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USAF OEHL REPORT

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AN EVALUATION OF FILTER EFFECTIVENESS FOR REMOVING AIRBORNE CHLORDANE IN CRAWL SPACE HOUSES AT MCCONNELL AFB KS

DECEMBER 1982

USAF Occupational and Environmental Health Laboratory
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This technical report has been reviewed and is approved for publication.

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A study to determine the effectiveness of polyurethane filters to remove chlordane from the air was performed in crawl space houses at McConnel AFB. The soil around and under the houses was treated with a 1% chlordane emulsion in 1974 and 1979. The ventilation ducts are located in the crawl space. Although the filter did adsorb chlordane, most airborne chlordane measurements in the study houses were above 5 μg/m³. The National Academy of Science has established 5 μg/m³ as a guideline for houses. A direct correlation between chlordane concentration and outside crawl space temperature was observed.

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DECEMBER 1982

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I. INTRODUCTION

The USAF OEHL has been investigating the presence of airborne chlordane in military family housing units located on USAF installations at the request of the AF Medical Service Center (AFMSC). All houses surveyed were constructed on soil which had been treated with chlordane as a subterranean termite preventative measure. The initial USAF OEHL effort was directed at houses constructed on a concrete slab with ventilation ducts in or below the slab. Houses treated with chlordane before and/or after construction were evaluated. Chlordane intrusion into the living area of the housing units was found in both houses treated prior to construction (1) and those treated after construction (2).

In March 1981, McConnell AFB KS, under the direction of the AFMSC, sampled five houses of the basement/crawl space design for ambient chlordane levels. The ventilation ducts were located in the crawl space and the crawl space soil had been treated with chlordane. The air samples yielded chlordane. This was the first indication of chlordane intrusion into this type house. Twenty-seven percent of the crawl space houses at McConnell AFB yielded chlordane levels exceeding the established guideline. Of the many methods evaluated to reduce chlordane levels in these housing units, a polyurethane filter installed in the ventilation system showed the greatest promise from a performance and economic standpoint.

II. BACKGROUND

A. General

1. Chlordane Information

Chlordane is a member of a group of chlorinated hydrocarbon insecticides generically termed "chlorinated cyclodienes." It is colorless and odorless. The chlorinated cyclodienes--chlordane, aldrin, dieldrin and heptachlor--are the principal pesticides used for control of subterranean termites. Chlordane has been extensively used in the U.S. for agricultural and household pest control since 1945. The U.S. Air Force, other DOD agencies and the civilian community have employed chlordane as the principal pesticide for subterranean termite control.

In December 1975, the Environmental Protection Agency (EPA) suspended the use of chlordane in the U.S. with the exception of fire ant control, subterranean termite treatment, and the dipping of roots and tops of nonfood plants. Chlordane application for fire ant control was suspended by EPA in December 1980. The suspension was based upon the persistence of chlordane in the environment and the discovery of its degradation product, heptachlor epoxide, in food, human tissue and wildlife. Persistence is an attribute of many chlorinated hydrocarbons and cyclodienes can be effective as termiticides up to 20 years after application. Approximately 20% of originally applied chlordane dosages are recoverable in soil ten years after application. Consequently, the probability for organism exposure to chlordane and the potential for bioaccumulation and biomagnification is greatly enhanced.

2. Chlordane Toxicity

Chlordane can be absorbed through inhalation, ingestion or dermal contact.

EPA cited results of experiments with rats and mice showing significant increases in cancerous tumors caused by heptachlor epoxide, a metabolite of chlordane. The tumors were found in several organs of these experimental animals, including the liver and other endocrine glands. The EPA also noted evidence indicating that heptachlor epoxide in humans is transferred from the mother to the fetus across the placenta. A more recent study by the National Cancer Institute (NCI) concluded that chlordane concentrations of 40 parts per million (ppm) and higher in the feed of mice caused a significant increase in liver cancer. In contrast, hepatocellular carcinomas failed to appear at a significant incidence in rats. Central nervous system effects--hyperexcitability, tremors and convulsions--have also appeared in laboratory animals fed various cyclodiene class termiticides.

Limited human studies involving chronic long-term exposure to chlordane have been confined to the occupational setting. They have not revealed any consistent or significant detrimental effect from exposure to chlordane (3). An examination of workers exposed to 1.2 to 1.7 micrograms per cubic meter ($\mu g/m^3$) for 1-15 years showed no job-related illness among the workers (4). A similar conclusion was given following a study of workers exposed to 10 milligrams of chlordane per cubic meter of air (mg/m^3) for three years (5).

A statistical evaluation of death records for individuals employed in the manufacture of chlordane noted a significant excess of deaths from cerebrovascular disease, but the researchers emphasized that this should not be accepted as evidence of a consequence of exposure to chlordane without further study(6).

A recent epidemiological study of workers producing chlordane concluded that there was no evidence to indicate that current or past workers are at an increased risk for health related problems. However, the suggestion of a trend in cancer deaths with duration of employment indicates that more complete data are needed before firm conclusions can be reached with regard to the carcinogenicity of chlordane in humans (7).

