Exposure to pentachlorophenol near a wood treatment plant

Exposición ambiental a pentaclorofenol procedente de una planta de tratamiento de maderas

Exposição ambiental ao pentaclorofenol procedentes de uma unidade de tratamento de madeira

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Abstract

Exposure to pentachlorophenol (PCP) near a wood treatment plant was investigated by collecting urine samples from residents (n=31), following air sampling. PCP was elevated in air and in urine following odor complaints. Airborne levels (8-hr maximum of 29 µg/m3) were higher than background ones (<1.3 µg/m3). Women more frequently had detectable urine PCP and had higher urine PCP than the US general population; men infrequently had detectable urine PCP and were not statistically different from the US general population. Approximately 22% (95%CI: 6.41–47, 64%) of the women had urine PCP levels that were above the 95th percentile of US women. Moreover, the 75th percentile concentration of community women averaged 4.7 times higher than the 75th percentile concentration of US women. In all households where at least one partner had detectable levels, women had higher PCP levels than men.

Keywords: Pentachlorophenol, biomonitoring, odor complaints.

Resumen

Se investigó la exposición a pentaclorofenol (PCF) en las proximidades de una planta de tratamiento de madera analizando tanto muestras de orina de residentes (n=31) como la concentración en aire. El PCF se encontraba en niveles elevados en aire y en orina en zonas donde se habían recibido quejas por olores. Los niveles en aire (máximo octohorario de 29 µg/m3) eran más altos que los niveles de fondo (<1,3 µg/m3). Las mujeres presentaron con mayor frecuencia niveles de PCF detectables en orina y niveles más altos que la población general de USA; en los hombres los niveles detectables de PCF en orina fueron poco frecuentes y sin diferencias estadísticamente significativas con los niveles de la población general. Aproximadamente el 22 % (IC 95%: 6,41-47,64%) de las mujeres presentaron niveles de PCF en orina que estaban por encima del percentil 95 de las mujeres americanas. Además, el percentil 75 de las concentraciones en las mujeres fue en promedio 4,7 veces más alto que el mismo percentil en las mujeres americanas. En todas las viviendas donde al menos una persona tenía niveles detectables, las mujeres tuvieron niveles más altos que los hombres.

Palabras clave: Pentaclorofenol, biomonitorización, denuncias por olores.

Resumo

Investigou-se a exposição a pentaclorofenol (PCP) nas proximidades de uma industria de tratamento de madeira analisando amostras de urina de residentes (n = 31) bem como a concentração deste composto no ar. Encontraram-se níveis elevados de PCP no ar e na urina em áreas onde foram registadas queixas de maus cheiros. Os níveis no ar (máximo de 29 µg/m^3 para oito horas) encontravam-se superiores aos níveis do tipo de influência fundo (<1,3 µg/m^3). As mulheres apresentaram com maior frequência níveis

de PCP detetáveis na urina e tinham níveis mais elevados de PCP na urina do que a população em geral dos USA. Nos homens foi pouco frequente a identificação de níveis de PCP detetáveis na urina e sem diferenças significativas relativamente à população em geral. Aproximadamente 22% (IC 95%: 6,41-47,64%) das mulheres apresentaram níveis de PCP na urina que estavam acima do percentil 95 das mulheres americanas. O percentil 75 das concentrações nas mulheres foi em média 4,7 vezes superior ao mesmo percentil nas mulheres americanas.
Em todos os agregados familiares, onde pelo menos uma pessoa possuía níveis detetáveis, verificou-se que as mulheres apresentavam sempre valores mais elevados que os homens.

Palavras-chave: pentaclorofenol, biomonitorização, queixas de maus cheiros.

