U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY
ATLANTA, GEORGIA 30333

FINAL REPORT
TECHNICAL ASSISTANCE TO THE
CHESTER COUNTY, PENNSYLVANIA
HEALTH DEPARTMENT
NOVEMBER, 1987

EXPOSURE STUDY OF PERSONS POSSIBLY EXPOSED TO POLYCHLORINATED BIPHENYLS IN PAOLI, PENNSYLVANIA

I. SUMMARY

An epidemiologic investigation of possible exposure to polychlorinated biphenyls (PCBs) was conducted following the discovery of widespread soil PCB contamination in Paoli, Pennsylvania. Concentration of PCBs in yard and street soil ranged from less than 1 ppm to more than 6,400 ppm. From several neighborhoods adjacent to or immediately downgradient from the source of contamination, 66 persons were selected through probability sampling to represent the entire population of the neighborhoods (396 persons). The geometric mean and distribution of serum PCB concentrations in this group did not differ from the means and distributions of a large sample of persons selected from across the United States having no known environmental exposure. Thus, the population near the site in Paoli did not show exposure different from other U.S. populations having no known unusual source of exposure.

Log serum PCB concentrations in this group were strongly associated with increasing age. An apparent association of years of residence in the study area and log serum PCB concentration was shown to be due to an underlying association of age with log serum PCB concentration. The probability selected group was compared with another group in the neighborhood, the preselected group, to see if the geometric mean serum PCB concentrations of the groups were different. The preselected group lived in homes with at least one yard soil measurement of PCB at a concentration greater than 150 ppm. There was no statistically significant difference between the means of the groups. From this investigation one cannot deduce sources of individual exposures to PCBs. Several persons had serum PCB levels at or near the upper limit of what would be expected in a population without additional occupational or known environmental exposure. One person with a serum PCB concentration much higher than expected probably had substantial occupational exposure to PCBs.

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II. INTRODUCTION

High concentrations of polychlorinated biphenyls (Aroclor 1260-like pattern) were found at a Southeastern Pennsylvania Transit Authority (SEPTA) electric car repair and maintenance facility and in the surrounding neighborhoods in Paoli, (Chester County) Pennsylvania. Polychlorinated biphenyls (PCBs) are a group of chlorinated hydrocarbon compounds that have been used extensively since the 1930s in electrical transformers and capacitors as highly stable dielectic fluids. Being lipid soluble, PCBs are retained in adipose tissue for extended periods. They are widespread contaminants throughout the environment, but are most often detected in sediments of streams and lakes. One would normally detect soil concentrations only in trace amounts, less than 1 ppb.

PCBs have been shown to produce a wide range of effects in animals, including disrupting reproduction, altering immune system response, and causing dermal lesions. A variety of biochemical effects have been detected in animals. Studies have shown some PCBs to be carcinogenic in animals (Kimbrough, 1985). Epidemiologic studies have suggested that some PCBs induce liver enzymes in humans, and limited epidemiologic evidence suggests an association between occupational exposure to PCBs and hepatobiliary cancer in humans (Brown and Jones, 1981).

Work practices at a repair and maintenance facility involving electric transformers with PCB containing dielectric fluid resulted in extensive, high-level PCB contamination of soil and surfaces--up to 420,000 parts per million (ppm) in one work area and 36,000 ppm in soil. Sampling by the Environmental Protection Agency also showed significant soil and sediment PCB contamination in nearby neighborhoods.

Soil contamination in residential neighborhoods in Paoli was widespread, but mostly at low concentrations. PCB concentrations in soil samples from yards and streets ranged from less than 1 ppm to more than 6,400 ppm (Table 1). A few yards and streets had levels from 500 ppm to more than 6,400 ppm. Local creeks and trout in them also contained elevated levels of PCBs (EPA, Region III unpublished data). Transport of contaminated soil and oil from the site during rain storms probably caused the environmental contamination.

III. METHODS AND MATERIALS

Sample Selection

Persons eligible for inclusion in this study resided in neighborhoods considered to have the highest potential for exposure to PCBs in soil and dust. Neighborhoods near the work site (SEPTA) were chosen on the basis of EPA soil sample results, local topography, and proximity to the site (Figure 1).

To select a cross section of persons who should reflect exposure in the community in general, we conducted a door-to-door census in the

study area. The neighborhood census of 112 households listed 396 current residents, including family members who had lived in the study area but were not living there at the time of the census. This latter group was included because they could have had an exposure as great as that of current residents. To assure that the study would include only those residents with ample opportunity for exposure, we determined that a resident must have lived in the area for at least 12 months to be eligible for a blood serum test. Children under 3 years old were excluded from the selection process.

