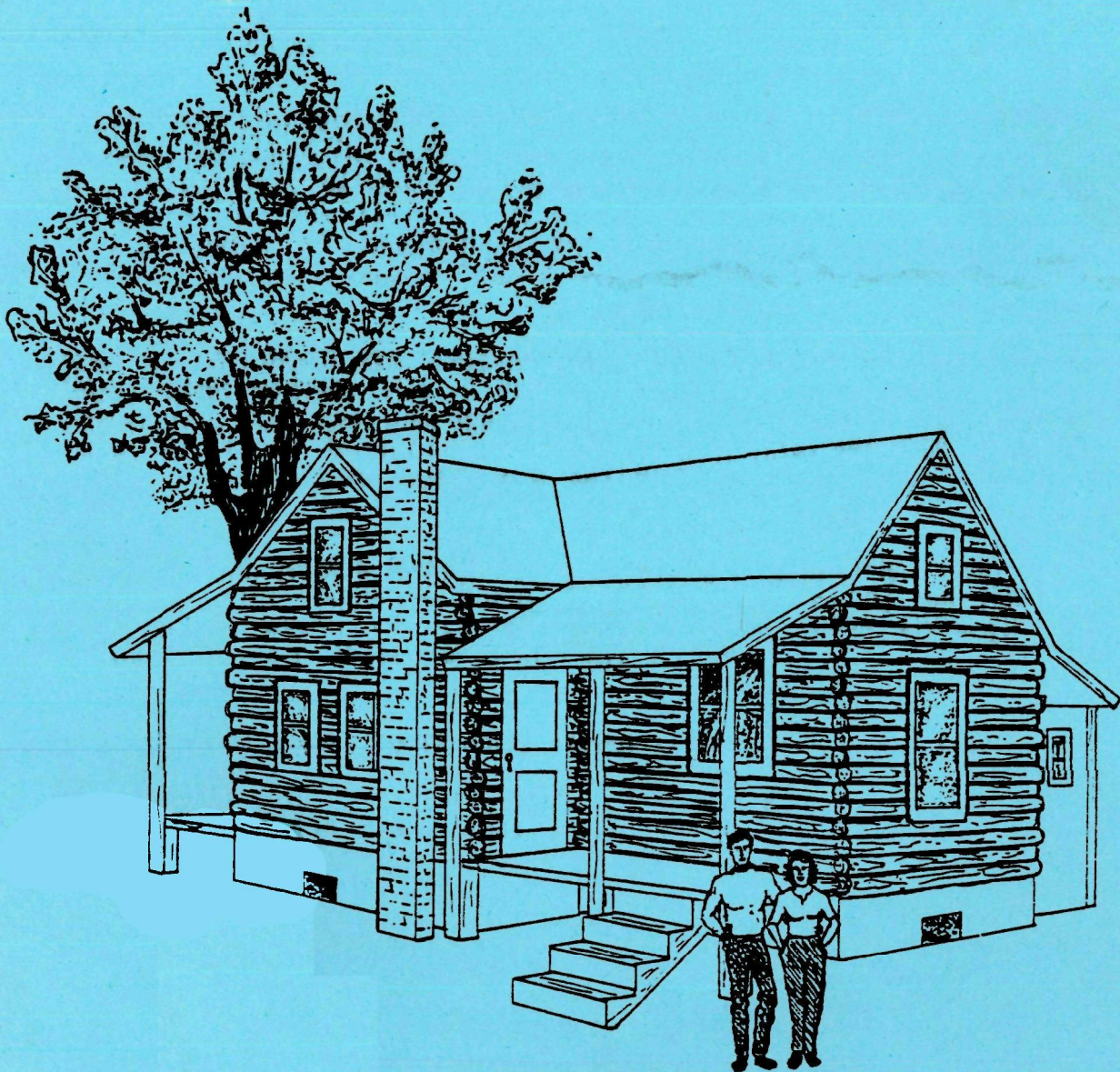




Pentachlorophenol in Log Homes: A Study of Environmental and Clinical Aspects

Executive Summary



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**PENTACHLOROPHENOL IN LOG HOMES: A STUDY OF
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EXECUTIVE SUMMARY

By

John M. Hosenfeld

**EPA Prime Contract Nos. 68-02-3938 and 68-02-4252
MRI Project Nos. 8201-A(11) and 8801-A(02)**

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Prepared for

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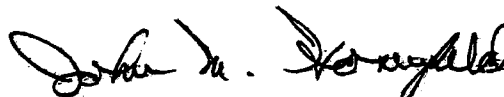
PREFACE

This executive summary provides an overview of the results obtained on Midwest Research Institute Project No. 8201-A, Work Assignment No. 11, "Development of Field Survey and Analysis Strategies" for the Environmental Protection Agency (EPA Prime Contract Nos. 68-02-3938 and 68-02-4252). This work was a joint venture between MRI and the Center for Occupational and Environmental Health (COEH) of Johns Hopkins University as a subcontractor (COEH Subcontract No. 117-7900-17 and 130-7900-9). Under the direction of Mr. John M. Hosenfeld, MRI was responsible for the overall task management, the environmental sampling (assisted by Ms. Marilyn J. Gabriel), and laboratory analyses of environmental and biological samples for pentachlorophenol (performed by Ms. Leslie Moody).

