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This study explores associations between breast cancer and body burdens of organochlorine chemicals, including dioxins, PCBs and pesticides. The targeted chemicals are lipophilic, bioaccumulate in adipose tissue, and have carcinogenic, estrogenic or anti-estrogenic properties. Cases are women with malignant disease and controls are women with benign histologic changes. Samples of breast adipose are obtained during surgery.

Preliminary results indicate low to moderate levels of most target chemicals, comparable to levels reported in other similar studies. The most prevalent pesticides are p,p'-DDE, trans-nonachlor and oxychlordane. The most prevalent PCBs are # 153, 180, and 138. Octa-, Hepta- and Hexa-Dioxins and Penta-Furan are the major Dioxin congeners. A wide range of lipid content was observed, mandating expression of results on a lipid basis. At the conclusion of the study, 50 cases will be compared to 50 controls. Body burdens will be contrasted and chemicals associated with disease will be identified, relative risks estimated and dose-response relationships established. Reduction of exposures to such chemicals could provide a means for primary prevention of breast cancer. Additionally, screening measures targeting women with an elevated body burden of such chemicals could enhance earlier detection of breast cancer, therefore decreasing morbidity and mortality.

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FOREWORD

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TABLE OF CONTENTS

FRONT COVER	1
REPORT DOCUMENTATION PAGE (SF 298)	2
FOREWORD	3
TABLE OF CONTENTS	4
INTRODUCTION	5
BACKGROUND	5
APPROACH	6
HYPOTHESIS/PURPOSE	6
TECHNICAL OBJECTIVES	7
METHODS	
STUDY POPULATION	7
QUESTIONNAIRES	8
SAMPLE HANDLING	8
HISTOPATHOLOGY	8
DATA TRACKING	9
PRELIMINARY RESULTS & DISCUSSION	9
PRELIMINARY CONCLUSIONS	11
TIMELINE	11
REFERENCES	12

INTRODUCTION

BACKGROUND

In the US, breast cancer is the most common cancer in women and the leading cause of death in women between the ages of 40 and 55 [1]. All known risk factors, however, are estimated to account for fewer than 30% of breast cancer cases [2]. Incidence rates have increased at a rate of 4% per year between 1982 and 1986 [3]. Although this increase is thought to be mainly due to earlier detection as a result of enhanced screening [4], part of the increase may be due to environmental factors. Extensive use of organochlorine pesticides and industrial chemicals in the first decades after WWII and the bioconcentration potential of these compounds in the food chain and in human tissues [5] may have placed a cohort of men and women at a high risk of exposure. As these women approach menopausal age, a well-documented risk factor [6], their body burden of these chemicals may place them at an even higher risk for developing breast cancer. A number of recent studies [7,14] have explored links between breast cancer and the presence of certain of these chemicals in humans. These studies vary in terms of sample size, matrix analyzed (serum vs. adipose), selection criteria and confounder adjustments. In the more recent and better designed studies, positive associations were found for β-HCH [9], DDE [10,11,12], DDT [10] and PCB 1260 [10]. On the other hand, no associations were found for DDE [13,14], or β-HCH [12] in subsequent studies. The inconsistency in these findings is noteworthy; DDE was the only chemical positively identified in more than one study. We believe that, in addition to differences in the design of the above studies (selection of cases and controls, covariates, statistical power), the selection of chemicals for analysis may have contributed to the inconsistent and conflicting results. A careful selection of chemical compounds which may be associated with the development of breast cancer is essential in the design of a study focusing on environmental risk factors.

The critical role of sex hormones in the development of breast cancer is well-accepted [15-17]. Experimental evidence indicates two mutually exclusive pathways in the metabolism of estradiol. One pathway leads to the formation of 2-hydroxyestrone (2-OH-E), a non-genotoxic metabolite with minimal estrogenic activity. The second pathway leads to the formation of 16-alpha hydroxyestrone (16a-OH-E) a genotoxic metabolite with high estrogenic activity [18]. It has been proposed that exogenous compounds may activate or inhibit each of these pathways [19]. Increases in the ratio of 16a-OH-E to 2-OH-E have been linked to breast cancer, while decreases appear protective. As an example, indole-3-carbinol, an ingredient of cruciferous vegetables decreases this ratio and also decreases the incidence of mammary tumors [20]. On the other hand, a number of chlorinated organic compounds, PAHs and pharmaceuticals are thought to increase the ratio of 16a-OH-E to 2-OH-E [19], or even act as direct estrogens. The direct estrogenic potential of some of the DDT analogs is well-documented [21-23]. There is also experimental evidence on the estrogenic properties of other chlorinated pesticides such as Methoxychlor [23], Beta-HCH [24], Heptachlor [25], Chlordane [25] and Kepone [25-27]. It would be desirable, therefore, to include such chemicals, as well as their metabolites (e.g., oxychlordane, heptachlor epoxide, etc.) and chemicals with similar structure (e.g. Mirex as a structural analog of Kepone) in a study of xenobiotics and breast cancer.

It is well known[28] that specific congeners of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans (PCDD/PCDFs) and Polychlorinated Biphenyls (PCBs) have significantly different potency in inducing diverse enzymes, modulating hormone receptor-binding activities, altering levels of thyroid hormone and vitamin A, and resulting in immunotoxicity, teratogenicity, hepatotoxicity, cancer and acute toxicity in various cell systems and animals. Of the over two hundred dioxin and furan congeners, seventeen are chlorinated in the 2,3,7,8 positions. The most extensively studied congener of this group is 2,3,7,8 tetra dioxin (TCDD). All seventeen congeners have a planar structure, exhibit the highest affinity for the Ah receptor [28] and bioaccumulate in human tissues [29]. Of the 209 Polychlorinated Biphenyls (PCBs), those substituted on both para- and at least two meta- positions are approximate isostereomers of 2,3,7,8 TCDD and exhibit high affinity for the Ah receptor [28]. Additionally, mono-ortho coplanar congeners exhibit affinity for the Ah receptor, but at a lower level. Recently, the anti-estrogenic potential of a number of these PCDD/PCDF and PCB congeners has been shown [30-33]. In general, their order of potency paralleled their binding affinities for the Ah receptor [30]. Unless these specific congeners are measured and controlled for in the analysis, exposures may be misclassified and associations missed.

APPROACH

We decided to examine the value of analysing breast adipose tissue for a wide range of chemical compounds that have the following properties:

1. They are lipophilic with long half-lives in human adipose tissue resulting in bioaccumulation, and
2. There is evidence for their carcinogenicity and/or their estrogenic or anti-estrogenic potential.

The selected chemical compounds (target analytes) are listed in Tables A, B and C in the Appendix.

HYPOTHESIS/PURPOSE

The purpose of the study is to drastically expand and refine the panel of chemical compounds that have been suspected of an association with breast cancer. Target compounds will include specific congeners of PCBs (rather than total PCBs); PCDDs/PCDFs and chlorinated pesticides with demonstrated carcinogenic or estrogenic/anti-estrogenic potency.