Since the reliability of questionnaires in selecting persons at highest risk of exposure may be inexact, a probability-based sample was chosen to evaluate neighborhood exposure (Stehr-Green et al., 1986). A sequential selection program was written by using dBase III Plus, with a random seed and an increment value, to select a sample of 107 persons from the study population. These persons were called the probability selected group. We assumed a 70 percent participation rate yielding 75 participants (0.7 x 107 = 75). To insure the inclusion of families that might be at higher risk of exposure, defined as those living near high soil concentrations, we also selected a group of homes with the highest yard soil PCB concentrations found in the neighborhood and requested that all eligible residents participate in the study. Using the neighborhood census and EPA soil sample results, we requested blood samples from all persons living in houses with at least one soil sample from their yard or roadside with PCB concentrations greater than 150 ppm. This was called the preselected group. Four persons were added at the request of the Chester County Health Department. The results of the testing of these four persons are reported here, but they were not included in the analysis.

Individuals selected by probability sampling (probability group) and by proximity to a soil sample with elevated soil PCB (preselected group) were asked to complete a questionnaire and have a blood sample taken in a nearby hospital. The questionnaire included a residential history and an occupational history of potential exposures to PCBs. An equal effort was made to contact all persons selected. At least four attempts over three days were made to contact each person.

After signed consents were obtained, the procedure and potential risks and benefits of the study were explained to participants. A 15-mL blood sample was taken by venipuncture. After 30-45 minutes, the tube was centrifuged, and 5 mL of serum was transferred into a Wheaton Bottle and frozen for transport to the laboratory. PCB concentration in the serum was determined at the Centers for Disease Control, Division of Environmental Health Laboratory Sciences, by gas chromatography with electron capture detection. The gas chromatograms of the serum residues were most comparable with technical Aroclor 1260 and were reported as such in parts per billion (Burse et al., 1983).

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To examine whether the probability selected group was comparable to the group identified in the neighborhood census, we analyzed desographic characteristics of these groups. Six variables that might affect serum PCB population statistics were considered: age, sex, map area, years lived in the study area, potential for occupational exposure to PCBs of subject and other family members, and whether or not an individual was in the preselected group. Selection bias resulting from differential participation was also examined in a similar fashion.

Because soil grab samples taken at one place at one point in time do not necessarily reflect the potential for exposure in a given location in the neighborhood, three measures of potential exposure were analyzed:

1. The study area was divided into three sections (Figure 2): (1) the area of highest potential for soil exposure was adjacent to the site and downgradient; (2) the area downgradient, but not directly adjacent to the site was rated as lower potential; and (3) the area upgradient from the site was considered to have the lowest opportunity for exposure to contaminated soil.

2. Total years of residence in the study area were calculated.

3. A dichotomous variable (yes or no)--living in a residence with at least one soil PCB sample greater than 150 ppm--was created. These houses were identified from EPA sample records.

Analysis

Statistical analysis of the data began by calculating univariate descriptions, including geometric and arithmetic means and percentage of the group with serum PCB below 20 ppb. For this type of data the geometric mean is a better measure of central tendency than the arithmetic mean because it is less affected by extreme values. To explore the association of serum PCB with sex, age, residence area, and years of residence, we calculated Pearson product moment correlation coefficients. The difference between means of the probability selected group and preselected group was tested with a T-test. For all calculations other than descriptive statistics, PCB values were transformed to logarithms to approximate a normal distribution.

The probability and preselected groups were combined to create the variable of "inclusion in the preselected group." To test whether there was an independent association between the surrogate measures of exposure and serum PCB concentration, we entered six variables into a stepwise linear regression analysis. Surrogates for exposure consisted of being in the preselected group and living in the map area with highest measured soil concentrations (Area 1 in Figure 2).

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IV. RESULTS AND DISCUSSION

Sample Selection

A neighborhood census in the study area identified 112 households out of 126 buildings (Table 2, Figure 2). Twenty-one buildings were not residences, were vacant, or no one was contacted in the residence during the study. Nine households declined to answer our questions. Screening questionnaires were completed for 98 households. The sex ratio and age distribution of the 107 persons in the probability selected group are comparable to those variables in the total neighborhood census group (N = 398) (Table 3). In the probability selected group, slightly fewer persons were in the 20- to 29-year age group and slightly more were in the 30- to 59-year age groups than in the total neighborhood census. The demographic differences between the tested population (N = 66) and the selected group (N = 107) were similar. The smaller preselected group was somewhat different from the total neighborhood census group, with a pronounced shift from younger ages to the 20- to 29- year old group and a greater proportion of males.