INTRODUCTION

Odors originating from pentachlorophenol (PCP) wood treatment are commonly reported by communities. Odors associated with the PCP process come from a mixture of solvents, wood residues, and PCP. Occupational exposure to PCP can damage the immune system and cause reproductive and developmental anomalies; yet, little is known about community exposures[1]. In July 2003, a private citizen petitioned the Agency for Toxic Substances and Disease Registry (ATSDR) for a public health evaluation of emissions from a local wood treatment plant in East Point, Georgia (GA) USA. The plant treated wood with creosote and PCP. The petitioner believed that these chemicals had been released into ambient air. From October 2003 to March 2004, the ATSDR collected air samples and identified many process-related chemicals, including PCP[2]. PCP was detected at a mean level of 8.3 µg/m^3 (and a range from 1.3 to 30 µg/m^3) in 9 of 10 downwind samples. Because of the lack of literature available to assess the effects of PCP inhalation exposures at those levels, the ATSDR proposed a second investigation that included air sampling followed by urine sampling[2]. The objective of this second investigation was to establish whether or not the urine PCP levels of residents within a mile of the wood treatment plant were elevated, as defined by the CDC's National Report on Human Exposure to Environmental Chemicals[3]. As recent studies have indicated that current PCP use results in little or no detectable dioxin exposure, possibly due to better PCP formulation, the investigation focused on PCP alone[4,5].

METHODS

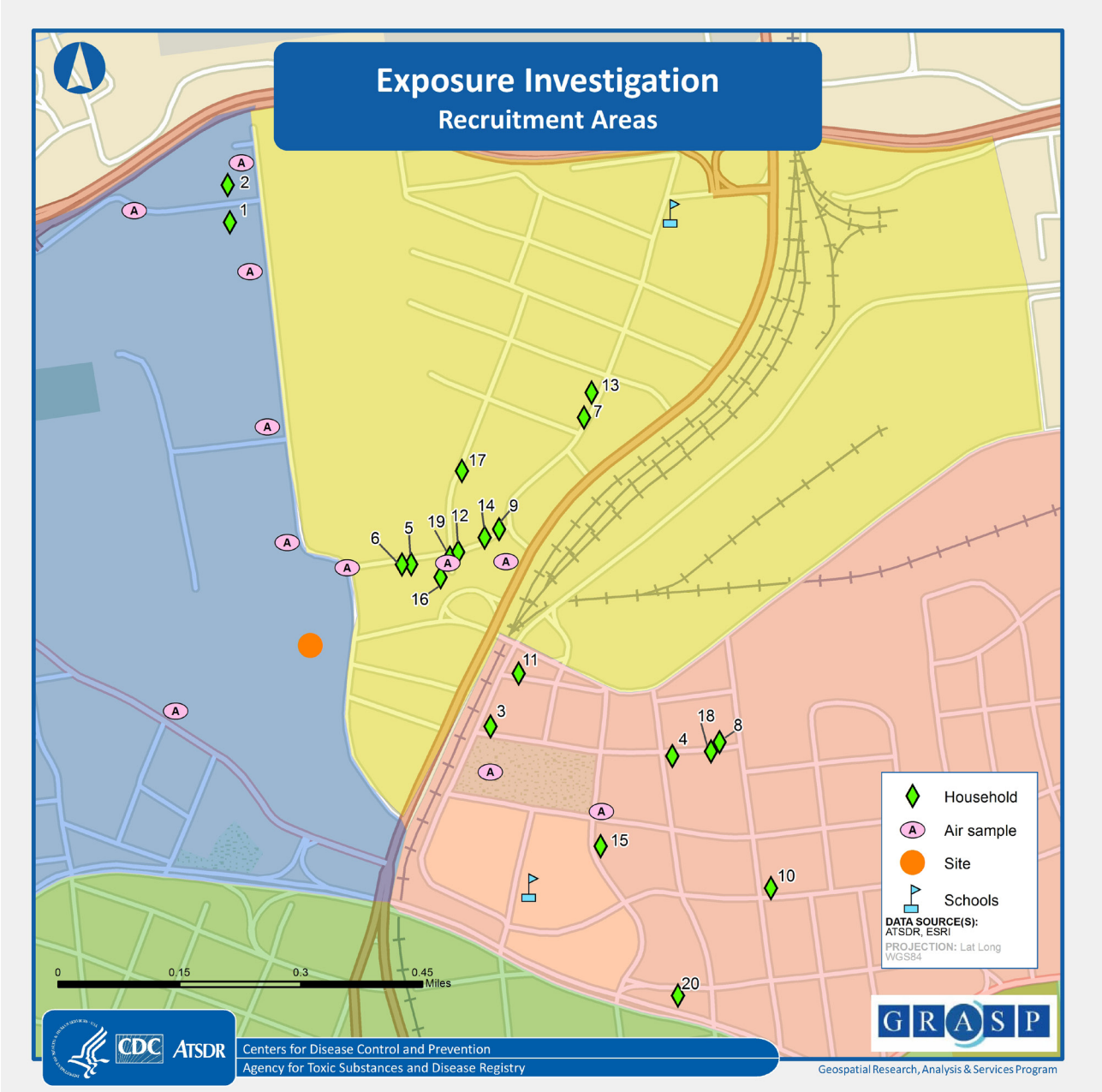
Sampling for air and urine was conducted within a zone where PCP was detected during the previous investigation. The zone included an area approximately 1 mile downwind from the plant in which approximately 2000 people live. At a community meeting with over 200 attendees, we presented the findings of our first (air) investigation and proposed a plan for a follow-up investigation focusing on PCP in urine. We presented a map with the wood treatment plant in the center and a circle providing a one-mile radius around the plant. The map was divided into four pie-shaped wedges of different colors to represent different wind sectors (Figure 1). Volunteers were asked to determine which sector they lived in, and to provide their contact information on a colored sheet corresponding to the relevant sector. Information was only requested from those volunteers who spent more than 12 hrs in the sector each day. Several dozen residents volunteered, and several indicated that they had additional family members who lived with them. One sector was represented by only one volunteer; therefore, this sector was visited to recruit other potential volunteers. Additional letters and e-mails were sent to the community, along with our contact information. In all, over 80 community people were willing to participate in the study. The residents were asked to call the ATSDR during an odor event. Soon after the time of the calls, air was sampled downwind of the plant and near the homes of residents who telephoned. All neighboring volunteers were contacted from the list of volunteers in each sector, and these volunteers visited other neighbors close by to secure urine samples. All urine samples were collected within three days of the air sampling.