The hypothesis to be tested can be formulated as follows:

Ho: For each chemical compound in Tables A, B and C, there is no statistically significant difference in its concentration in breast adipose tissue of cases and matched controls.

TECHNICAL OBJECTIVES

The aim of the study is to elucidate the associations between breast cancer and the presence of organochlorine pesticides and specific PCB and PCDD/PCDF congeners in adipose tissue of women undergoing breast surgery.

The specific objectives of the study are:

1. To recruit, screen and select women for participation in the study.
2. To administer a questionnaire on medical and reproductive history, dietary habits and other health behaviors, environmental exposures, demographics and socioeconomic status.
3. To obtain samples of breast adipose tissue during surgery.
4. To analyze the adipose samples for a panel of chemicals.
5. To determine any correlations between chemicals measured in tissues of cases and controls. This would allow us to a) control for highly correlated measurements in a multivariate analysis of the data, and b) identify chemicals which can be used as surrogates for others, therefore reducing the number of analytes that would need to be measured in future studies.
6. To use multivariate logistic regression to calculate exposure-specific odds ratios while controlling for other risk factors, including other chemical compounds.

METHODS

STUDY POPULATION

The study subjects are recruited from among women undergoing open surgical biopsy, lumpectomy, or mastectomy at Stanford University Hospital. Stanford is a referral hospital drawing patients from a wide area in Northern California. While the target population is not representative of the general population of the State, it is representative of women at highest risk for breast cancer: predominately white and of higher socioeconomic status. The demographic and clinical profiles of study subjects will be compared to those for Stanford Hospital in general and, for breast cancer cases, to those reported via the population-based surveillance system covering the greater San Francisco Bay Area.

For the purpose of this study, cases are defined as women with definitive breast malignancies, and controls as women classified with benign histologic changes. Because of the strong association between atypical hyperplasia and subsequent breast cancer, women with atypical hyperplasia are excluded from the control group. Women with carcinoma in situ are also excluded as this is thought to be a tumor marker for elevated risk for development of future breast cancer in either breast. Also excluded from both the case and control groups are women with previous cancer diagnoses and women taking tamoxifen. Controls will be matched to cases by five-year age intervals. A total of 50 pairs will be accessioned into the study.

QUESTIONNAIRES

All study-eligible women are asked to sign a consent form and a medical release for access to medical records information, including the pathology report and associated diagnostic data. They are then asked to participate in an epidemiologic interview with two questionnaires:

1. Dietary Questionnaire. The dietary instrument is Gladys Block's short (60-item) inventory. The instrument has been used in a variety of cancer epidemiology studies by the California Department of Health Services, and serves well to estimate relative consumption of many dietary constituents, including total percent calories from fat.
2. Breast Cancer Study Questionnaire. The in-person interview solicits information on medical and reproductive history, family history, occupational and environmental exposures, health habits, and demographic characteristics.

Whereas the Dietary Questionnaire is used without any modifications, the Breast Cancer Study Questionnaire was developed specifically for this study. The instrument was field tested on 15 women in the pilot phase of this study, repeatedly modified and further refined to its current final form. Both the Dietary and the Breast Cancer questionnaires have the patient's medical record number as the sole identifier to ensure confidentiality during data review and coding.

SAMPLE HANDLING

In women undergoing surgical breast biopsy or wide local excision (lumpectomy or tylectomy), about 2 grams of breast adipose tissue are obtained from beyond the edges of the biopsy or excision cavity. For women undergoing mastectomy, similar amounts of breast adipose tissue are obtained from a site distant from the tumor in order not to interfere with pathologic analysis. The removed adipose tissue is immediately placed in chemically clean glass jars with teflon-lined screw caps. The jars are labeled with the medical record of the patient, with no other identifiers to ensure confidentiality and unbiased chemical analysis. Samples are frozen to below -20 C^{o} and transported to the Hazardous Materials Laboratory (HML) for analysis.

HISTOPATHOLOGY

Histologic sections of all breast lesions are evaluated by the Stanford University Department of Pathology. Diagnoses are coded as invasive malignant disease, non-invasive malignant disease, or benign histologic changes. Patients with breast disease classified as atypical hyperplasia or carcinoma in situ are excluded from the analysis.

A copy of the pathology report is reviewed for the definitive diagnosis and, for the cancer cases, additional tumor information is extracted including TNM staging; cell type; tumor size; histologic grading determined by nuclear atypia, mitotic activity, and tubule formation; and angiolymphatic perineural invasion. For invasive tumors only, presence of axillary lymph node metastases; estrogen

and progesterone receptor status; and possible DNA flow cytometry and S-phase fraction analysis is obtained.

DATA TRACKING

All completed questionnaires, medical records and pathology reports are kept by the PI in a secure filing cabinet. Periodically, information is extracted, coded and entered in a computerized data base specifically designed for the study (FilemakerPro). The patient's medical record number is the sole identifier in this data base. At the completion of the study, this data base will be merged with the data base of chemical analysis results and the combined data base will be subjected to statistical analysis.

A listing of all specimens archived in the laboratory freezer is also kept by the PI. A status report on completed analyses is updated biweekly.

PRELIMINARY RESULTS & DISCUSSION

As of October 1998, tissue samples from 84 participants had been extracted and prepared for analysis. Because analysis involves three different process streams with different instrumentation, not all analyses are performed in parallel. As a result, 82 samples have been analysed for dioxins and coplanar PCBs and 61 samples have been analysed for PCBs and OC pesticides. Analyses will proceed in the most optimal way to complete the project.

Selected demographic characteristics and distributions of selected covariates for the 84 participants (40 cases and 44 controls) are shown in Table 1. Incidence data from the California Cancer Registry for Stanford (1995, the most recent year recorded) are shown in Table 2. Both our study and the Stanford cases are predominantly Non-Hispanic White, but our study population is dominated by subjects in their 40s. At the end of the study a review of hospital accession data will allow us to examine how representative this population is of the population served by the hospital, and of the Bay Area population at large.

A wide range of lipid content was observed in the specimens received for analysis, as shown in Fig.1. In addition, there is a modest but significant association between lipid content and age. It is, therefore, imperative that results be expressed on a lipid basis to avoid misclassifications. This finding raises questions regarding the validity of certain published studies where data were used without lipid adjustment (Table 3). Perhaps some of the reasons for the conflicting findings may be traced to this issue.

Measurements of the major analytes are summarized in Table 4. The number of patients whose samples have been analysed so far (indicated as "N" in Table 4) differs from one type of analysis to the other. In addition, the percentage of those samples that were measured above the respective detection limit for each analyte is also shown. These preliminary data for the entire group of 84 women (cases

and controls combined) are compared to data from other appropriately selected studies in Figs 2-4. All data are expressed on a lipid weight basis

Fig.2 shows the major OCPs from this study ranked in decreasing order. The comparison population is a group of 17 controls from a Canadian Breast Cancer Study [13]. Not all OCPs measured in our study were measured in the Canadian study. Overall, levels appear similar, with the California study showing higher levels of trans-nonachlor and oxychlordane, both metabolites of chlordane. This may reflect lower historic use of chlordane in Canada, consistent with a colder climate.