Participation rates in the probability selected and in the preselected groups were comparable. The participation rate among the probability selection group (107 persons) was 62 percent, yielding 66 persons (Table 4). Among the 34 persons eligible in 13 households with elevated soil PCB concentrations (preselected group) the participation rate was 68 percent. This is lower than the anticipated 70 percent participation for both groups.

PCB Serum Concentrations

Blood samples were analyzed for 89 persons: 66 in the probability group, 23 in the preselected group (4 in the preselected group were also in the probability group), and 4 not in either group. This last group was tested at the request of the Chester County Health Department and was not included in the analysis. In these four persons serum PCB concentrations ranged from 4.7 to 9.3 ppb, with an arithmetic mean of 7.0 and a geometric mean of 6.7 ppb.

In the group chosen as representative of the community--the probability selected group--serum PCB concentrations in 66 persons ranged from less than 1 ppb to 23.7 ppb, with a geometric mean of 4.4 and an arithmetic mean of 6.0 (Table 5, Figure 3).

Two variables were strongly associated with log PCB concentration, age and total years of residence in the study area. Serum PCB concentration increased with age, and the correlation was statistically significant ($p < 0.001$.) The mean for the oldest age group was more than twice that of the youngest group. There was virtually no difference between males and females, and no pattern of association with soil PCB concentrations (indicated by area of residence). Total years of residence in the area

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was significantly correlated ($p < 0.05$) with serum PCB concentration; however, since age and total years of residence are likely to be highly correlated, this apparent link needed to be further explored. When all these variables were considered in a multivariate linear regression model, only age was significantly associated with log serum PCB concentration ($p < 0.0001$). Thus, there was no independent significant association of years of residence and serum PCB concentration.

PCB Serum Concentrations in the Preselected Group

We compared serum PCB concentrations in the preselected group and the probability selected group to investigate the possibility that persons in the preselected group might have had greater exposure because of their proximity to highly contaminated soil. The geometric mean serum PCB concentration were slightly higher in the preselected group, but the difference between the means was not statistically significant ($P < 0.1$), Table 6). In 97 percent of the probability selected group, the serum PCB concentrations were 20 ppb or less. Ninety-one percent of the preselected group had a concentration below 20 ppb. In this group there was one extreme value (76.9 ppb). When this value is removed, the percent below 20 ppb increases to 95 percent.

Regression Analysis

The data from the probability and preselected groups were combined, creating a new variable to indicate which individuals were in the preselected group. These data were used in a multiple linear regression analysis. This analysis tested whether there was a difference in serum PCB concentrations between the two groups, and differences in age and other factors were controlled for. The six predictor variables in the regression analysis were age, sex, map area, years lived in the study area, a ranked indicator of potential occupational exposure of self and family members to PCB, and whether or not an individual was in the preselected group. These variables were entered into the regression model in stepwise fashion and retained if they had an association at the level of $p < 0.15$.

Two variables had an association with serum PCB concentration that approached statistical significance (Table 7). Age accounted for the greatest amount of variance in serum PCB concentration with a high level of significance ($p < 0.0001$). When the model accounted for the effect of age, only one other variable retained an association that approached a 0.05 level of significance. Inclusion in the preselected group was positively associated with serum PCB concentration ($p < 0.06$). The strength of this association rests largely on one extreme value. When this value of 76.9 ppb is removed, the means are within the margin of error for laboratory measurement and the association is not significant ($p > 0.15$). Outliers such as this are often examined carefully because of the concern that one unusual outlier should not, by itself,

determine the outcome of comparisons. The next highest serum PCB concentration was less than half the value of the outlier. A reasonable explanation for the high value is that this individual reported having frequent skin contact at work with fluids containing high concentrations of PCBs. Despite a similar length of residence in the house, serum values for other family members were between 5 and 9 ppb. Thus this high serum PCB concentration probably did not reflect soil exposure and can reasonably be removed from the statistical analysis.

Background Levels of PCBs in Humans

PCBs, like many other organochlorine compounds such as DDT, are detected in serum and adipose tissue of a high percentage of the U.S. population with no known unusual exposure to PCBs (Kreiss, 1985). PCBs are present in many environmental media in small quantities. The presence of small amounts in humans may reflect an accumulation of PCB from daily intake of very small amounts in foods and in the air and does not necessarily indicate unusual environmental or occupational exposure. It is difficult to differentiate body burdens of low dose exposures to PCBs from these typical background levels.