A. Air sampling

In the first investigation, which took place between Octover 2003 and March 2004, the ATSDR collected 10 PCP-related downwind air samples. In the second investigation, between Octover 2004 and September 2005, the ATSDR collected 14 PCP-related air samples[5]. Each air sampling event was triggered by an odor complaint downwind of the plant. The samples were collected on the properties of volunteers who were home on that day or in the public right-of-way in their sectors. The sampling locations are indicated in Figure 1. No on-site weather data were collected. PCP in air samples was collected with sorbent tubes, consistent with Occupational Safety and Health Administration (OSHA) method number 39 for the determination of PCP in air. The samples were collected by use of personal sampling pumps at a rate of 0.2 L/min over an 8-hour period. Samples were

shipped to the laboratory according to chain of custody and storage procedures, and were then analyzed by high performance liquid chromatography/ultraviolet detection. One trip blank was sent along with each round of samples. Although this methodology is less sensitive than others, it does offer portability of equipment, simplicity of deployment, and protection from tampering. This analytical method offers 96% (±13.5%) recovery for up to 19 days, and the coefficient of variance is 0.010[6]. The analytical standard error for the method is less than the variability of the pump flow rates. The flow rates for each analyzed sample in this investigation varied by less than 15% during sampling; however, the range of flow rates for all analyzed samples varied by as much as 41% (range 0.18–0.27 L/min).

Figure 1. Exposure Investigation. Recruitment Areas



B. Urine sampling

During the second investigation, October 2004 to September 2005, the ATSDR collected 34 urine samples (from 31 residents and 1 ATSDR investigator). Among these 34 urine samples, two were collected from a single resident and two were collected from one of the ATSDR investigators (once after the ATSDR investigator spent time in the area and once after the investigator spent time away from the area). Community samples were collected at 20 households marked on Figure 1. Employees of the facility and children under 6 years of age were excluded from the study. This age limitation afforded a comparable age group with the sample in the CDC's Report on Human Exposure to Environmental Chemicals[7].