Major PCB congeners are shown in decreasing order in Fig.3. The same Canadian population[13] is used for comparison and our data appear elevated for some congeners and similar for the rest. A number of PCB congeners were not measured in the Canadian study.

Major Dioxins and Furans, as well as the three coplanar PCBs are shown in Fig.4. Three populations are used for comparisons: Dioxin and Furan measurements in 48 composite adipose tissue samples collected in 1987 from the general US population[34], dioxin and furan measurements in adipose tissue from 17 women from the San Francisco Bay Area collected in 1988[35], and coplanar PCB measurements in 28 adipose samples from Atlanta[36] collected during autopsies in 1984-1986. Because of the small size of our tissue samples (sometimes less than 0.5 g), some PCDD/PCDF congeners were below detection. In such cases, I-TEQs were calculated using half the detection limit of the non-detected congeners. To facilitate comparisons with the other two data sets where, because of larger tissue samples, most congeners were above detection, an adjusted TEQ (Adj-TEQ) was introduced utilizing only those congeners that were consistently measured in most samples.

Dioxin and Furan levels appear similar to those in the earlier studies, particularly since subjects in these studies had different age distributions, a known confounder in dioxin body burdens. No systematic data are available from the US to establish US-based time trends. Similarly, no systematic data exist for co-planar PCBs in the US population. The Atlanta co-planar PCB data appear similar over all to our data.

An important finding was the high proportion of women with Carcinoma In Situ recruited into our study. Since these women cannot be included in either the Cases or the Control groups, we are setting them aside in search of additional funding that would allow analysis of these women as a separate exposure group. Inclusion of this third group would enhance our power to establish dose-response relationships.

In addition, the age distribution differs between the recruited Cases and Controls, the former being older than the latter. Since our study design calls for 100 age-matched cases and controls, the pool of eligible women needs to increase beyond the 160 currently in the study. Our efforts to balance the age frequencies in the two groups has resulted in a distribution favoring women in their 40s, the age range with the most overlap. This age distribution is different from the age distribution of the majority of women with breast cancer (Table 2). Such differences need to be taken into account when extrapolating findings of this study. On the other hand, our study population has a high proportion of premenopausal women, allowing sub-group comparisons.

PRELIMINARY CONCLUSIONS

Based on preliminary data, the following preliminary conclusions can be drawn:

1. Results need to be expressed on a lipid basis because the lipid content in the specimens is variable. This finding raises questions regarding the validity of certain published studies where non-lipid normalized data were used.
2. Body burdens of major organochlorine analytes appear overall similar, with a few exceptions, to data reported in other similar studies.

TIMELINE

During the first year (9/94-8/95) a number of organizational actions were taken, such as hiring and training the field personnel, as well as developing, field testing and refining the Breast Cancer Questionnaire as part of a pilot/training phase. The study started formally in January 1995, with the recruitment, interview and surgical procedures of the first five patients. In February 1995, our surgeon (Dr. Jeffrey) went on maternity leave and returned in January 1996. A one-year no-cost extension was requested and granted at that point.

In 1995-96 another surgeon (Dr. Ellen Mahoney) from Stanford Hospital was invited to participate in the study to enhance the recruitment pace. As a result, patient recruitment increased sharply, as shown in Fig. 5. Excluding women with non-eligible pathologies (atypical hyperplasia, etc.), all participants were interviewed and their specimens archived for chemical analysis. Analytical methodologies were refined, validated and used in the analysis of specimens. Chemical analysis of study specimens commenced.

In 1996-97, recruitment proceeded at a moderate pace, and all eligible patients were included in the study. To further enhance the recruitment pace we expanded the study to include another hospital (Kaiser-Oakland). After lengthy negotiations among the various Institutional Review Boards (DOD, Kaiser, Public Health Institute, California Department of Health Services) we finalized a communal Consent Form. Recruitment from Kaiser-Oakland started in the spring of 1998 and has provided us with a number of eligible patients. The recruitment rate is shown in Fig. 5.

All questionnaires received have been coded and entered in a data base. As of October 1998, approximately 80% of the analytical work has been completed.

Methodologies and preliminary results were presented at the International Dioxin Conferences[37-39] and at the Era of Hope meeting [40].

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TABLE 1. Selected demographic characteristics among breast cancer cases (n=40) and benign controls (n=44).

Characteristic	Controls n (%) *	Cases n (%) *	p (x^2)
Age Group			
< 40	9 (20.4)	4 (10.0)	
40-49	25 (56.8)	18 (45.0)	
50-59	7 (15.9)	11 (27.5)	
60+	3 (6.8)	7 (17.5)	0.12
Race/ethnicity:			
Non-Hispanic White	37 (84.1)	32 (80.0)	
Hispanic	4 (9.1)	2 (5.0)	
Black	1 (2.3)	0 (0.0)	
Asian/Pacific Islander	0 (0.0)	4 (10.0)	
Other	2 (4.5)	2 (5.0)	0.15
Country of birth			
US Born	35 (79.6)	33 (82.5)	
Foreign Born	9 (20.4)	7 (17.5)	0.81
Family Income:			
< 50,000	8 (18.2)	8 (21.6)	
50,000 – 99,999	18 (40.9)	10 (27.0)	
100,000 +	18 (40.9)	19 (51.3)	0.38
BMI (kg/m^2)			
≤ 22	24 (54.6)	22 (55.0)	
> 22	20 (45.4)	18 (45.0)	0.89
Menopausal Status			
Premenopausal	28 (68.3)	21 (52.5)	
Postmenopausal	13 (31.7)	19 (47.5)	0.11
Age at Menopause			
< 45	7 (53.9)	6 (33.3)	
45+	6 (46.1)	12 (66.7)	0.25
Age at Menarche			
≤ 12	27 (61.4)	16 (41.0)	
> 12	17 (38.6)	23 (59.0)	0.06
Parity			
Nulliparous	13 (31.0)	10 (25.0)	
Parous	29 (69.0)	30 (75.0)	0.55
Age at first live birth			
< 30	21 (72.4)	22 (75.9)	
30+	8 (27.6)	7 (24.1)	0.76
Breastfeeding (parous women only)			
Ever	25 (86.2)	24 (80.0)	
Never	4 (13.8)	6 (20.0)	0.52
Lifetime duration of breastfeeding			
> 0 to < 6 months	5 (20.0)	11 (45.8)	
≥ 6 to < 12 months	8 (32.0)	5 (20.8)	
12+ months	12 (48.0)	8 (33.3)	0.15
Tumor ER status			
Positive	N/A	29 (76.3)	
Negative	N/A	9 (23.7)	—

* Totals do not always sum up because of missing information

TABLE 2. Study Patients (Cases only) vs. all Invasive Female Breast Cancer Patients treated at Stanford (1995)

	Study	Stanford
Age:		
< 40	10%	9%
40 - 49	45%	20%
50 - 59	28%	29%
60+	17%	42%
Non-Hispanic White	80%	80%

TABLE 3. Summary of findings in similar studies. Analytes found to have a significant association with development of breast cancer are shown along with the tissue sampled and the type of lipid adjustment, if any.