Human serum concentrations of PCBs have been measured in a sufficient number of persons without known exposure to PCBs to estimate background rates and distribution of concentrations in populations. In 17 studies of serum PCB concentrations involving almost 4,300 persons without occupational exposure in the United States, serum PCB concentrations ranged from 0 to 79 ppb (Kreiss, 1985; Stark et al., 1986; Emmett, 1985; Christiani et al., 1986) (Table 8). The geometric mean serum PCB concentrations varied from 4.2 ppb to 6.4 ppb. No apparent route of exposure was described in these studies. The few individuals with serum PCB concentrations above 20 ppb usually reported occupational or unusual food chain exposure (contaminated fish). From her own work and an extensive review of published data, Kreiss (1985) concluded that geometric mean serum PCB concentration in unexposed populations were about 10 ppb. Generally about 95 percent of the persons tested had serum PCB concentrations less than 20 ppb.

The geometric mean of the Paoli probability selected group (4.4 ppb) falls between the means of the two study groups (4.2 ppb and 6.4 ppb; N = 1,631 and N = 990 respectively), and the difference between the values is less than laboratory measurement error. The laboratory analytical technique has about a 10 percent uncertainty factor at the range of the means. Thus it was was not necessary to perform a statistical test to determine that no difference existed between the Paoli group and the two largest comparison groups in published reports. In the probability selected group, 97 percent of the values were 20 ppb or less (Table 6).

A strong correlation between serum PCB concentration and age or sex has been reported in several studies (Kreiss et al., 1981; Kreiss et al.,

1982). Serum PCB concentrations increased with age and was greater in males than in females in every age group. We observed a similar relationship in the probability selected group. Males had a higher geometric mean serum PCB concentration for three age groups (Figure 4). In the oldest age group, the mean serum PCB concentration for males was less than that for females, but the difference was trivial. Despite differences between the groups that would tend to increase the mean serum PCB concentration in the preselected group relative to the probability selected group--more males than females in the preselected compared with the probability selected group, and a slight shift in the proportions in each age group (Table 3)--the geometric mean serum value in the preselected group was not significantly greater than in the probability selected group.

In populations with known sources of environmental exposure, means and distributions of PCB serum concentrations are distinctly different. Four populations that consumed PCB contaminated fish had a geometric mean or median between 17.2 ppb and 56 ppb with a range of individual values from 3 to 366 ppb (Humphrey, 1983a, 1983b; Kreiss et al., 1981a, 1981b). The Paoli groups did not resemble these groups.

V. CONCLUSIONS

1. The probability group is a representative sample of the neighborhood census group for the demographic variables measured. The mean and distribution of serum PCB concentrations in the probability selected group should be representative of the whole neighborhood population.

2. We could not evaluate individual exposures or the proportional contribution of possible sources of exposure to serum PCBs concentrations. Several persons had PCB concentrations at or near the upper limit expected in a population without additional occupational or known environmental exposure. One person, who had a concentration much higher than expected, had a history of substantial contact with highly concentrated PCB fluids, and this higher serum PCB concentration probably reflects occupational exposure.

3. The geometric mean and distribution of serum PCB concentrations in the probability group were not different from geometric means and distributions obtained from published studies of populations without known additional environmental or occupational exposure, but they were quite different from populations with unusual environmental exposure (eating PCB contaminated fish).

4. The population in Paoli near the work site experienced exposure similar to populations found elsewhere in the United States showing typical background exposures.

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5. Serum PCB concentrations were strongly associated with increasing age. An apparent association of years of residence in the study area and serum PCB concentration was shown to be due to an underlying association of age and serum PCB concentration.

6. We compared serum PCB concentrations in the preselected group and the probability selected group to investigate the possibility that persons in the preselected group might have had more exposure to more highly contaminated soil (at least one sample soil PCB concentration greater than 150 ppm) than did the community at large. There was no statistically significant difference between the geometric means. Multiple linear regression analysis, controlling for age, sex and other factors, found no difference in serum PCB concentration between the two groups. Age was the only variable significantly associated with serum PCB concentration. There was no significant association between serum PCB concentration and being in the preselected group or living in the map area with highest measured soil levels. There is no evidence of increased exposure in the groups closest to the most highly contaminated soil.

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Other Acknowledgments:

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VII. TABLES and FIGURES

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TABLE 1

ENVIRONMENTAL LEVELS OF PCBs NEAR PAOLI RAIL YARD
PCB EXPOSURE STUDY, PAOLI, PA.