Residents on the lists were contacted during the air sampling to provide urine samples the following day. Immediately following air sampling, ATSDR staff visited the volunteers and their neighbors. Available residents provided urine samples within a few days following the air samples. A spot urine sample from each person was obtained because spot samples are 1) easier and more convenient for the community members, thereby maximizing compliance, and 2) consistent with the methodology used by the Centers for Disease Control and Prevention (CDC) to evaluate the US population[7]. After signing a consent form, each participant received an acid-washed specimen container and was instructed to provide a spot urine sample. Participants were instructed to place the filled container in a zip-lock bag and refrigerate it until ATSDR staff returned to collect it. Written instructions were also provided. The urine samples were analyzed by the National Center for Environmental Health (NCEH)/ CDC laboratory in Atlanta, GA, following the protocol described in Hill and Needham et al. (1990)[8].

C. Statistical analytical methods

Ten PCP-related air samples were collected in the first investigation, and 14 air samples and 34 urine samples during the second one. All 24 air measurements were plotted using a Robust Regression on Order Statistics (ROS) plot. A test was then carried out to verify the log-normality assumption using the applied parametric model (cenreg function), controlling for dates (Lee 2010)[9]. Subsequently, air PCP was compared with the closest urine PCP results. Two air samples were excluded from this statistical analysis, because they were not from areas close to the volunteers. In addition, two urine samples from the ATSDR investigator and one duplicate urine sample from one resident were excluded, with 31 samples remaining for statistical analysis.

The air analysis presented here involved comparing the frequency at which PCP was detected in the air at the same time it was detected in the urine samples of the male and female volunteers. The comparison was carried out by calculating odds ratios for periods when PCP and urine were both in agreement and periods when they were not. The actual air sample closest to the resident was used directly. Some air samples were taken close to the residences of several volunteers; other air samples, however, were not as close to the residences of some volunteers as we would have desired, but they were the most suitable available. From these same data, the Relative Risk, Chi-Square, and Phi Coefficient were calculated.

Urine results were reported as raw results, and they were creatinine-corrected. Creatinine-corrected PCP levels adjust for the effects of urine dilution to track a person's relative PCP levels. Raw (uncorrected) results were used for comparing the group with results from other populations, and the corrected values were used to interpret an individual's relative values. Populations are more appropriately compared by use of uncorrected values, because of the mathematical limits in the correction formula and the great diversity of creatinine levels in the general population[10,11]. However, both values are provided here in case other researchers desire to perform some other analysis, because corrected values are considered appropriate to account for individual differences in hydration[12].

The relatively low participation rate (n=31) introduces an element of uncertainty in any comparison of urine test results with those of the general population described by the NCEH in 2005. As PCP is infrequently detected in the United States, there is no geometric mean for the general population by which one can compare results.

The statistical methods appropriate for a small sample size were used for our analysis. The first method involved calculating percentile groups for our sample and comparing them to the percentile groups of the general population for two sets of years, 1999–2000 and 2001–2002[3]. Distribution-free statistics were used to estimate percentiles and the 95th percent confidence intervals. With this method, the coverage for each percentile group was also calculated, because coverage provides the actual confidence interval rather than the 95th percent confidence interval. Those confidence intervals that fell below 95 percent were then regarded as not reliable.

The second method was to use exact statistics to calculate the proportion of the investigated community (n=31) that was higher than the upper confidence limit of the 95th percentile of the general population in

the National Health and Nutrition Examination Survey (NHANES 1999–2000 and NHANES 2001–2002), as well as exact 95% confidence intervals for that proportion. In addition, two-sided p-values were calculated using the exact test—testing to find out if the proportion of the investigated community above the 95th percentile of the general population was different from the 5th percentile of the general population.

RESULTS

PCP was found in the community's ambient air and in the residents' urine.

A. Air

PCP was detected in 14 of 24 (58%) of air samples collected throughout the community during both investigations. During the second investigation, PCP was detected in 36% (5 of 14) of the air samples, ranging from non-detectable (ND, LOD<1.3 µg/m^3) to 29 µg/m^3. The PCP concentrations measured throughout the community are shown in Table 1.