TISSUE	LIPID ADJUSTMENT	ANALYTE	REFERENCE
ADIPOSE	GRAVIMETRIC	-	UNGER, 84
	GRAVIMETRIC	β-HCH	MUSSALO-RAUHAMA, 92
	GRAVIMETRIC	DDE, PCB	FALK, 92
	NONE	DDE, PCB	DEWAILLY, 94
	GRAVIMETRIC	OCDD	HARDELL, 96
	NONE	-	VAN'T VEER, 97
SERUM	NONE	DDE	WOLF, 93
	NONE	-	KRIEGER, 94
	GRAVIMETRIC	-	LOPEZ-CARILLO, 97
	CHOLESTEROL+ TRIGLYCERIDES	PCB	MOYSICH, 98
PLASMA	NONE	HCB	
	CHOLESTEROL	-	

TABLE 4. Concentrations of OCPs, Dioxins and Furans, co-planal PCBs and non-coplanar PCBs among all study participants with complete data. Data expressed as ng/g fat (OCPs, non-coplanar PCBs) or pg/g fat (Dioxins and Furans, co-planal PCBs).

Chemical	n	% Detected	Mean	Std. Dev.	Median	Min.	Max.
Fat (%)	84	100	70	21	78	10	95
OCPs (ng/g fat):							
DDE	60	100	745	364	682	120	2200
trans-nonachlor	60	98	136	148	87	20	690
Oxychlordane	59	97	72	57	56	17	340
DDT	56	92	50	43	40	8	260
HCB	61	100	46	28	35	14	170
β-HCH	57	93	42	37	33	1	210
Dieldrin	59	98	34	30	28	8	230
PCBs (ng/g fat):							
153/132	61	100	159	97	131	44	559
180	61	100	139	78	123	55	497
74	61	100	86	107	56	12	790
138	61	100	98	68	80	16	402
182/187	61	100	47	31	40	15	212
170	61	100	60	34	50	21	165
196/203	61	100	36	20	33	12	132
194	61	100	42	23	36	16	117
199	61	100	29	17	27	9	103
156	61	100	34	28	26	4	160
118	61	100	27	16	24	6	86
206	61	100	22	19	15	6	117
183	61	100	18	13	15	6	79
99/113	61	100	18	13	13	5	89
177	61	100	18	14	14	3	85
Coplanar PCBs(pg/g fat)							
PCB 126	71	94	106	114	85	1	870
PCB 169	73	92	63	42	55	2	204
PCB_TEQ	78	100	38	23	34	7	110
Dioxins & Furans (pg/g fat):							
TCDD	81	68	5	4	4	1	20
PeCDD	82	59	11	7	9	3	29
123678-HxCDD	82	100	61	38	54	10	232
HpCDD	82	100	72.2	48	62	13	293
OCDD	82	98	573	568	404	136	3290
23478-PeCDF	82	94	10.4	5.3	9.5	3	26
123478-HxCDF	82	89	6	6	5	2	48
123678-HxCDF	82	85	5	3	4	1	15
I-TEQ	82	100	17.8	13	14	6	78
Adj-TEQ *	82	100	20	13	17	3	72