LOCATION	CONCENTRATION RANGE (ppm)
Soil in residential yards adjacent to site	1 - 6,400
Soil in residential yards along Central Avenue	1 - 440
Soil along side of Central Avenue and North Cedar Hollow Road	1 - 577
Sediment in tributary of Valley Creek	1 - 86
Fish flesh fillet (trout) downstream from site	1 - 6.6

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TABLE 2

HOUSEHOLD COMPLETION STATUS
PCB EXPOSURE STUDY, PAOLI, PA.

BUILDING TYPE	NUMBER	PERCENT OF IDENTIFIED HOUSEHOLDS
Households With Complete Screening Questionnaires	98	88
Refusal To Participate	9	8
Apparently Occupied But No Contact	5	4
Vacant	7	-
Not A Residence	2	-
Total Addresses	128	
Total Identified Households (128-7-9)	112	

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TABLE 3

PERCENTAGE DISTRIBUTION OF INDIVIDUALS BY AGE AND SEX
BY SELECTION STATUS
PCB EXPOSURE STUDY, PAOLI, PA.

		SELECTION STATUS		
	TOTAL NEIGHBORHOOD CENSUS	PROBABILITY SELECTED	PROBABILITY SELECTED/ TESTED	PRESELECTED TESTED
	%	%	%	%
AGE				
0-9	10	8	9	0
10-19	9	6	6	5
20-29	30	22	20	48
30-44	20	26	27	19
45-59	16	21	21	14
60+	15	16	17	14
TOTAL*	100	100	100	100
SEX				
Male	53	56	55	62
Female	47	44	45	38
TOTAL	100	100	100	100
NUMBER OF CASES	396	107	66*	23*

* Percentages may not sum to 100 because of rounding.

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TABLE 4

PARTICIPATION STATUS FOR INDIVIDUALS
BY SELECTION CATEGORY
PCB EXPOSURE STUDY, PAOLI, PA.

SELECTION CATEGORY	TOTAL	PARTICIPATION STATUS Number (%) YES	NO
Probability Selection	107	66*(62)	41 (38)
Preselected	34	23*(68)	11 (32)

*4 individuals were in both the probability and preselected groups

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TABLE 5

SERUM PCB VALUES FOR PROBABILITY SELECTED PERSONS
BY SEX, AGE, AREA OF RESIDENCE, AND YEARS OF RESIDENCE
PCB EXPOSURE STUDY, PAOLI, PA.

	ARITHMETIC MEAN (ppb)	GEOMETRIC MEAN (ppb)	RANGE (ppb)	NUMBER	R[1]
ALL PERSONS	6.0	4.4	<1 - 23.7	66	
SEX					0.0
Male	6.0	4.4	1.1 - 20.4	36	
Female	6.0	4.4	0.7 - 23.7	30	
AGE					0.52**
1 - 19	4.0	2.7	1.1 - 17.5	10	
20 - 34	4.3	3.3	0.8 - 20.4	20	
35 - 49	5.2	4.1	0.7 - 13.3	13	
50 +	8.8	7.4	2.6 - 23.7	23	
RESIDENCE AREA					-0.14
1	5.1	3.7	0.8 - 23.7	17	
2	6.7	4.6	0.7 - 20.4	19	
3	6.0	4.8	1.1 - 17.5	30	
YEARS LIVED IN AREA					0.26*
<5	4.9	3.2	0.8 - 23.7	13	
5-14	6.2	4.5	1.5 - 20.4	19	
15+	6.2	5.0	0.7 - 19.7	34	

1 Pearson correlation coefficient with log PCB.
* Significant at $p < 0.05$
** Significant at $p < 0.001$

Note: for estimating the correlation coefficients sex is coded male = 1, female = 0; area is coded 1 = Area 1, other areas = 0; the other variables were treated as continuous variables.

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TABLE 6

COMPARISON OF MEAN SERUM PCB LEVELS FOR PROBABILITY AND PRESELECTED GROUP PCB EXPOSURE STUDY, PAOLI, PA.

GROUP	NUMBER	ARITHMETIC MEAN (ppb)	GEOMETRIC MEAN (ppb)	PERCENT <20 ppb	T
Probability	62*	5.8	4.3	97	
Preselected	23	10.4	5.9	91	1.38**
Preselected Without the Outlier	22	7.4	5.3	95	

*Excludes four individuals also in preselected group.

**T-Test for difference between means
$p > 0.13$

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TABLE 7

RESULTS OF STEPWISE MULTIPLE REGRESSION OF SERUM PCB
ON SIX DEMOGRAPHIC VARIABLES
PCB EXPOSURE STUDY, PAOLI, PA.