PCP was detected in fewer air samples after urine sampling began. The second investigation (shown in bold) had more samples collected further from the plant (greater distances). When samples collected at the same distances and locations from the plant were compared, results from both investigations were similar when PCP was detected. For example, the maximum of 29 µg/m^3 found in the second investigation (01/05/2005) was measured at the same location (1) where 30 µg/m^3 was measured in the first investigation (10/27/2003). Moreover, 8.1 µg/m^3 and 22 µg/m^3 were measured at the same locations (2 and 4) where measurements of 7.9 µg/m^3 and 22 µg/m^3, respectively, were recorded in the first investigation. Such similarity was not the case, however, for samples collected after April 2005, because no PCP was detected after that date. As a result of PCP not being detected after April of 2005, there were only four sampling periods to determine any associations between air concentrations and distance. Each of those four periods showed a decrease of concentration with distance from the plant, but peak concentrations varied widely for each sampling period. Higher maximum values were found on two days, lower maximum values on two days, and no detectable PCP on three days. Applying the parametric model, controlling for differences in concentrations by date, a significant negative association was found between concentration and distance ($p<0.01$). The r^2 value was 0.91 and 0.86 for two (of four) sampling events where PCP was detected.

Table 1. Pentachlorophenol (PCP) concentrations measured in air at varying distances from the wood treatment plant throughout two investigations

Date Sampled	Distance (ft)	Concentration (µg/m^3)
10/27/2003	5700	4.27
10/27/2003	110	22.0
10/27/2003	100	30.0
03/05/2004	3900	1.8
03/05/2004	220	1.3
03/05/2004	200	3.5
03/05/2004	220	3.6
03/05/2004	220	6.9
03/05/2004	220	7.9
03/05/2004	300	ND
11/04/2004	**3600**	**3.9**
11/04/2004	**3900**	**5.4**
11/04/2004	**220**	**8.1**
01/05/2005	**110**	**22.0**
01/05/2005	**100**	**29.0**
04/21/2005	**2400**	**ND**
04/22/2005	**100**	**ND**
04/22/2005	**3100**	**ND**
04/22/2005	**1800**	**ND**
09/14/2005	**3030**	**ND**
09/14/2005	**3020**	**ND**
09/14/2005	**5700**	**ND**
09/14/2005	**1400**	**ND**
09/14/2005	**110**	**ND**

ND = PCP not detected in sample. Detection level = 1.3 µg/m^3
Bold values identify air samples collected during the urine sample investigation.

B. Urine

Twelve of the 31 (39%) residents had detectable levels of PCP in their urine (LOD=0.5 µg/L); the concentrations ranged from ND to 6.66 µg/L. Table 2 shows the urine-PCP levels for each participant per liter of urine (µg/L) and per gram of creatinine (in µg/g of creatinine), together with the air sample collected closest to the participant's residence.

No urinary PCP level was considered high in the community, but the percentage of individuals with detectable levels was considered to be high. PCP in residents ranged from ND to 6.66 µg/L, whereas PCP in the general population (n=5023) ranged from ND to 325.19 µg/L

(CDC, 2005)[3]. In the community as a whole, 39% of the tested residents had PCP in their urine, whereas less than 20% of the general population had similarly detectable levels of PCP in their urine. Moreover, the ATSDR investigator had 60% higher corrected (and 32% higher uncorrected) PCP levels following the time spent in the area, as compared with the levels after time spent away. A similar difference in PCP levels was not observed in the one resident (in house 9) who also spent time in the area and time away, but the air concentration associated with that resident was also not detected outside that individual's home.

Further inspection reveals that PCP was disproportionately higher in women. Nine of 18 women residents had detectable levels, compared to only 3 of 13 men residents. To emphasize these differences, in Table 2 the urine PCP levels for women and men are listed separately. The first eight households listed in Table 2 are houses with two or more participants. Five of the 10 women (50%) in these households had detectable levels, while only 1 of the 8 men (12%) had detectable levels. Furthermore, in every household with both men and women, the women had higher levels. Only two homes had both partners at home nearly all day for several days, and only two homes had the entire family home half the day. This information was not provided in a formal survey, but was obtained through follow-up conversations. Therefore, the actual number of hours spent at home was not certain in many households. Nevertheless, although based on only a few households, the urine-PCP concentration difference between males and females in the same household is striking, and that observed difference does not appear to be associated with the length of time either men or women spent in the home.