* Adj-TEQ: Based only on the 8 congeners listed

FIG. 1. LIPID CONTENT OF BREAST ADIPOSE vs. AGE
R2 = 0.14, p<0.001, N=84

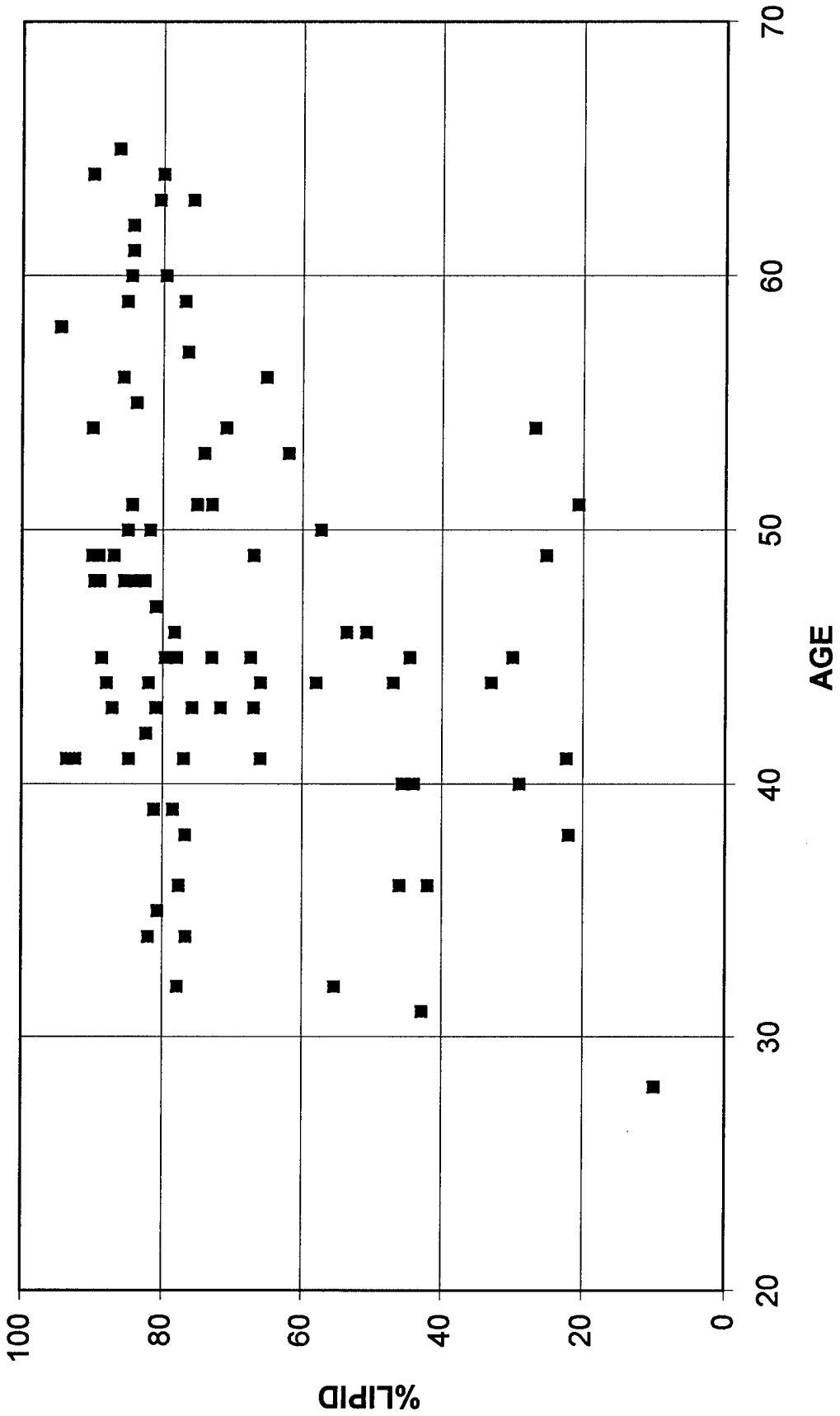


FIG. 2. MAJOR OCPs in BREAST ADIPOSE TISSUE in 61 WOMEN from THIS STUDY AND 17 CANADIAN CONTROLS

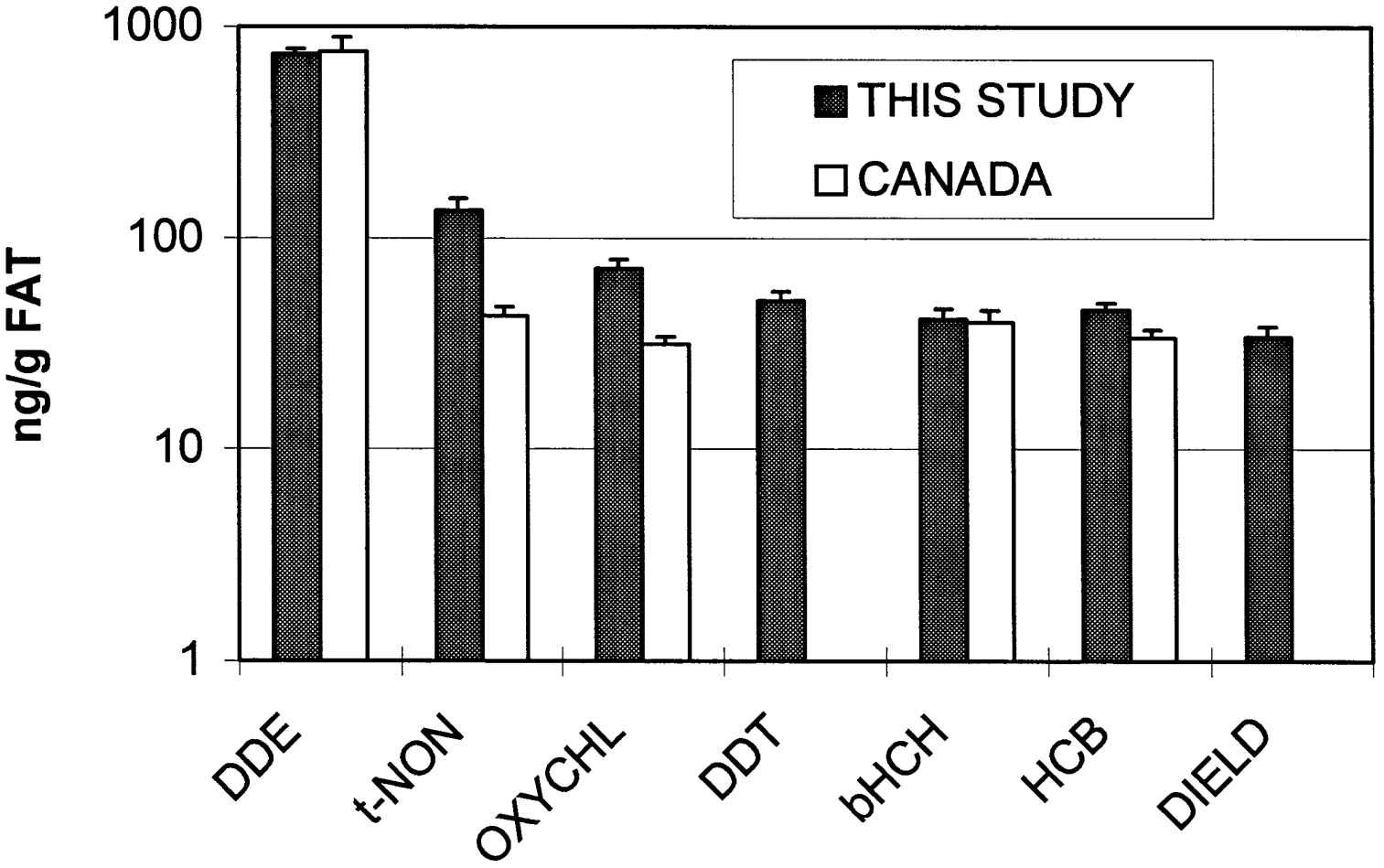