COEH, under the direction of Dr. Edward A. Emmett, was responsible for recruitment and project coordination (performed by Ms. Robin M. Friesem), assistance in environmental sampling (Dr. Peter S.J. Lees, Mr. Patrick Breysee), collection of biological samples and physical examinations (Drs. Rebecca Bascom and Diane Bennett), statistical analysis of environmental, clinical, biochemical data (Ms. Joan L. Jefferys) and data interpretation in conjunction with MRI. The clinical laboratory tests were performed by Pathologists Service Professional Associates, Atlanta, GA, and Montefiore Medical Center, Bronx, NY. This summary report was prepared by Mr. Hosenfeld.

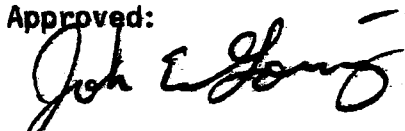
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I. SUMMARY

A. Background and Objectives

The U.S. Environmental Protection Agency's Office of Toxic Substances conducted a survey of pentachlorophenol (PCP) treated log homes and their occupants at the request of the Kentucky Department for Health Services. This study was conducted because of the possible exposure of log home residents to PCP from the treated logs. The results of this study are presented in this report.

The primary objectives of this study were (a) to determine the extent of environmental levels of PCP in log homes which had been treated with PCP; (b) to determine the extent of biological exposure in log homes treated with PCP; and (c) to examine the relationship between selected health variables and biological PCP concentrations. These health variables and biological PCP concentrations were analyzed in a search for possible effects of residues in a PCP treated log home.

B. Scope

The target population was the residents of log homes that had been treated with PCP, located in the State of Kentucky and that had been sampled in an earlier study conducted in 1980. Twelve of these previous study homes were included in the present study together with nine homes constructed from logs not treated with PCP according to the manufacturer.

C. Data Collected

Environmental and medical data were collected. An environmental evaluation of each of the 21 homes was conducted. The evaluation consisted of house treatment questionnaire administered to the head of the household, and collection of wood core, surface wipes (2), indoor air samples (3), and water samples. All samples were examined for PCP concentration.

The medical evaluation consisted of a health history questionnaire; a directed, standardized physical examination with particular attention to abnormalities of the skin and nervous system and the presence or absence of lymphadenopathy. Sample collection from the log home residents consisted of blood drawing for serum PCP concentration, serum liver and renal function tests, and tests for blood morphology and abnormalities, and a collection of the first voided urine of the day for tests for renal and adrenal dysfunction, enzyme induction and urinary PCP--both free and conjugated. All of the biological samples were collected within 18 h of the environmental sampling in each each study participant home.

D. Major Findings

Following are the major findings of this study.

All houses examined in this study had some levels of PCP in the logs. There were actually six treatment categories in which the 21 studied log homes fell. The highest PCP levels were found in the manufacturer treated homes (4); next in the manufacturer treated homes and subsequently sealed (4); next in the manufacturer treated and subsequently sealed and neutralized (1); next in the manufacturer treated homes and subsequently neutralized (3); next exterior treatment only (4) and lowest PCP levels in never treated homes (4). The "never treated" homes had some level of PCP due to the probable spraying of the logs during storage to prevent fungal growth.

Environmental PCP contamination was detected in all the homes of the study population. Environmental PCP concentrations spanned a wide range and were up to several orders of magnitude greater in treated homes than in untreated homes. PCP was detected in 62 of 63 air samples with a limit of detection (LOD of 0.001 ng/L), in 21 of 21 composite wood core samples (LOD = 0.9 ng/g), in 21 of 21 composite wipe samples of log surfaces (LOD = 0.3 ng/100 cm²), and in 4 of 21 water samples (LOD = 0.2 ng/L).

Significant differences ($\alpha = 0.05$) were seen among the six house treatment categories for air, wood core, and surface wipe PCP concentrations with the lowest values in the never-treated category, next lowest in the external treatment category, and highest values in the various manufacturer treated categories. PCP was found in the drinking water of four houses, all of which had been treated and all of which used a cistern as the only source of water.

Wood, air and surface-wipe concentrations of PCP were highly correlated with each other. An analysis of the relationship between air and wood core PCP concentrations in the treated and sealed and treated and neutralized categories showed significantly lower air PCP concentrations relative to wood concentrations in homes which had been treated and subsequently neutralized. However, no significant effect was seen for homes which had been treated and subsequently sealed.

Wood core PCP concentrations had a statistically significant ($\alpha = 0.05$) positive correlation with the age of the home. Among the house treatment categories the exterior treated and never-treated houses were newer houses than those in the other treated categories. It was felt that these associations reflected changes in building construction and PCP treatment practices in newer homes.

The age, sex, and time spent at home in the 48-h period before blood sampling of the participating individuals were found to be similarly distributed among the homes in the different treatment categories.

Biological PCP contamination was also detected in all samples collected from the study participants. PCP was detected in the sera (LOD = 0.25 ng/mL) and the urine (LOD = 0.08 ng/mL) of all 66 participants sampled. As was the case with measures of environmental PCP contamination, biological PCP concentrations spanned a wide range and were generally considerably higher in occupants of treated homes than in occupants of untreated homes.

The distribution of serum PCP, urinary free PCP and urinary total PCP concentrations were significantly different among the house treatment categories. Whereas the exterior treated and never-treated categories did not differ significantly from each other, concentrations in the manufacturer treated categories were mostly significantly higher. Serum PCP concentrations did not differ significantly with subject age group but both free and total urinary PCP concentrations were significantly different among the examined age groups (4 to 7, 8 to 12, and over 12 yr old) with the highest concentrations in the youngest age group and the lowest concentrations in the over 12 age group.

