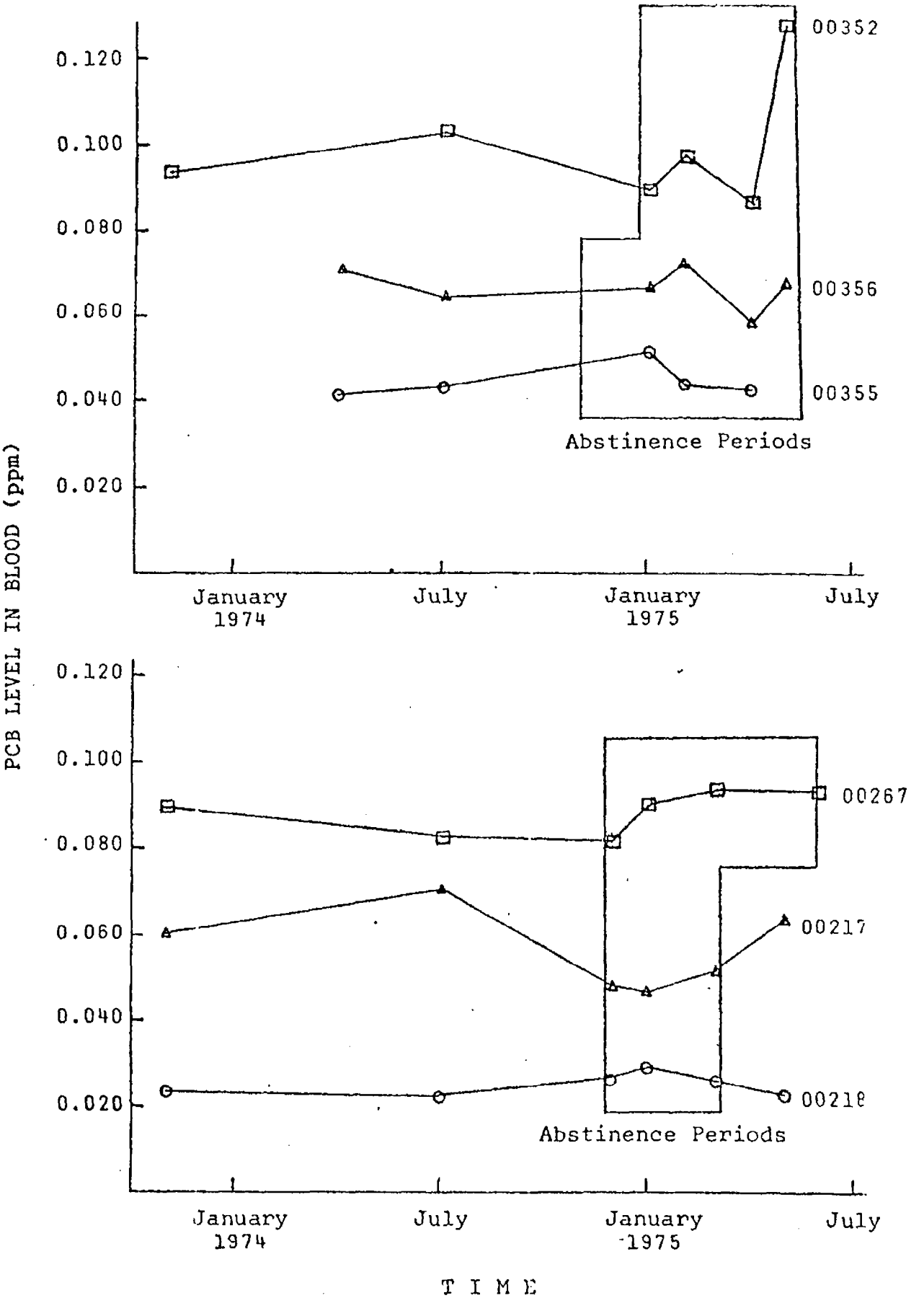

FIGURE 12. CHANGE IN BLOOD PCB LEVELS OVER TIME FOR PERSONS WHO ABSTAINED FROM LAKE MICHIGAN FISH CONSUMPTION

DSW 038447

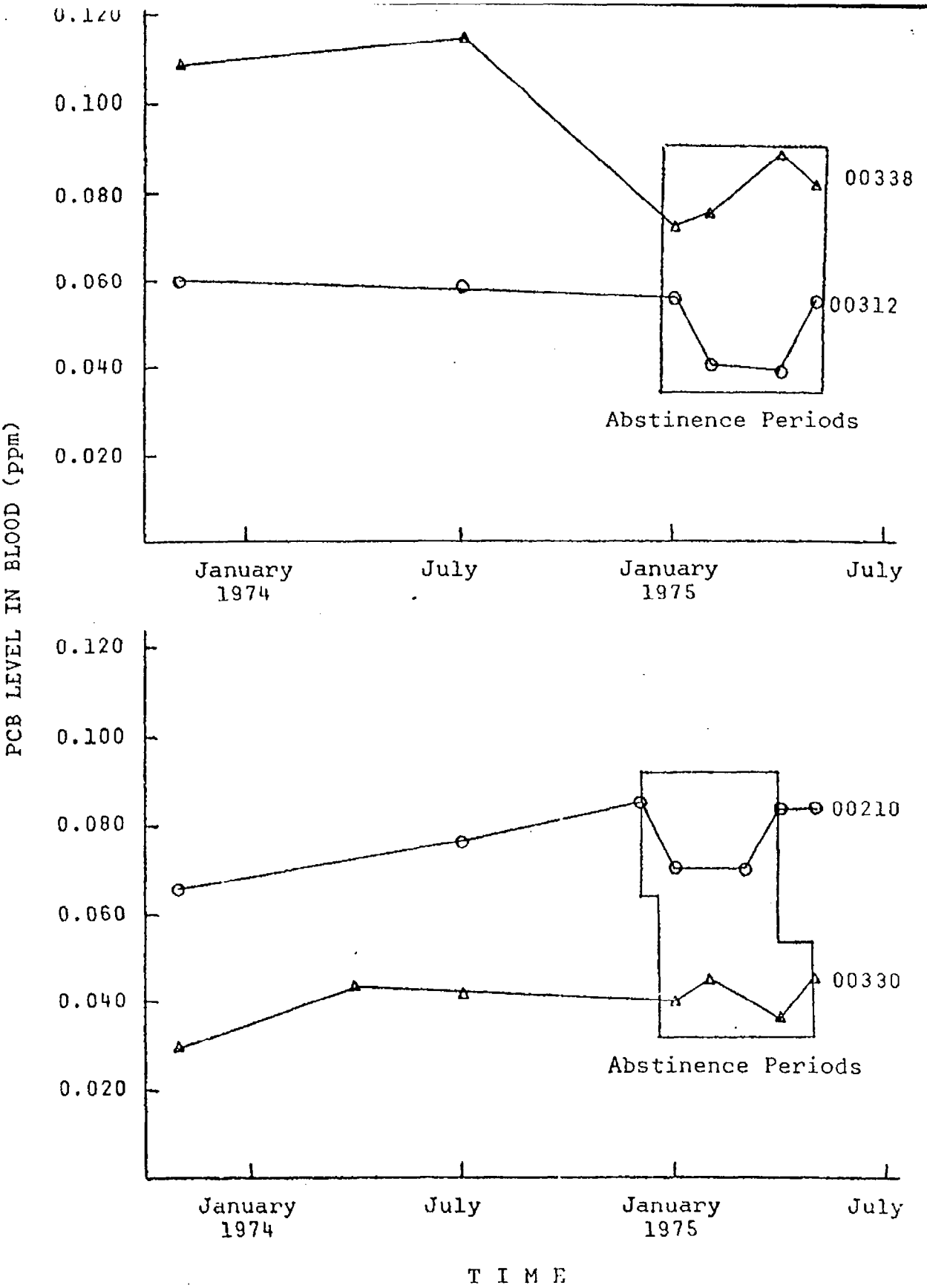

FIGURE 13. CHANGE IN BLOOD PCB LEVELS OVER TIME FOR PERSONS WHO ABSTAINED FROM LAKE MICHIGAN FISH CONSUMPTION

DSW 038448

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