FIG. 3. MAJOR PCBs IN BREAST ADIPOSE TISSUE
FROM 61 WOMEN IN THIS STUDY & 17 CANADIAN CONTROLS

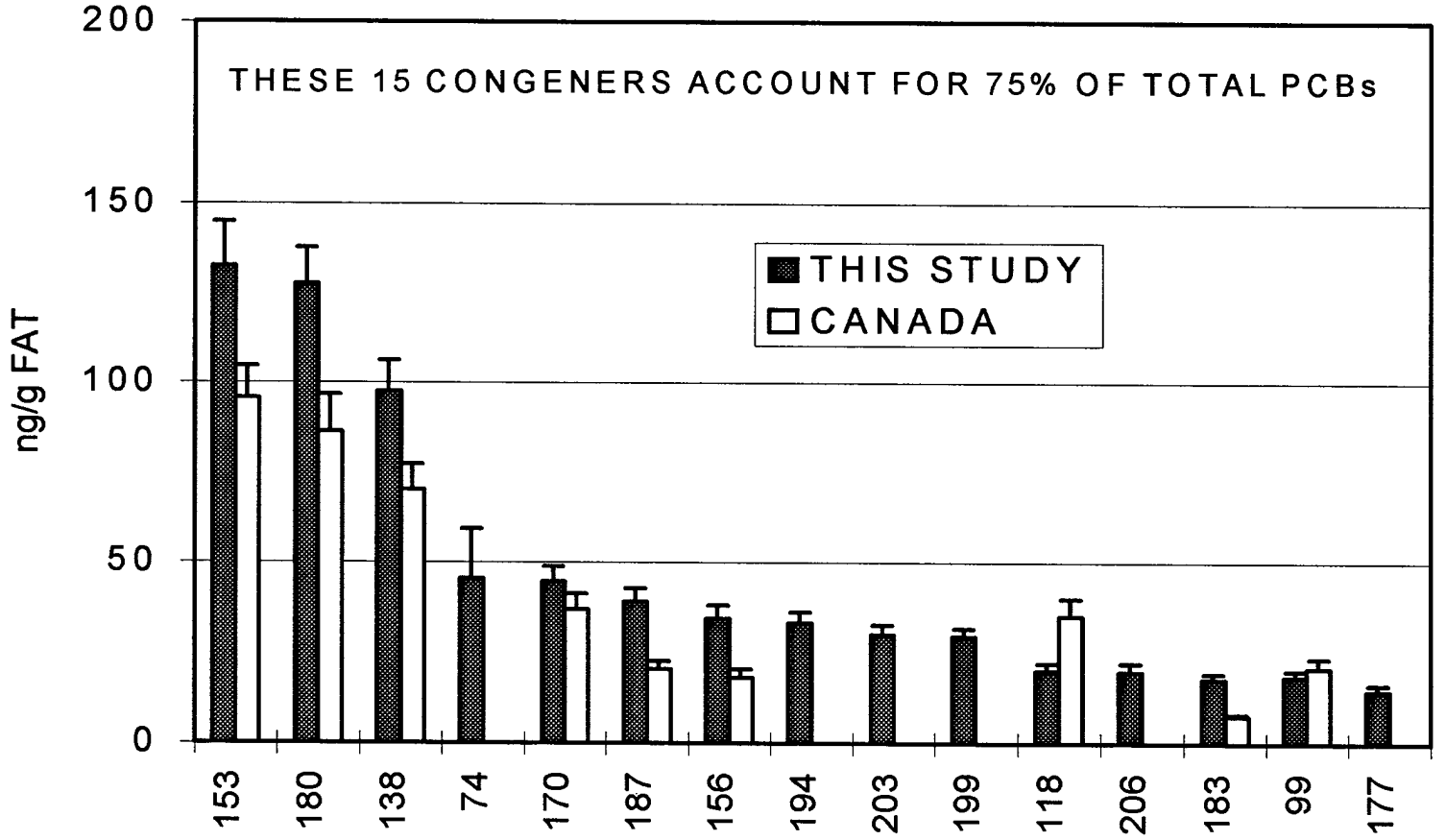


FIG. 4. MAJOR PCDD/Fs and CO-PLANAR PCBs in 82 WOMEN FROM THIS STUDY & 1980's US POPULATIONS

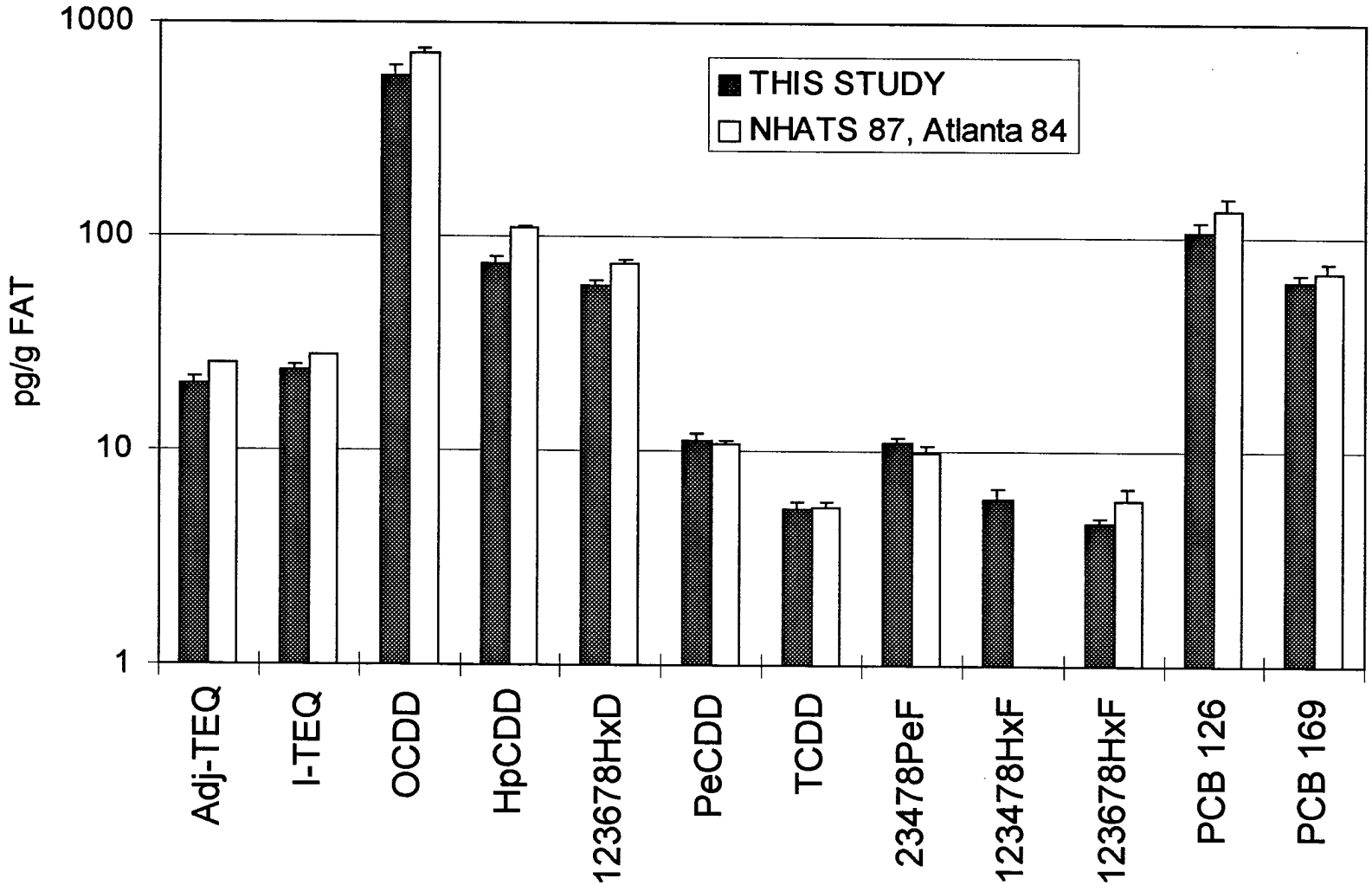
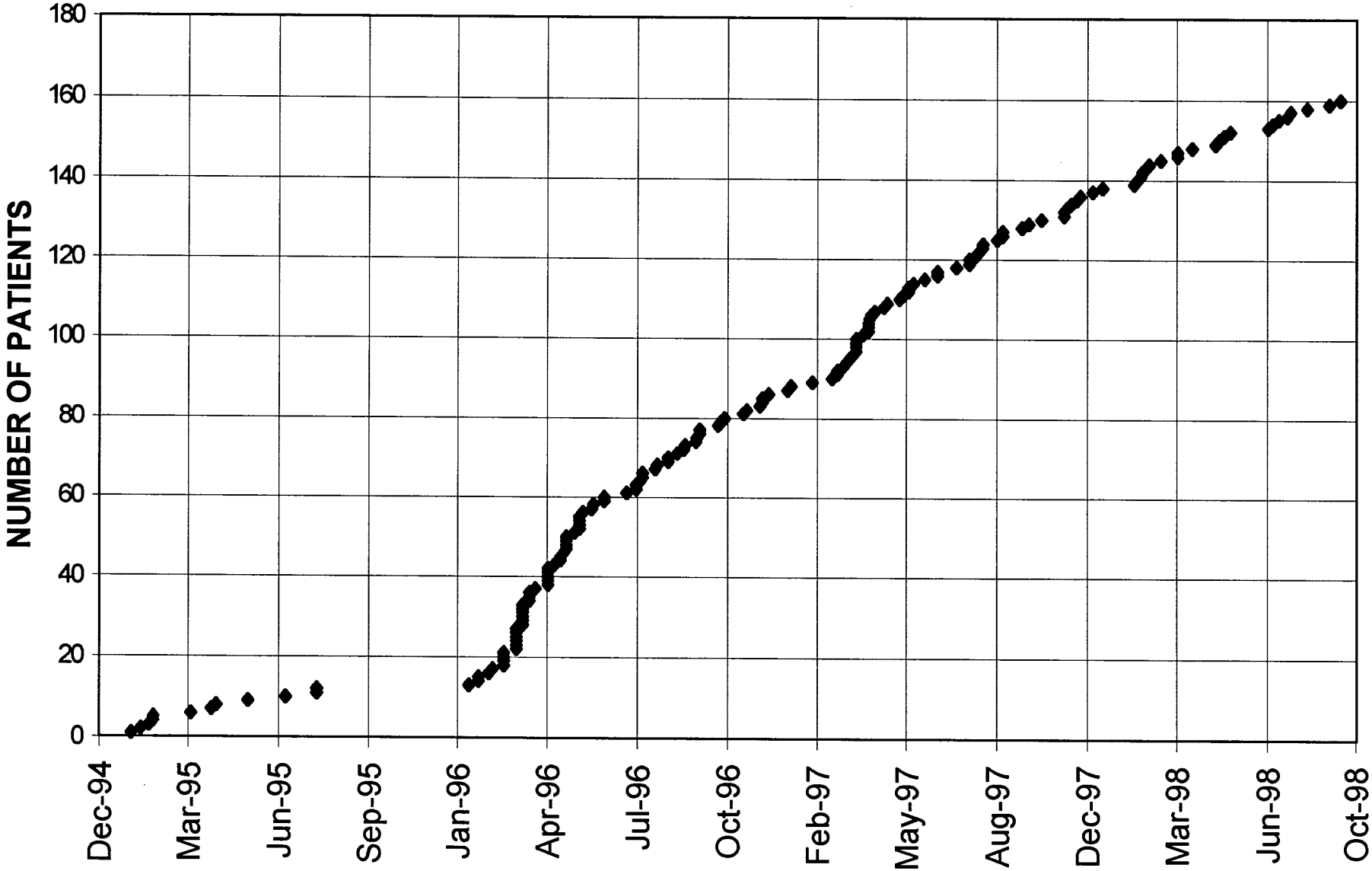