Mean serum, free urinary and total urinary PCP concentrations for households, adjusted for the age group distribution in the household, were highly correlated with each other. The environmental PCP concentrations (wood core, air, surface wipe) were highly correlated ($\alpha = < 0.03$) with biological PCP concentrations (serum, free urinary and total urinary) for households adjusted for the age group distribution in the household.

The age group adjusted association between estimated mean serum and total urinary PCP concentrations and certain possible health effects of PCP determined by responses to the medical questionnaire were examined. No significant ($\alpha = 0.05$) associations were seen between the PCP concentration and the reported history of eczema, acne, tumor or lump removed, rash or dermatitis in the past year, currently taking medication, fever at least once or more than once within the last 6 mo, unexplained weight loss in the last 6 mo, irritation of eyes, tearing of eyes, or swelling of eyelids since occupying the present house.

The association between mean serum PCP and total urinary PCP concentrations for households and certain biochemical variables for the household, adjusted for age group distribution in the household, were explored. No significant association was seen for liver function tests, a test of microsomal enzyme induction, and a renal function test. Statistically significant ($\alpha = 0.05$) negative associations were seen for serum total protein and serum creatinine and both biologic PCP concentrations. The reason for these negative associations was unclear; several explanations are possible and they probably do not reflect toxic effects.

The age group adjusted association between estimated mean serum and urinary total PCP concentrations and the presence or absence of lymphadenopathy or of abnormalities of skin or neurologic examination was studied. There was no significant association with lymphadenopathy or neurologic abnormalities. There was a statistically significant ($\alpha = 0.05$) positive association between the presence of skin abnormalities noted during the physical examination and PCP concentrations. It could not be determined whether this reflected more absorption of PCP through abnormal skin, effects of PCP on the skin, or some other factor.

A comparison of results from the same log home residents who participated in the 1980 and 1984 surveys was made to determine if there were differences. The concentration of PCP in serum was significantly lower in 1984 than in 1980 but the urinary levels were the same for both studies. No differences were seen for the clinical biochemistry tests performed in both studies.

E. Conclusions

Following are the major conclusions of the study.

1. PCP found in the indoor air of the log homes is a result of treatment of the logs with PCP.
2. The environmental levels of PCP in the log home are related to the type and degree of PCP treatment of the logs.
3. Cisterns in PCP treated log homes are a source of PCP to humans if the water is used for drinking purposes.
4. A source of the PCP found in the study participants was the PCP treated logs.
5. Children under age 12 living in PCP treated log homes excrete PCP at the highest rate as compared to over 12 age group.
6. The presence of skin abnormalities may be indicative of PCP exposure.

II. INTRODUCTION

In 1980, as part of an investigation conducted by the United States Environmental Protection Agency (EPA) and the Centers for Disease Control (CDC) into the possible health effects of human exposure to pentachlorophenol (PCP)-treated wood used in packing crates, a family living in a commercially manufactured log home in Kentucky was found to have elevated serum and urine levels of PCP as compared to control individuals (Lakings et al. 1980). A subsequent study conducted by CDC and the Kentucky Department of Human Services included retesting some members of the index family along with 29 volunteer residents of other PCP-treated log homes, and 13 controls who did not inhabit PCP-treated log homes. Selected clinical and biochemical measurements were performed. Results demonstrated significant differences in serum and urinary PCP concentrations between residents of PCP-treated homes and controls. Inter-family differences in residents of PCP-treated homes suggested that there was a dose-response relationship between the amount of time spent in the home and serum PCP concentrations and that children experienced the highest biological PCP concentrations (CDC, 1981).

A medical follow-up study of those persons previously identified as inhabiting PCP-treated homes in 1980 and living in Kentucky was conducted by Midwest Research Institute (MRI) and the Johns Hopkins University Center for Occupational and Environmental Health (COEH) for EPA in response to a request from the Kentucky Department of Human Services. A comparison population of persons inhabiting log homes which had not been constructed of PCP-treated logs were studied concurrently. The control population was as similar as possible in demographic parameters and geographic location to the group inhabiting PCP-treated log homes.

This study included, as far as possible, the blood sampling and analysis procedures carried out in the 1980 study. In addition, several components were added, particularly environmental measurements of PCP in log homes and house treatment history. Also, medical questionnaires, additional clinical biochemistries, and medical examinations were added. Efforts were made to duplicate methods of chemical analysis to ensure compatibility of results with existing data from the 1981 study.

III. EXPERIMENTAL METHODS

The procedures used to identify candidate houses, and recruit the occupants, to determine rationale for collecting environmental and biological samples are discussed along with questionnaires developed.

A. Study Participants

There were 29 family members, representing 17 families, in the 1980 study living in PCP-treated homes in Kentucky. All were volunteers who had responded to articles in newspapers, radio, and television who contacted their State or county health departments, and were directed to CDC. EPA was provided with the names and addresses of these households by the Kentucky Department of Human Services.

In order to obtain a comparison population living in log homes not treated with PCP, contact was made with log home manufacturers and dealers. The names and addresses of untreated log homeowners who were within 100 miles of Louisville were obtained from log home builders who were listed in a guide to the industry. These households were contacted and recruited.

B. Rationale for Selection of Study Items

1. Environmental Measurements

a. Air PCP Concentrations

Air samples were collected in the home of every study participant to estimate the family member's PCP intake via the respiratory route.

b. Wood PCP Concentrations

Wood core samples of logs on the interior of the home were collected in each study home to confirm statements gathered on the Environmental Questionnaire concerning the preservative treatment history of each log home included in the study. The wood core samples provided an indicator of the PCP concentration.

c. Surface Wipe PCP Concentrations

Surface wipe samples were collected from interior log surfaces in every home in the study to estimate the potential for PCP dermal exposure of log home residents.

d. Drinking Water PCP Concentrations

A tap water sample was collected from each home to estimate each participant family's PCP intake via the water used for drinking, bathing, and cooking.