Air concentrations measured at the closest air sample from each residence are also reported here. Air samples were collected before the urine samples, so that some air samples reported in Table 1 have no associated urine samples in Table 2. Therefore, there were fewer samples in which PCP was detected in both urine and air. On 13 occasions PCP was not detected in the urine of residents within a household or in the associated air sample (analysis to follow). There were five occasions when the women had PCP in their urine associated with PCP detected in the closest air sample, but there were no such cases for men.

Table 2. Participants' urine PCP concentrations (with and without creatinine correction) and the closest air sample to the residence

House	Males µg/L (µg/g of creatinine)	Females µg/L (µg/g of creatinine)	Air* (nearest to home) µg/m³
1	ND	1.66 (0.57)	3.43
1		0.74 (0.36)	3.43
2	ND	6.66 (5.46)	3.43
3	ND	ND	3.43
4	ND	ND	ND
5	ND	ND	ND
6	0.55 (1.54)	0.90 (1.67)	ND
7	ND	ND	ND
7	ND		ND
8		0.63 (0.23)	ND
8		ND	ND
8		ND	ND
9	ND		ND
9(d)	ND		ND
10	ND		ND
11	ND		ND
12	1.75 (0.78)		ND
13	3.68 (1.53)		ND
14		ND	ND
15		ND	ND
16		ND	ND
17		0.58 (0.61)	ND
18		2.44 (1.18)	8.10
19		2.73 (2.08)	ND
20		3.70 (1.73)	8.10
ATSDR	1.22 (0.76)		NS
ATSDR (d)	1.62 (1.22)		ND**

ND = Not Detected (LOD urine = 0.5 µg/L and LOD air = 1.3 µg/m³)
NS = Not Sampled
(d) = Second sample collected after time spent near the plant
ATSDR = Samples collected from one investigator
Households with >1 participants are shaded (homes1–8)
*Many samples were collected in the neighborhood, but only the data nearest the volunteers are presented.
**The investigator spent time near the plant and at several locations in the neighborhood; the community samples were ND.

C. Air and urine association

Odds ratios for the data provided in Table 2 were used to determine the association between PCP in the air and urine. A summary of the statistical assessment is provided in Table 3. From the summary table, it can be seen that no statistically significant association was found between the detection of PCP in men's urine and air. When PCP was not detected in air (n=10), 33% of the men had detectable levels of PCP in urine.

Table 3. Association between PCP in air and urine for males and females in the community

PCP Air Results	Male Urine Results		Female Urine Results	
	Detect	ND	Detect	ND
Detected in Air	0 (0%)	4 (40%)	5 (83.3%)	1 (16.7%)
ND in Air	3 (33.3%)	6 (66.6%)	4 (33.3%)	8 (66.6%)
Relative risk (CI)	0		5.0 (0.72-34.7)	
Odds Ratio	0		10.0 (0.85-117)	

(CI) = 95% Confidence Interval
ND = PCP Not Detected

The association in women is apparent, but not statistically significant. When PCP was detected in air (n=9), 83.3% of the women had detectable levels of PCP in urine. As with the men, 33.3% of women had detectable urine PCP levels when PCP was not found in air. The resulting relative risk for women was 5, elevated, and the confidence interval contained the null value of 1, indicating that the result was not statistically significant. Chi-Square value was 4 with a probability of 0.0455 and the Phi Coefficient was 0.4714.

D. Urine comparison between community and general population

Two statistical methods were required to show the difference between the exposed community and the general population. Table 4 provides concentrations for the percentile groups of men and women in the exposed community and the general population.

Table 4. Pentachlorophenol (PCP) in the urine of residents near a wood treatment plant: comparison with the US population

	The Investigated Population*		The US Population			
Percentile Groups	Women (n=18)	Men (n=13)	cWomen 1999–2000	cMen 1999–2000	cWomen 2001–2002	cMen 2001–2002
95th (95% CIs)	6.66† (<LOD–6.66)	3.68† (<LOD–3.68)	0.860 (0.280–2.00)	1.40 (0.400–2.20)	1.92 (1.54–2.42)	1.94 (1.47–3.09)
90th (95% CIs)	3.70 † (<LOD–6.66)	1.75† (<LOD–3.68)	<LOD	0.63 (<LOD–1.30)	1.10 (<LOD–1.78)	1.31 (0.680–1.80)
75th (95% CIs)	1.66 (0.58–6.66)	<LOD (<LOD–3.68)	<LOD	<LOD	<LOD	<LOD
50th (95% CIs)	0.54 (<LOD–1.66)	<LOD (<LOD–0.55)	<LOD	<LOD	<LOD	<LOD