FIG. 5 RECRUITMENT RATE



Appendix 1 Target chemical compounds

Organochlorine pesticides (Table A)
Dioxins and furans (Table B)
Congener-specific PCBs (Table C)

TABLE A. ORGANOCHLORINE COMPOUNDS TARGETED FOR ANALYSIS

Common Name	CAS Registry	Molecular Formula	Chemical Name
DDT (o,p')	789-02-6	$C_{14}H_9Cl_5$	1-(o-chlorophenyl)-1-(p-chlorophenyl)-2,2,2-trichloroethane
DDT(p,p')	50-29-3	$C_{14}H_9Cl_5$	1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane; 1,1-bis(4-chlorophenyl)-2,2,2-trichloroethane
DDE(o,p')	3424082-6	$C_{14}H_8Cl_4$	1-(o-chlorophenyl)-1-(p-chlorophenyl)-2,2-dichloroethylene
DDE(p,p')	72-55-9	$C_{14}H_8Cl_4$	2,2-bis-(p-chlorophenyl)-1,1-dichloroethylene
Methoxychlor	72-43-5	$C_{16}H_{15}Cl_3O$	1,1,1-trichloro-2,2bis(4-chlorophenyl)ethane
HCB	118-74-1	C_6Cl_6	Hexachlorobenzene
α-BHC	319-84-6	$C_6H_6Cl_6$	α-1,2,3,4,5,6-Hexachlorocyclohexane
β-BHC	319-85-7	$C_6H_6Cl_6$	β-1,2,3,4,5,6-Hexachlorocyclohexane
γ-BHC	58-89-9	$C_6H_6Cl_6$	γ-1,2,3,4,5,6-Hexachlorocyclohexane
α-Chlordane	5103-71-9	$C_{10}H_6Cl_8$	1-exo,2-exo,4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
β-Chlordane	5103-74-2	$C_{10}H_6Cl_8$	1,2,4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene
γ-Chlordane	5564-34-7	$C_{10}H_6Cl_8$	1-exo,2-endo,4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
Oxychlorodane	26880-48-8	$C_{10}H_4Cl_8O$	1-exo,2-endo-4,5,6,7,8,8-octachloro-2,3-exo-epoxy-2,3,3a,4,7,7a-hexahydro-4,7methanoindene
trans-Nonachlor	39765-80-5	$C_{10}H_5Cl_9$	1-exo,2-endo,-3-exo,4,5,6,7,8-Nonachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane
Heptachlor	76-44-8	$C_{10}H_5Cl_7$	1,4,5,6,7,8,8-Heptachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindane
Heptachlor epoxide	1024-57-3	$C_{10}H_5Cl_7O$	1,4,5,6,7,8,8-Heptachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindane
Chlorodecone	143-50-0	$C_{10}Cl_{10}O$	1,2,3,4,5,5,6,7,8,9,10,10-Dodecachlorooctahydro-1,3-4-metheno-2-cyclobuta-[c,d]-pentalone
Mirex	2385-85-5	$C_{10}Cl_{12}$	1,1a,2,2,3,3a,4,5,5,5a,5b,6-Dodecachlorooctahydro-1,3-4-metheno-1H-cyclobuta-[c,d]-pentalone