2. Clinical Studies

The following clinical laboratory tests were selected to assist in determining the health status of the individuals participating in the study. Tests were selected on the basis of clinical usefulness for the detection of potential effects of PCP as well as their use in the 1980 study by CDC.

a. Laboratory Tests on Blood and/or Serum

- Hemoglobin, hematocrit, total white blood cell count and differential count (tests for blood morphology and abnormalities).
- Serum lactic dehydrogenase, alkaline phosphatase, gamma glutamyl transpeptidase, glutamic oxaloacetic transferase, glutamic pyruvic transaminase, total bilirubin, total protein, albumin (tests for liver function), blood urea nitrogen and creatinine (tests for renal function).
- Serum PCP level.

b. Laboratory Tests on Urine

- Urinalysis (tests for renal dysfunction)
- 6-Beta-hydroxycortisol and free urinary cortisol (tests for adrenal dysfunction)
- Creatinine (test for renal dysfunction and used to normalize urinary PCP concentrations).
- Urinary PCP-free and conjugated

3. Physical Examinations

The physical evaluations consisted of standardized hepatic, neurologic, and dermatologic examinations. This type of directed physical examination was selected on the basis of reported health effects of PCP.

C. Questionnaires

The Environmental Questionnaire was designed to quantify factors which were thought to possibly affect PCP concentrations in log homes or which could be used to help understand otherwise unexplained clinical findings. Questions included in the Environmental Questionnaire focused on features of the log home and occupant practices or habits which might affect environmental measurements.

The Medical Questionnaire was administered by a trained interviewer to obtain information on:

- Possible confounding factors that might affect the results of the laboratory investigations, including smoking and alcohol habits, drug consumption, and personal history of relevant diseases;
- Other sources of exposure to PCP;
- Approximate amounts of time spent in the home for the 48 h prior to sampling;
- Selected symptoms potentially associated with exposures to PCP.

IV. RESULTS AND DISCUSSION

A. Study Population

Field studies were conducted in the 21 recruited homes during the 11 day period from February 15 to 25, 1984.

1. House Characteristics

It was originally anticipated that the houses would fall into two groups according to PCP treatment. In fact, analysis of the responses from the environmental questionnaire and a review of the results of PCP concentrations from the wood core samples revealed that all but four of the supposedly untreated homes had been treated with PCP in some manner.

As a result, the following house treatment categories were developed. As will be seen later, the wood core PCP concentration data indicated that this was a useful categorization.

Treated: Included all log homes which were reported to have been treated by the manufacturer with a PCP-containing wood preservative in a manner which immersed the entire log (either by dipping or pressure treating) and had not subsequently been sealed or chemically neutralized. This process resulted in both the interior and exterior surfaces of the house being PCP-treated. There were four houses so treated in the study population.

Treated and Sealed: Included all log homes which were reported to have been treated with a PCP-containing wood preservative in the manner described in the "Treated" category (above) and in which the interior surfaces of the house had been subsequently treated with some type of sealant. The four houses included in this category had the majority of the interior log surfaces treated with polyurethane (two houses) or varnish (two houses).

Treated and Neutralized: Included all log homes which were reported to have been treated with a PCP-containing wood preservative in the manner described in the "Treated" category (above) and in which the interior surfaces

of the house had been treated with a chemical agent designed to react with, and thereby neutralize, PCP in the wood. The three houses included in this category had the majority of the interior log surfaces treated with Permatox-Pentite®, manufactured and distributed by Chapman Chemical Corporation (Memphis, Tennessee) for this expressed purpose. Although the specifics of the chemical reaction are proprietary, the mode of action was described as chemical neutralization.

Treated and Sealed and Neutralized: Included all log homes which were reported to have been treated with a PCP-containing wood preservative in the manner described in the "Treated" category (above) and treated with a sealant in the manner described in the "Treated and Sealed" category (above) and treated with a neutralizer in the manner described in the "Treated and Neutralized" category (above). One house received both treatments. Although the order of treatment was not stated by the homeowner, it is presumed that the logs were neutralized and then sealed.

Exterior Treatment: Included all log homes which were reported to have been treated with a PCP-containing wood preservative by spray-application of the preservative to the exterior surfaces of the house at the time of construction. Interior surfaces of homes included in this category were reported not to have been treated with a PCP-containing wood preservative. There were four houses so treated in the study population.

Never Treated: Included all log homes which had been reported to have never been treated on any surface with a PCP-containing wood preservative. There were four such houses in the study population.

Treatment Unknown: For one house the treatment history was unknown by the original owner-occupant-builder. Analysis of the wood core samples collected from the house confirmed that the house had been treated with a PCP-containing wood preservative, but the method of application was unknown and it was not known whether it had been subsequently sealed and/or neutralized.

2. Personal Characteristics of Study Participants

A total of 72 individuals took part in the study, although there were 80 inhabitants above the age of 4 that resided in the study houses. One participant did not complete the study questionnaire but did provide some samples so that most data is reported for only 71 participants. The ages of participants ranged from 4 to 66, with a mean age of 26.1 and a median age of 30. There was an even distribution of male and female participants. There were 50 participants aged greater than 12, 11 aged from 8-12, and 10 aged from 4-7. All participants were white.