PRIOR TO REMOVAL OF THE OUTLIER

STEP	VARIABLE ENTERED	F VALUE	PROBABILITY
1	age	30.15	0.0001
2	preselected group	3.71	0.06

N = 85

variables not entered because p > 0.15

sex
residence area
years lived in the area
worked with PCBs

RESULTS OF STEPWISE MULTIPLE REGRESSION OF SERUM PCB
ON SIX DEMOGRAPHIC VARIABLES AFTER OUTLIER IS REMOVED

STEP	VARIABLE ENTERED	F VALUE	PROBABILITY
1	age	37.58	0.0001

variables not entered because p > 0.15

preselected group
sex
residence area
years lived in the area
worked with PCBs

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TABLE 8

SERUM PCB CONCENTRATION IN US POPULATIONS
WITHOUT OCCUPATIONAL EXPOSURE
PCB EXPOSURE STUDY, PAOLI, PA.

NUMBER OF PEOPLE	PCB (ppb) ARITH. MEAN	PCB (ppb) GEOMET. MEAN OR MEDIAN*	PCB (ppb) RANGE	AREA SOURCE OF SAMPLES	REFERENCE
616	4.9		0-29	S. Carolina volunteers	Finklea, et al., 197[illegible]
29	17.3	15*	5-41	Michigan random fish eaters	Humphrey, 19[illegible]
110	18.8		6-79	Bloomington, IN volunteers	Baker, et al. 1980
1,631	7.7	6.4	1-87	Michigan PBB cohort	Kreiss, et a 1982
17	7.5	5.8	2-30	Montana meat-packers	Drotman, et al., 1982
105			<5	Franklin, ID volunteers	Drotman, et al., 1982
19	12		10-27	Random workers	Chase, 1982
7	4.9	4.2	2-11	Newton, KS volunteers	Vernon, et a 1981
418		6.6*	3-60	Lake Michigan fish eaters/random	Humphrey, 19
10	7.1	5.2	1-18	Canton, MA volunteers	Condon, 1982
138	3.6		3-43	Old Forge, PA volunteers	Reid and Fix 1982
59	5.8	4.4	1-45	Jefferson, OH volunteers	Stehr-Green, et al., 1986

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TABLE 8 (Continued)
SERUM PCB CONCENTRATION IN US POPULATIONS
WITHOUT OCCUPATIONAL EXPOSURE
PCB EXPOSURE STUDY, PAOLI, PA.

NUMBER OF PEOPLE	PCB (ppb) ARITH. MEAN	PCB (ppb) GEOMET. MEAN OR MEDIAN*	PCB (ppb) RANGE	AREA SOURCE OF SAMPLES	REFERENCE
40	6.7	5.0	1-23	Fairmont, WV volunteers	Stehr-Green, et al., 1984
990	4.9	4.2	2-30	Norwood, MA volunteers	Condon, 1981
61	6.8			Syracuse, NY nonexposed	Stark et al. 1986
54	4.6		1-15	operating engineers controls	Emmett, 1981
17	4.8		1-20	machine shop office workers	Christiani, et al., 1986
66	6.0	4.4	1-24	Probability group	THIS STUDY
23	10.4	5.9	1-77	Preselected group	THIS STUDY

**Personal communications, as sited in Kriess, K. 1985. Studies on popul exposed to polychlorinated biphenyls. Environmental Health Perspectives.

Modified from Kreiss, 1985

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FIGURE 1

STUDY AREA AND SEPTA SITE
PCB EXPOSURE STUDY, PAOLI, PA.