TABLE B. PCDD/PCDFS TARGETED FOR ANALYSIS

Common Name	CAS Registry	Molecular Formula	Chemical Name
2,3,7,8-TCDD	1746-10-6	$C_{12}H_4Cl_4O_2$	2,3,7,8-Tetrachlorodibenzo-p-dioxin
Total-TCDD	41903-57-5	$C_{12}H_4Cl_4O_2$	Tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF	41903-57-5	$C_{12}H_4Cl_4O$	2,3,7,8-Tetrachlorodibenzofuran
Total-TCDF	55722-27-5	$C_{12}H_4Cl_4O$	Tetrachlorodibenzofuran
1,2,3,7,8-PeCDD	40321-76-4	$C_{12}H_3Cl_5O_2$	1,2,3,7,8-Pentachlorodibenzo-p-dioxin
Total-PeCDD	36088-22-9	$C_{12}H_3Cl_5O_2$	Pentachlorodibenzo-p-dioxin
1,2,3,7,8-PeCDF	57117-41-6	$C_{12}H_3Cl_5O$	1,2,3,7,8-Pentachlorodibenzofuran
2,3,47,8-PeCDF	57117-31-4	$C_{12}H_3Cl_5O$	2,3,4,7,8-Pentachlorodibenzofuran
Total-PeCDF	30402-15-4	$C_{12}H_3Cl_5O$	Pentachlorodibenzofuran
1,2,3,4,7,8-HxCDD	39227-28-6	$C_{12}H_2Cl_6O_2$	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin
1,2,3,6,7,8-HxCDD	57653-85-6	$C_{12}H_2Cl_6O_2$	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin
1,2,3,7,8,9-HxCDD	19408-74-3	$C_{12}H_2Cl_6O_2$	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin
Total-HxCDD	34465-46-08	$C_{12}H_2Cl_6O_2$	Hexachlorodibenzo-p-dioxin
1,2,3,4,7,8-HxCDF	70648-26-8	$C_{12}H_2Cl_6O$	1,2,3,4,7,8-Hexachlorodibenzofuran
1,2,3,6,7,8-HxCDF	57117-44-9	$C_{12}H_2Cl_6O$	1,2,3,6,7,8-Hexachlorodibenzofuran
1,2,3,7,8,9-HxCDF	72918-21-9	$C_{12}H_2Cl_6O$	1,2,3,7,8,9-Hexachlorodibenzofuran
2,3,4,6,7,8-HxCDF	60851-34-5	$C_{12}H_2Cl_6O$	2,3,4,6,7,8-Hexachlorodibenzofuran
Total-HxCDF	55684-94-1	$C_{12}H_2Cl_6O$	Hexachlorodibenzofuran
1,2,3,4,6,7,8-HpCDD	35822-46-9	$C_{12}H_1Cl_7O_2$	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin
Total-HpCDD	37871-00-4	$C_{12}H_1Cl_7O_2$	Heptachlorodibenzo-p-dioxin
1,2,3,4,6,7,8-HpCDF	67562-39-4	$C_{12}H_1Cl_7O$	1,2,3,4,6,7,8-Heptachlorodibenzofuran
1,2,3,4,7,8,9-HpCDF	55673-89-7	$C_{12}H_1Cl_7O$	1,2,3,4,7,8,9-Heptachlorodibenzofuran
Total-HpCDF	38998-75-3	$C_{12}H_1Cl_7O$	Heptachlorodibenzofuran
OCDD	3268-87-9	$C_{12}Cl_8O_2$	Octachlorodibenzo-p-dioxin
OCDF	39001-02-0	$C_{12}Cl_8O$	Octachlorodibenzofuran

TABLE C. PCBS TARGETED FOR ANALYSIS

IUPAC Number	CAS Registry	Molecular Formula	Chemical Name
77	32598-13-3	$C_{12}H_6Cl_4$	3,3',4,4'-tetrachlorobiphenyl
126	57465-28-8	$C_{12}H_5Cl_5$	3,3',4,4',5-pentachlorobiphhenyl
169	32774-16-6	$C_{12}H_4Cl_6$	3,3',4,4',5,5'-hexachlorobiphenyl
28	7012-37-5	$C_{12}H_7Cl_3$	2,4,4'-trichlorobiphenyl
56	41464-43-1	$C_{12}H_6Cl_4$	2,3,3',4'-tetrachlorobiphenyl
60	33025-41-1	$C_{12}H_6Cl_4$	2,3,4,4'-tetrachlorobiphenly
66	32598-10-1	$C_{12}H_6Cl_4$	2,3',4,4'-tetrachlorobiphenly
74	32690-93-0	$C_{12}H_6Cl_4$	2,4,4',5-tetrachlorobiphenly
105	32598-14-4	$C_{12}H_5Cl_5$	2,3,3',4,4'-pentachlorobiphhenyl
114	74472-37-0	$C_{12}H_5Cl_5$	2,3,4,4',5-pentachlorobiphhenyl
118	31508-00-6	$C_{12}H_5Cl_5$	2,3',4,4',5-pentachlorobiphhenyl
123	65510-44-3	$C_{12}H_5Cl_5$	2',3,4,4',5-pentachlorobiphhenyl
156	38380-08-4	$C_{12}H_4Cl_6$	2,3,3',4,4',5-hexachlorobiphenyl
157	69782-90-7	$C_{12}H_4Cl_6$	2,3,3',4,4',5'-hexachlorobiphenyl
167	52663-72-6	$C_{12}H_4Cl_6$	2,3',4,4',5,5'-hexachlorobiphenyl
189	39635-31-9	$C_{12}H_3Cl_7$	2,3,3',4,4',5,5'-heptachlorobiphenyl
52	35693-99-3	$C_{12}H_6Cl_4$	2,2',5,5'-tetrachlorobiphenyl
99	38380-01-7	$C_{12}H_5Cl_5$	2,2',4,4',5-pentachlorobiphenyl
101	37680-73-2	$C_{12}H_5Cl_5$	2,2',4,5,5'-pentachlorobiphenyl
128	38380-07-3	$C_{12}H_4Cl_6$	2,2',3,3',4,4'-hexachlorobiphenyl
137	35694-06-5	$C_{12}H_4Cl_6$	2,2',3,4,4',5-hexachlorobiphenyl
138	35065-28-2	$C_{12}H_4Cl_6$	2,2',3,4,4',5'-hexachlorobiphenyl
146	51908-16-8	$C_{12}H_4Cl_6$	2,2',3,4',5,5'-hexachlorobiphenyl
153	35065-27-1	$C_{12}H_4Cl_6$	2,2',4,4',5,5'-hexachlorobiphenyl
158	74472-42-7	$C_{12}H_4Cl_6$	2,3,3',4,4',6-hexachlorobiphenyl
170	35065-30-6	$C_{12}H_3Cl_7$	2,2',3,3',4,4',5-heptachlorobiphenyl
180	35065-29-3	$C_{12}H_3Cl_7$	2,2',3,3',4,4',5,5'-heptachlorobiphenyl
190	41411-64-7	$C_{12}H_3Cl_7$	2,3,3',4,4',5,6-heptachlorobiphenyl
191	74472-50-7	$C_{12}H_3Cl_7$	2,3,3',4,4',5',6-heptachlorobiphenyl
194	35694-08-7	$C_{12}H_2Cl_8$	2,2',3,3',4,4',5,5'-octachlorophenyl
177	52663-70-4	$C_{12}H_3Cl_7$	2,2',3,3',4',5,6-heptachlorobiphenyl
178	52663-67-9	$C_{12}H_3Cl_7$	2,2,3,3',5,5',6-heptachlorobiphenyl
182	60145-23-5	$C_{12}H_3Cl_7$	2,2',3,4,4',5,6'-heptachlorobiphenyl
183	52663-69-1	$C_{12}H_3Cl_7$	2,2',3,4,4',5',6-heptachlorobiphenyl
187	52663-68-0	$C_{12}H_3Cl_7$	2,2',3,4',5,5',6-heptachlorobiphenyl