B. PCP Concentrations in Homes

1. Air Sampling Results

Three air samples were collected in every home in the study population, together with appropriate quality control samples (i.e., blank, duplicate or spike) in selected homes, according to the protocol previously described.

PCP was detected in 62 of the 63 samples collected. Detected concentrations ranged from 0.001 ng/L to 0.904 ng/L but were fairly consistent within any given house, usually varying by no more than a factor of two.

The PCP residues in air are summarized by house treatment category in Table 1. As seen on the table, and confirmed by statistical analyses, air concentrations of PCP for Never Treated houses are significantly lower than those for all treated houses. Among treated houses, the air concentrations for Treated and Sealed houses are significantly higher than those for houses that were Treated and Neutralized or had External Treatment. Therefore, it is, thus, concluded that there are real and significant differences in the air concentrations of PCP among several of the treatment categories.

2. Wood Core Sample Results

From 12 to 21 individual wood core samples were collected from the interior surfaces of logs in every home and subsequently composited to a single sample for each home.

PCP was detected in the wood core samples from all 21 houses in the study population. Detected concentrations ranged from 44 ng PCP/g wood to 438,500 ng PCP/g wood. The wood core PCP concentrations appeared to be distributed in a manner which corresponded with the different methods of PCP treatment which had been used in the study houses as stated by the homeowner. As a result, the six categories of house PCP treatment indicated earlier were used in further analysis. The never treated homes had PCP concentrations as a possible result of the logging industry spraying stockpiled logs with PCP to prevent mold and mildew.

Concentrations of PCP in wood are summarized by house treatment category in Table 2. As seen in the table, and confirmed by statistical analyses, the mean wood PCP concentration in the Never Treated category was significantly different from that of each of the treated categories. There were no statistically significant differences between those categories which had been treated with PCP. The number of houses in each treatment group was small, however, and it is quite likely that given the same geometric means from a larger study population, there may have been statistically significant differences between the treatment groups.

3. Surface Wipe Sampling Results

Two composited sets of surface wipe samples were collected from the interior surfaces of logs in every home, together with appropriate quality control duplicates in selected homes. One of these sets, designated as "adjacent" samples, was collected from logs immediately contiguous to wood core samples for the purpose of determining how accurately a surface wipe sample reflected the PCP concentration in the underlying wood. The second set, designated "exposure" samples, was collected from surfaces throughout the house which were thought to be frequently contacted by occupants of the home. This set was collected in order to help estimate the potential dermal exposure to PCP.

Table 1. Summary of PCP Concentrations (ng/L) in Air
by House Treatment Category

Treatment category ^a	N	Median	Range	Geometric mean	95% Confidence interval
T	4	0.421	0.090 - 0.810	0.314	0.116 - 0.850
TS	4	0.433	0.185 - 0.758	0.383	0.195 - 0.751
TN	3	0.068	0.062 - 0.083	0.071	0.060 - 0.084
TSN	1	0.209	0.209 - 0.209	0.209	-
XT	4	0.072	0.028 - 0.113	0.064	0.036 - 0.112
NT	4	0.010	0.003 - 0.019	0.007	0.003 - 0.030
TU	1	0.016	0.016 - 0.016	0.016	-
ALL	21	0.083	0.003 - 0.810	0.080	0.040 - 0.162

^aT=treated; TS=treated and sealed; TN=treated and neutralized; TSN=treated, sealed, and neutralized; XT=exterior treated; NT=never treated; TU=treatment unknown.

Table 2. Wood PCP Concentration (ng/g Wood) by House Treatment Category

Treatment category	N	Median	Range	Geometric mean	95% Confidence interval
T	4	78,800	8,000 - 438,000	53,600	8,650 - 330,000
TS	4	190,000	101,000 - 340,000	183,000	106,000 - 316,000
TN	3	45,000	8,000 - 113,000	34,400	7,510 - 157,000
TSN	1	102,000	102,000 - 102,000	102,000	-
XT	4	11,300	6,000 - 33,400	12,500	6,040 - 25,900
NT	4	110	44 - 1,600	159	32 - 496
TU	1	28,000	28,000 - 28,000	28,000	-
ALL	21	28,000	44 - 438,000	15,900	5,020 - 50,200

PCP was detected in all 21 of the "adjacent" wipe samples (Table 3) and in 20 of the 21 "exposure" wipe samples (Table 4). The "adjacent" wipe samples usually showed greater PCP concentration than the composited "exposure" wipe samples for a given house. This result is expected as all "adjacent" wipe samples were taken from the source of PCP contamination in the house (the logs), while the "exposure" wipe samples were taken from frequently contacted surfaces which may or may not have been contaminated with PCP.

Statistical analyses of PCP concentrations in "adjacent" wipe samples showed Never Treated houses differed statistically from Treated, Treated and Sealed, and Treated and Sealed and Neutralized houses. In addition, houses which received External Treatment differed only from Treated and Sealed houses.

Statistical analyses of PCP concentrations in "exposure" wipe samples showed that only the highest (Treated) and lowest (Never Treated) treatment categories were statistically different.

4. Drinking Water Sampling Results

PCP was detected in only 4 of the 21 homes in the study population. The PCP residues detected in these four homes ranged from 0.2 ng/L to 1.0 ng/L. In all other homes the PCP concentration was below the analytical limit of detection, 0.2 ng/L.