Note: LOD PCP in urine for NHANES 1999–2000 is 0.25 µg/L, and for NHANES 2001–2002 it is 0.50 µg/L(National third report, page 461). LOD for this study is 0.50 µg/L.<LOD=0.35= 0.5/√(2).
*The difference between the urine PCP levels for men and women for all percentile groups of the exposed community were not statistically significant using distribution free statistics.
†There were too few samples to permit calculation of 95% confidence intervals for the 90th and 95th percentile by use of distribution free statistics; therefore, the range overlaps the 75th lower confidence level.

As only a small number of the exposed population volunteered for urine tests, the distribution free 95th confidence intervals for most of the percentile groups overlap. However, the 75th percentile can be compared. The confidence interval of the 75th percentile for women in the community overlaps with that of men for the community, but it is higher than those for men and women in NHANES. Therefore, despite the small number of volunteers, there is still sufficient statistical power to suggest that women in the community had higher PCP levels than women in the two NHANES surveys.

Exact statistics were also used, again because of the small number of urine samples, to compare portions of the community that were higher than the 95th percentile of the general population. This comparison was undertaken by determining the percentage of the community that was higher than the upper confidence level of the 95th percentile of both NHANES reports (from Table 3); the upper confidence levels were 2.20 µg/L and 3.09 µg/L for men, and 2.00 µg/L and 2.42 µg/L for women.

By definition, it would be expected that only 5% of the women (and men) would be above the 95th percentile group. However, the results of the exact statistics found that over 22% (95% CI: 6.4–47.6) of the women of the investigated population were above the 95th percentile group of the previous two NHANES. The p-value was 0.021 for two-sided hypothesis testing (less than 0.05).

The percentage for men in the community was not statistically higher; only 7.69% (95% CI: 19–36.0) above that for the 95th percentile of either NHANES, with a p-value of 0.97. Only the percentage for women in the community was significantly higher than that for women of the general population.

The results of both analyses indicate that when compared to the general population, women of the community were more likely to have detectable PCP levels and more likely to have higher concentrations of PCP in their urine. Men of the community were not more likely to have detectable levels and not more likely to have statistically higher levels than the general population. However, the differences observed between the men and women of the community in both these analyses were not statistically significant.

DISCUSSION

Background ambient air PCP levels are estimated to range from 0.00015 to 0.136 µg/m^3 in the United States, and from 0.00043 to 0.00368 µg/m^3 in Canada[13,14]. In the studied community, the four (of 24) highest air concentrations were more than 200 times higher than the highest reference background levels.

To provide further perspective on the air exposures in this community, note that indoor PCP ranged from 0.2 to 0.38 µg/m^3 in a PCP-treated log homes study[15]. Other log home studies[16] found PCP ranging from 0.5 to 104 µg/m^3. At several production, application, or pressure operations[6,17,18], PCP ranged from 0.3 to 50 µg/m^3. At seven PCP dipping plants, and at 11 PCP spray plants[19], PCP in the air ranged from 3 to 69 µg/m^3. Therefore, the ambient concentrations found during this investigation —although not sufficient to allow determination of a statistical average— are among those levels considered to be high.

The highest urine PCP levels in the community and the National Survey were lower than the lowest urine level (950 µg/L) shown to have renal effects in men[12]. However, few studies involving PCP-exposed women include urine testing. We did not find any supporting evidence from a literature search to indicate higher urine PCP concentration in women than in men. Such a finding for PCP was not observed in the US general population[3], nor was it reported in the previous US general population studies[20,21,22,23] or in any of the log home studies[24,25,15,16]. Only one human exposure study reported a PCP concentration difference between males and females. However, that particular study[25] reported the difference in serum levels and found that male concentrations were higher, and also reported that serum PCP in the general population was more frequently detected in males and averaged higher in males. These higher levels were expected due to widespread worker exposures, and not due to metabolic (or toxicokinetic) differences between the sexes[6].