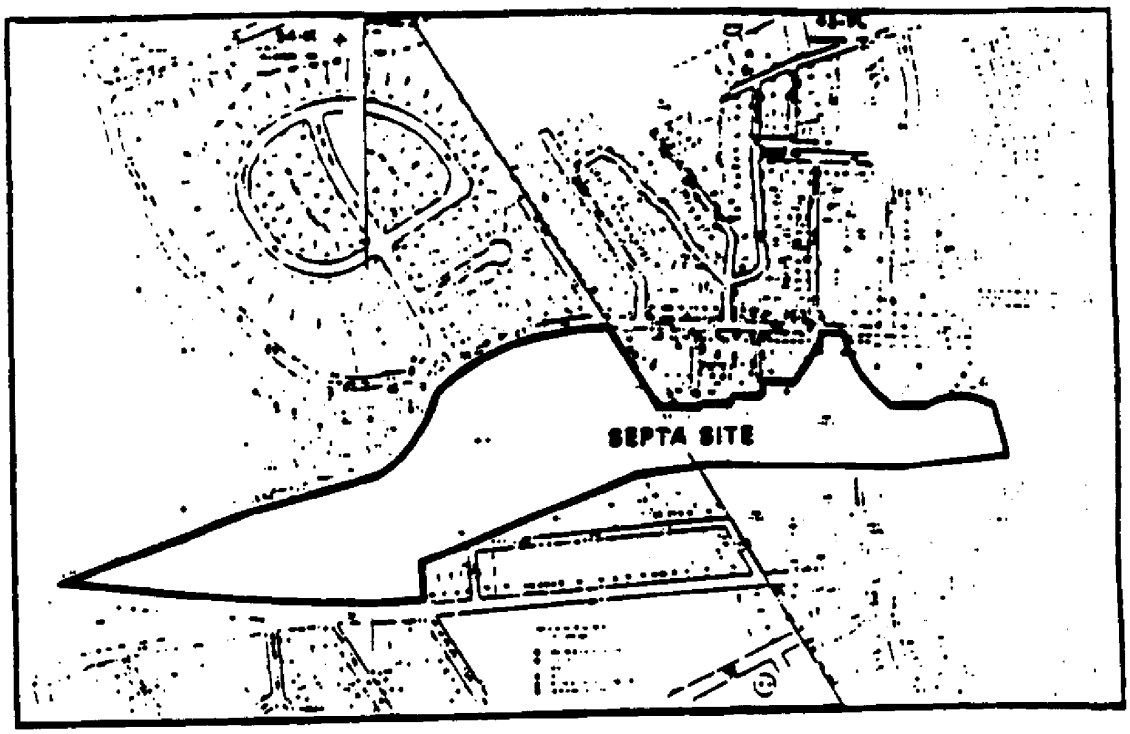

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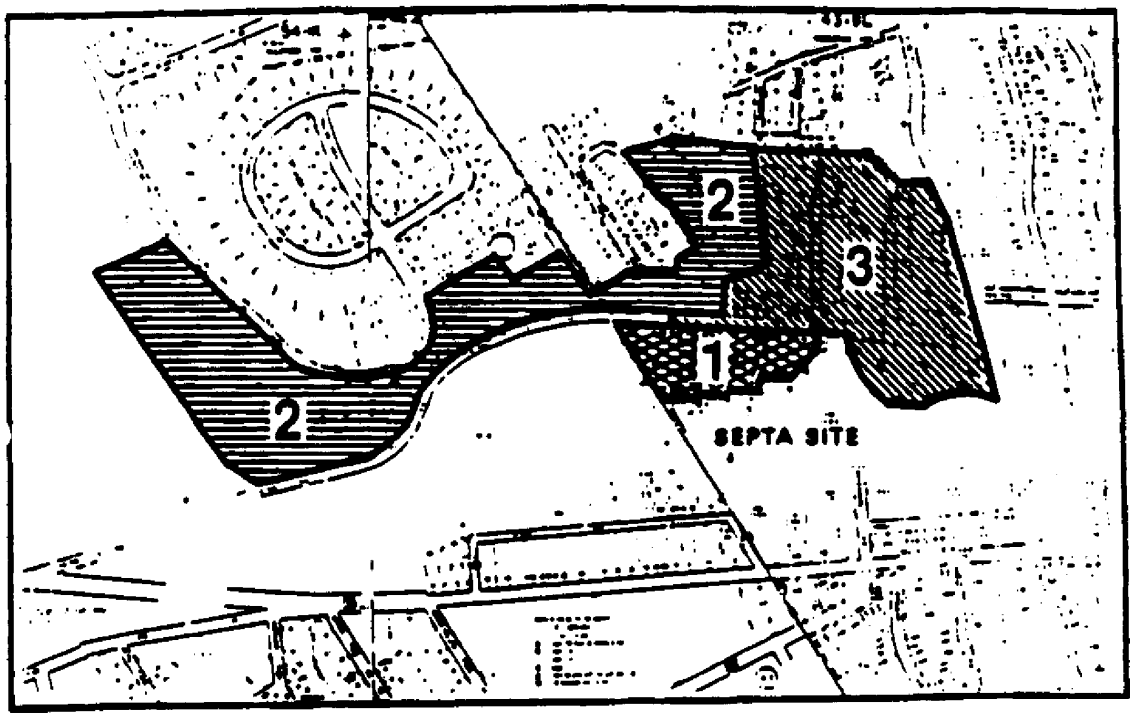
FIGURE 2

SECTION OF STUDY AREA
PCB EXPOSURE STUDY, PAOLI, PA.