Analysis of the presence of PCP in drinking water by house treatment category showed that all four of the homes in which PCP was detected had been treated. The distribution was across house treatment categories: one Treated and Sealed and Neutralized (0.2 ng/L), one Exterior Treatment (0.3 ng/L), one Treated and Sealed (1.0 ng/L), and one which was treated in an unknown manner (0.6 ng/L). In all cases, PCP contaminated drinking water came from a house that utilized a cistern as the source of water. Statistical analysis of this distribution by source of water showed this relationship between source of water and the presence of PCP contamination of that water to be significant.

C. Biological PCP Concentrations

1. Serum and Urine PCP Concentrations

Blood samples were collected and the concentration of PCP determined. The range, median, geometric means and 95% confidence intervals for serum PCP concentrations by house treatment category are given in Table 5. Statistical analysis showed that there were significant differences among the house treatment categories; specifically, the mean household serum PCP concentrations for the Exterior Treatment and Never Treated house treatment categories, while not differing significantly from each other, differed significantly from the means of the other four treatment categories. The serum PCP concentration in the Exterior Treatment category was almost twice as high as that in the Never Treated category, and those of the other four categories were from 4 to 7 times higher than the Never Treated category.

Table 3. Summary of Surface PCP Concentrations (ng/100 cm²) Determined from Wipe Samples of Surfaces "Adjacent" to Wood Core Samples by House Treatment Category

Treatment category	N	Median	Range	Geometric mean	95% Confidence interval
T	4	402	345 - 2290	596	245 - 1450
TS	4	1040	184 - 1231	699	289 - 1690
TN	3	214	82.6 - 276	171	83.8 - 348
TSN	1	227	227 - 227	227	-
XT	4	113	82.1 - 198	121	84.9 - 173
NT	4	43	6.7 - 108	34.9	11.5 - 106
TU	1	48	48 - 48	48	-
ALL	21	198	6.7 - 2290	187	106 - 333

Table 4. Summary of Surface PCP Concentrations (in ng/100 cm²) Determined from Wipes of "Exposure" Surfaces by House Treatment Category

Treatment category	N	Median	Range	Geometric mean	95% Confidence interval
T	4	318.0	244 - 400	316	259 - 386
TS	4	232.9	81.5 - 427	195	88.6 - 431
TN	3	147.0	92.9 - 192	139	92.1 - 210
TSN	1	172.0	172 - 172	172	-
XT	4	57.1	12.3 - 233	56.9	18.1 - 179
NT	4	43.9	ND - 62.5	18.2	2.7 - 130
TU	1	10.0	10.0 - 10.0	10.0	-
ALL	21	117	ND - 427	89.6	47.9 - 167

Table 5. Serum PCP Concentration (ng/mL) by House Treatment Category^a

Treatment category	N	Range	Median	Geometric mean	95% Confidence interval
T	13	32.5 - 160	106	95.9	74.2 - 124
TS	12	21.7 - 151	111	81.1	55.9 - 118
TN	11	27.7 - 163	65.5	69.9	47.5 - 102
TSN	5	92.0 - 168	108	114	93.3 - 140
XT	12	9.4 - 55.7	23.0	22.8	17.9 - 29.1
NT	8	7.0 - 23.3	11.6	11.2	8.3 - 15.1
TU	4	16.0 - 25.1	18.3	19.1	13.1 - 27.9
ALL	65 ^b	7.0 - 168	54.0	47.6	37.8 - 59.9

^aLimit of detection = 0.25 ng/mL.

^bSerum PCP concentration is unknown for seven participants because the specimen could not be collected.

Two urine PCP concentrations were measured for each individual: the concentration of free PCP in urine and the total PCP concentration which is considered a more reliable indicator of PCP total excretion. Urinary PCP concentrations were normalized for potential variations in urine concentration by expressing the excretion in terms of mg PCP/g of creatinine expected. Table 6 provides summary statistics for total urinary PCP concentrations by house treatment category. Statistical analysis showed that there were significant differences among the house treatment categories; specifically, the mean values for the category Treated and the category Treated, Sealed and Neutralized were significantly higher than the mean for Exterior Treatment. The means for all other categories but the Exterior Treatment category were significantly higher than the mean for the Never Treated category. The mean total urinary PCP concentrations in the Exterior Treatment category were 3 times as high as those in the Never Treated category. Those of the other four categories were from 5 to 11 times higher than the Never Treated category.

Table 7 shows the summary statistics for free urinary PCP concentrations by house treatment category. For the population as a whole the median and geometric mean concentrations of urinary free PCP were, respectively, 48% and 43% lower than those found for urinary total PCP concentrations. Statistical analysis showed that there were significant differences among the house treatment categories; specifically, the mean household unhydrolyzed urine PCP concentrations for the Treated category differed significantly from the Exterior Treatment category, and the Treated, Treated and Sealed, and Treated and Neutralized differed significantly from the Never Treated category. By analogy then, the Exterior Treatment and the Never Treated categories are not different from one another.

These data clearly indicate that blood and urine PCP concentrations of residents in PCP-treated log homes were considerably higher than in residents of log houses not treated with PCP.

2. Influence of Age on Biological PCP Concentrations

In evaluating biological PCP concentrations it was considered that age was likely to be an important covariable. This is due to both behavioral and physiological differences between children and adults. Young children tend to spend more time than many adults in the house and have play activities which are likely to bring them into closer contact with potentially PCP contaminated surfaces such as floors. By the teenage years, more adult patterns of behavior in these respects are generally established. Physiologically there are differences with age in the absorption, distribution and possibly metabolism of xenobiotics like PCP. These differences include higher ventilation rates in children relative to body mass, larger relative surface area available in children for percutaneous absorption, higher metabolic rates in children, and differences in the relative proportions of different tissues into which xenobiotics might be distributed. Once puberty is reached these relationships tend to remain relatively stable throughout adult age.