While PCP metabolism and toxicokinetics have been studied only in men, they have been studied in animals of both sexes[26,27,28]. In animals, kinetic differences between the sexes have shown that:

- Absorption was faster in females of both monkeys and rats.
- Female monkeys absorbed PCP twice as fast as the males, and female rats absorbed PCP 78% faster than the males.
- Of all animals tested, plasma PCP concentrations were consistently higher in females.
- The absorption half-life in men —1.3 hours— is similar to that in male rats, but slower than the half-life in male monkeys.
- Animal kinetics can be compared only with men, as no women have been studied.

Elimination is relatively slow and first order in men[27]. The half-life of PCP in the body appears to be 3 days from an oral dose and perhaps as long as 20 days following inhalation exposure[26,27,28,29,30]. Both enterohepatic circulation and plasma-protein binding influence elimination kinetics. Other absorption and elimination data that apply to our episodically exposed community provide evidence of faster absorption and elimination following single doses[12,28,30,31].

IMPLICATIONS

The toxicokinetic differences between women and men have implications for women's health. Several studies suggest that women are uniquely affected by PCP exposures; animal studies and worker investigations suggest similar unique health effects. When minks were exposed to technical grade PCP, only the females exhibited a decrease in relative thyroid weight[32]. In a developmental study of technical grade PCP in rats, most developing females did not survive, while the males did[32]. Although this result was not repeated in other studies, significant increases in the time of vaginal patency and preputial separation were observed[34,35,36,37]. A recent study on water fleas found that females have a lower tolerance to acute PCP exposures; a 60% lower effective concentration (EC_{50}) was reported for females than for males[38]. In a study of upholstery workers, women with a mean blood PCP level of 73 µg/L had an association with infertility, and those with a mean of 42 µg/L had an association with menstrual dysfunction[39]. Unfortunately, blood PCP is not as easily compared in these worker studies, because PCP levels in blood tend to be higher than in urine in worker studies; in fact, 2 to 10 times higher in blood than in urine[4]. Further study of these women found gynecological and endocrine disorders associated with elevated (median level of 35 µg/L) PCP in blood[40,41]. This contrasts with the findings in male workers, where no health effects were observed in several male workers who had blood serum levels as high as 1300 µg/L[24,42]. The lowest observed level associated with effects in men was 2600 µg/L (in blood), but these were renal effects[12]. Recall that the lowest urine effect level was 950 in that study.

Our finding of higher levels of urine PCP in women (only) has not been reported in other human study populations, but such higher levels in females have been reported in animal studies. As most exposures have been due to highly segregated occupations (e.g., women exposed from textiles and men exposed from wood-working), direct comparison of men to women has not been available. However, the log home studies may offer additional information. In these studies, although sex and age urine PCP concentration data were collected, only statistical results for age were reported, showing a significant increase in concentrations in children[15,24,25]. Within the raw data of those studies, meaningful information about differences in concentrations by sex might be found. In the absence of such data, however, we propose that the PCP metabolic differences between the sexes observed in animals also apply to humans, and we further propose that additional studies addressing the metabolic differences between men and women are needed.

LIMITATIONS

This was an investigation rather than a study; so we did not have a formal survey or a control population. The facility did not advise us when it was treating wood with PCP, so that the air sampling was conducted on the basis of odor alone. We requested the operations log, but we have not yet received a copy. Wind data were not collected close to the site.

Our results were based on a small sample size. People in homes closest to the air sampling devices only participated a few times. Many people were provided sampling jars and did not return them. Our detection levels were too high to allow characterization of PCP in residential air. Both factors impacted on the odds ratio calculations. Moreover, people tend to spend more time indoors than outdoors in the locations where the air was sampled.

CONCLUSIONS

1. PCP was elevated at times in the air of a community located near a wood treatment plant. The levels varied widely, but decreased with distance from the plant.

2. PCP detected in the urine of women had a very weak (not significant) association with PCP detected in the air. No association was found with men.

3. Women in the community had more PCP in urine than men in the community and women in the general US population; the PCP concentrations in men in the community were not significantly elevated. However, differences between men and women of the community were not statistically significant, due to the small number of participants.

4. There are differences in the toxicokinetics of males and females that warrant further study of community exposures that affect both men and women.

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