1 = Downgradient Adjacent
2 = Downgradient
3 = Upgradient

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FIGURE 3

DISTRIBUTION OF SERUM PCB CONCENTRATIONS
PCB EXPOSURE STUDY, PAOLI, PA.

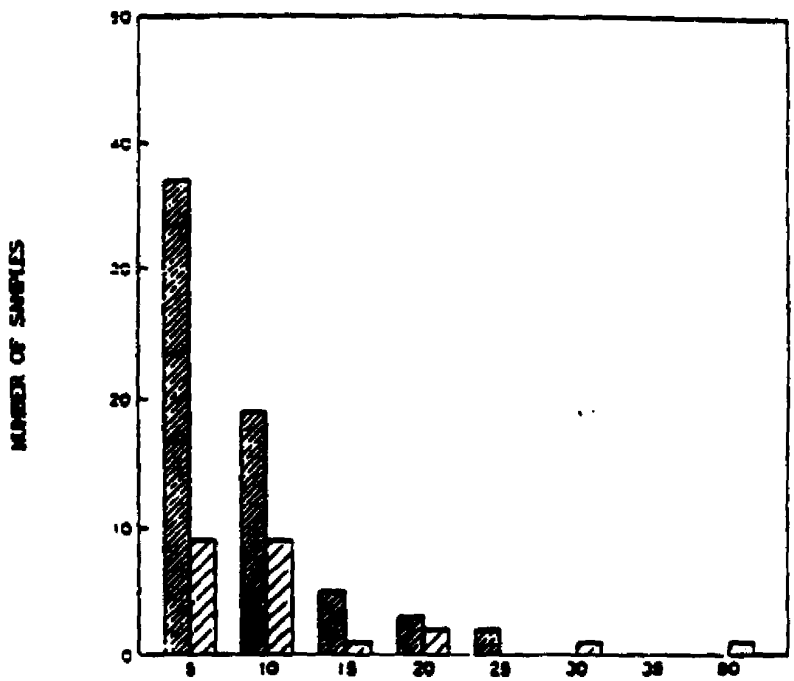

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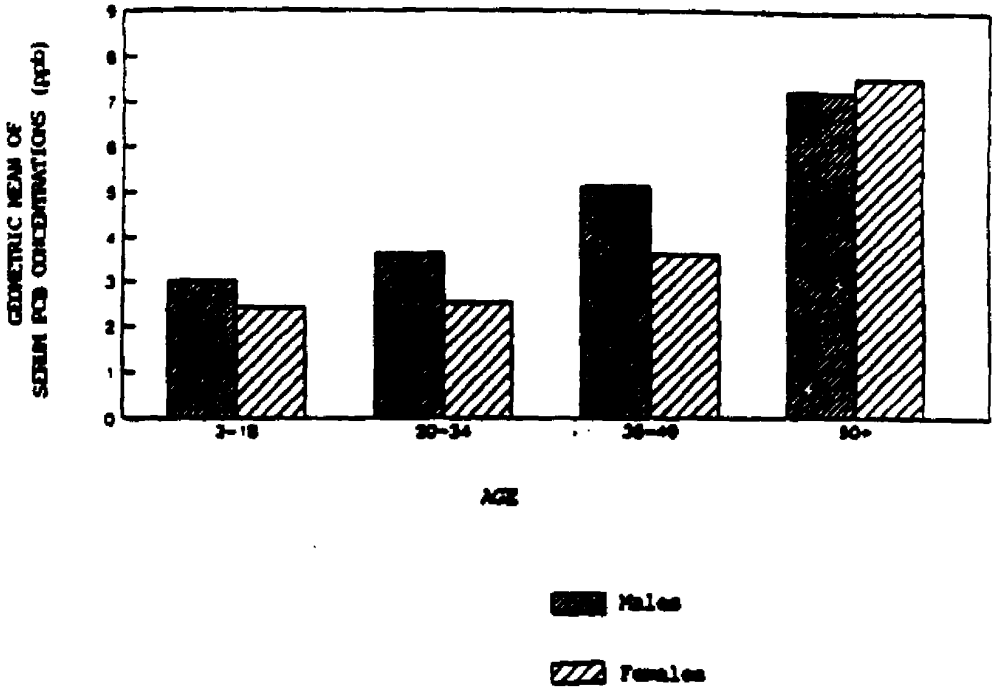
FIGURE 4

GEOMETRIC MEANS OF SERUM PCB CONCENTRATIONS
BY AGE AND SEX GROUPS
PCB EXPOSURE STUDY, PAOLI, PA.



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