Table 6. Total Urinary PCP Concentration (mg/g Creatinine)
by House Treatment Category

Treatment category	N	Range	Median	Geometric mean	95% Confidence interval
T	13	0.012 - 0.179	0.036	0.044	0.026 - 0.074
TS	12	0.006 - 0.139	0.028	0.030	0.017 - 0.052
TN	12	0.008 - 0.082	0.026	0.026	0.018 - 0.038
TSN	5	0.028 - 0.134	0.056	0.060	0.035 - 0.100
XT	12	0.005 - 0.039	0.015	0.009	0.007 - 0.013
NT	8	0.000 - 0.013	0.004	0.004	0.003 - 0.006
TU	3	0.006 - 0.010	0.006	0.007	0.004 - 0.012
ALL	65 ^a	0.000 - 0.179	0.021	0.021	0.016 - 0.028

^aTotal urinary PCP concentration corrected for creatinine is unknown for seven participants because no specimen was received.

Table 7. Free Urinary PCP Concentration (mg/g Creatinine)
by House Treatment Category

Treatment category	N	Range	Median	Geometric mean	95% Confidence interval
T	13	0.007 - 0.120	0.034	0.031	0.018 - 0.052
TS	12	0.003 - 0.052	0.012	0.013	0.007 - 0.022
TN	12	0.006 - 0.101	0.016	0.017	0.011 - 0.026
TSN	5	0.011 - 0.028	0.018	0.018	0.013 - 0.025
XT	12	0.003 - 0.027	0.009	0.009	0.007 - 0.013
NT	8	0.002 - 0.006	0.005	0.004	0.003 - 0.005
TU	3	0.001 - 0.007	0.002	0.003	0.000 - 0.014
ALL	65 ^a	0.001 - 0.120	0.011	0.012	0.009 - 0.016

^aFree urinary PCP concentration corrected for creatinine is unknown for seven participants because no specimen was received.

In order to account for possible differences in age, study participants were considered in three age groups: 4 to 7, 8 to 12 and over 12 yr old. As there were no individuals aged less than 4 or more than 65 yr, it was not necessary to consider the very young or very old in our analyses.

Table 8 shows the association of age group with biologic PCP concentrations, adjusted for household. The serum PCP concentration was slightly higher in the younger age group but the differences among the groups were not statistically significant. Highly significant differences among the groups were seen for urinary free and total PCP concentrations, with the highest values in the 4 to 7 age group and the lowest in the over 12 age group, whose mean values were less than half those of the youngest group.

D. Relationships Between Selected PCP Measurements

1. Correlations Within Environmental Samples

Statistical analysis of the measured concentrations of PCP in air, wood cores, "adjacent" and "exposure" surface wipe samples was performed. All values were highly correlated and all the correlations were statistically significant. PCP concentrations measured in the air of the log homes were highly correlated with the PCP concentration in the wood core samples. This suggests that PCP is continually vaporized from the logs to the air. Air concentrations were measured under a narrow range of temperatures and with closed windows defined by the study protocol to assess sample comparability; under other conditions the association may not be as strong.

PCP concentrations measured in "adjacent" wipe samples were also found to be highly correlated with the wood core PCP concentration and the air PCP concentration. This presumably reflects that the wood surface is the interface (i.e., site of vaporization) between the log and air.

PCP concentrations measured in "exposure" wipe samples were also significantly correlated with concentrations of PCP measured in air and wood samples, although the correlations were not as strong as in the case of the "adjacent" wipe samples. This is not unexpected since the "exposure" wipe samples reflect concentrations on various surfaces throughout the house rather than just the interface between logs and air. "Exposure" wipe samples were collected from both log and other surfaces thought to be frequently contacted by inhabitants of the house. Many of these surfaces may not have been PCP-treated, although they may have become PCP-contaminated through condensation. Other surfaces such as around light switches, door jabs, and window frames probably were touched and may have been treated with PCP. As a result the correlation between "exposure" wipe samples and other environmental measures of exposure would be expected to be lower because of the sample being "diluted" with possible non-PCP treated surfaces.

2. Relationship Between House Treatment History and Air PCP Concentrations After Adjustment for Wood Core PCP Concentrations

The effectiveness of the sealing and/or neutralizing PCP treated logs in reducing air PCP concentrations was explored.

Table 8. Association of Age Groups with Biologic PCP Concentrations
Adjusted for Household

Biological PCP measure	Age group	Number of participants in age group	Geometric least squares means	Ratio of means ^a	Overall P-value ^b
Serum PCP (ng/mL)	4-7	10	51.5	1.00	0.194
	8-12	11	38.0	0.74	
	> 12	50	41.1	0.80	
Urinary free PCP (mg/g creatinine)	4-7	10	0.027	1.00	0.0001
	8-12	11	0.019	0.70	
	> 12	50	0.010	0.37	
Urinary total PCP (mg/g creatinine)	4-7	10	0.036	1.00	0.004
	8-12	11	0.029	0.81	
	> 12	50	0.017	0.47	

^aCompared with 4 to 7 yr old age group.

^bP-value associated with F-test for differences among age groups.
Results of pairwise comparison of age groups at the 0.05 level for
urinary free and urinary total PCP: Age group > 12 differs significantly
from age groups 4-7 and 8-12.

When air PCP concentrations were adjusted for differences in wood core PCP concentrations, sealing of the interior surface (with polyurethane or varnish) of the log homes included in the study population did not significantly reduce the air PCP concentration. Air concentrations were, in fact, slightly (although not statistically) elevated. Air PCP residues in homes constructed of treated logs which had subsequently been neutralized (with Permatox-Pentite) were found to be 44% of the expected concentration had the logs not been neutralized. This difference was statistically significant ($p = 0.039$).

3. Relationships Between Environmental and Biological PCP Concentrations

Statistical analysis was performed between various environmental PCP concentrations (wood core, air, "exposure" surface wipes) and biological PCP concentrations (serum, free urinary, and total urinary) for household (weighted by the number of people in the household) and adjusted for age group distribution in the household. All studied correlations were strongly positive and statistically significant.

E. Relationship Between Serum and Urinary PCP Concentrations and Clinical Findings

1. Questionnaire Responses

The significance of the age group, serum PCP or total urinary PCP concentrations and certain questionnaire responses was examined. There were no significant differences for any of the health questions.

2. Clinical Laboratory Evaluations

The association between serum biochemical results and serum, or total urinary PCP concentrations was evaluated. The association with total urinary PCP was examined both with and without correction for the urinary excretion of creatinine. Most values, including various serum liver function tests (albumin, bilirubin, alkaline phosphatase, glutamic oxaloacetic transferase, glutamic pyruvate transaminase, lactic dehydrogenase and gamma glutamyl transpeptidase), a test of microsomal enzyme induction (ratio of urinary 6-beta-hydroxycortisol to free cortisol), and a renal function test (blood urea nitrogen) were not different among the groups.

There was a statistically significant negative association between the serum total protein concentration and both the serum PCP and the urine total PCP concentrations. The total serum protein concentrations measured a large number of proteins and the data did not allow determination of what fraction or fractions of proteins might be responsible for this association. The reason, if any, for this apparent association remains obscure and needs further exploration. Serum albumin, however, which constitutes the bulk of serum protein, was not statistically significantly associated with serum PCP or urinary PCP concentration.

There was a curious and not readily explained strong negative association between both the serum PCP and urinary PCP concentrations with the serum creatinine concentration. Both associations were highly statistically significant. The serum creatinine is an indicator, among other things, of renal function. If PCP nephrotoxicity were occurring the creatine level would be expected to rise with increasing PCP concentrations, but the reverse is the case here so that nephrotoxicity is not a tenable explanation.

The production of creatinine and therefore its concentration in serum, given normal urinary function, is a function of body muscle mass. It is conceivable that the negative correlation between PCP concentrations and serum creatinine reflects some alteration in distribution of PCP within the tissues of exposed individuals, but this explanation remains conjectural.

3. Physical Examination

No significant difference was seen for the neurologic examination or for lymphadenopathy. However, both the estimated mean PCP serum and estimated mean total urinary PCP concentration for those with abnormal skin examinations were statistically significantly higher than for those with normal skin examinations. It could not be determined whether there may have been more absorption of PCP through the skin as a result of pre-existing skin abnormalities, whether the PCP might have caused skin abnormalities, or whether there was some other factor accounting for both skin abnormalities and increased biologic PCP concentrations.

F. Comparison of Results for Participants in the 1980 and 1984 Studies

It was possible to compare biochemical indicators of organ functions between 1980 and 1984 in those participants who were studied at both times. Because of substantial variations in these indicators in children and changes in age which occurred over the 4-yr period such comparisons will only be valid in adults.

The results of longitudinal analysis showed that the serum PCP concentrations were significantly lower by a factor of almost 5 in 1984 compared with 1980. However, the urinary unhydrolyzed PCP concentrations were somewhat higher in 1984, although the differences were not statistically significant. A ready explanation for these differences is not apparent. Both the collection of specimens and the laboratory analysis were performed by different groups in the two studies so that differences in sampling and analysis cannot be excluded as responsible for the variations. It is also possible that substantial reduction in PCP exposure has occurred over the 4-yr interval but that for some unaccountable reason, it is not reflected in the urinary unhydrolyzed PCP concentrations. The results of serum biochemistries did not differ between the two years and the mean values obtained were quite similar on both occasions.

V. REFERENCES

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16. Abstract (Limit: 200 words) A survey of pentachlorophenol (PCP) treated log homes was conducted to determine environmental levels and the extent of biological exposure and to examine the relationships of biological PCP concentrations and selected health variables. A directed survey was conducted in 21 log homes that were subsequently found to be in six treatment categories. The highest levels of PCP were found in the category manufacturer treated homes; next highest in the manufacturer treated and subsequently sealed homes; next in the manufacturer treated and subsequently sealed and neutralized homes; next in the manufacturer treated and subsequently neutralized homes; next in exterior treatment only; and lowest levels in "never treated" homes. Concentrations of PCP in air, wood core, and surface-wipe samples were highly correlated with each other. PCP was detected in all 66 occupants sampled, and spanned a wide range, but levels were generally considerably higher in occupants of treated homes than untreated homes. The biological levels of PCP concentrations (serum, free, and total urinary) were highly correlated with the environmental PCP concentrations. In general, no significant associations were seen between biological PCP concentrations and liver function, microsomal enzyme induction, or renal function tests. Comparison of results from some of the occupants who participated in this survey and the survey conducted in 1980 showed no biochemical differences although serum PCP was lower in the present survey. Urinary PCP levels were the same for both studies.			
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