3. *Exposure Standards*

The American Conference of Governmental Industrial Hygienists (ACGIH) 1982 has adopted a threshold limit value-time weighted average (TLV^R-TWA) of 0.5 mg/m^3 for chlordane in workroom air (8). This is the maximum allowable level to which it is believed workers may be continuously exposed in the occupational environment (8 hours/day, 5 days/week) without adverse effect. The short-term exposure limit (STEL) was set at 2 mg/m^3.

The Occupational Safety and Health Administration's (OSHA) permissible workplace exposure limit is also 0.5 mg/m^3. Both agencies noted that chlordane is absorbed through the skin and that dermal exposure should, therefore, be avoided.

Cognizant that neither the ACGIH nor OSHA criteria were applicable to the home environment because of increased exposure time and a significantly different population involved, the USAF requested the National Academy of Science (NAS) to provide guidance.

In 1979, the NAS Committee on Toxicology concluded that it "could not determine a level of exposure to chlordane below which there would be no biologic effect of prolonged exposure of families in military housing." However, it did suggest an interim airborne concentration of 5 $\mu g/m^3$. The guideline was pragmatically determined on the basis of known concentrations of chlordane in military housing, a review of reported health complaints of residents of contaminated housing, and a comparison with the acceptable daily intake derived from long-term animal feeding studies. The NAS Committee on Toxicology concluded in an August 1982 report that there was no new data to justify a change in the 5 $\mu g/m^3$ guideline (3).

In 1980, EPA initiated a formal risk-benefit review of chlordane to determine whether its registered uses for subsurface termite control should be limited or canceled, and whether the health of people living in houses treated with chlordane is being adversely affected. To date, EPA has not published its findings.

B. McConnell AFB

1. Housing Construction

There were 485 housing units constructed on McConnell AFB in 1959 using a partial crawl space and partial basement design. Nine different floor plans exist for this type house and the crawl space may be located below bedrooms or common living areas of the house dependent upon the floor plan. The furnace and ventilating system are located in the basement, and the supply and return air ductwork is in the crawl space. The return air ducts are formed using the wooden floor joists and sheet metal to shape an air chamber. Supply air is routed to floor registers through sheet metal ducting.

2. Termiticide Treatment

All 485 crawl space units were treated with 1% chlordane water emulsion in 1974 and 1979. The houses were retreated in 1979 because the high number of in-house treatments required in the interim years (62 total) indicated the 1974 treatment was not adequate to suppress termite infestation. The 1979 treatment consisted of applying chlordane around all building exterior perimeters by rodding, by holes drilled through concrete slabs, through holes drilled in the brick veneer, by saturation of the soil in the crawl spaces adjacent to foundation walls and support piers, some by saturation of the wood sill surface in the crawl spaces, and by drilling holes through the concrete slabs supporting block walls which support wood structures (such as carport roofs).

3. Initial Survey Results

Initial air sampling in the 485 housing units was accomplished during September and October 1981. The number of units found to equal or exceed 5 µg/m³ was 129, or 27% of the total. The highest concentration measured was 43 µg/m³ and only four samples were nondetectable (ND). The remaining 352 samples varied between ND and 5 µg/m³.

4. Proposed Corrective Actions

In November 1981, five engineering modifications developed to reduce chlordane concentrations in nine housing units were undertaken.

The modifications included: positioning fiberglass insulation between floor joists, sealing and painting basement walls, laying a plastic cover over crawl space soil, installing a positive ventilation system in the crawl space, and putting a plastic cover between floor joists. Although test results of these five different modifications proved inconclusive, cleaning and sealing of air ducts, included as part of all modified quarters, appeared effective in reducing chlordane levels. Duct cleaning entailed vacuuming accomplished by a contractor. Contractor performance was not supervised. During February-March 1982, polyurethane foam filters installed in place of normal furnace filters were tested as another technique to reduce chlordane concentration. A North Carolina State University research team had reported polyurethane filter use to collect chlordane. The preliminary filter study in four houses at McConnell AFB indicated that the filters showed promise as a means to reduce chlordane concentrations in the crawl space houses. A more extensive USAF OEHL-sponsored study of the polyurethane filter ensued.

III. POLYURETHANE FILTER STUDY PROTOCOL

The objective of the study was to evaluate the effectiveness of a 1/4 inch polyurethane filter and to determine the frequency of filter replacement Representatives from HQ AFMSC/SGPA, HQ USAF/LEEV, HQ SAC/SGPB and DEMM, MConnell AFB personnel and the USAF OEHL participated the protocol development.

A. Experimental Design

Twenty houses were used for the study. All houses had partial crawl space/partial basements and a similar layout (e.g., basement below living room in all houses). Duct cleaning was accomplished in all houses involved in the study prior to filter installation. The 20 houses were divided into four groups of five houses; a control group and 30, 60 and 90 day filter groups. Only the control houses remained unoccupied throughout the evaluation. All houses were sampled at approximately the same time. Two samples were collected from all the houses prior to the installation of filters. Polyurethane foam filters were installed in 15 test houses and one air sample collected from each house every 15 days for the first month. The filters were then removed from five houses at the end of the first month. The remaining 15 houses were sampled every 15 days for the second month; the filters were then removed from another five houses after the second month. The remaining ten houses were sampled every 15 days for the third month; the filters then were removed from the final five houses. All control houses remained in the sampling program throughout the three-month study.

B. Sampling and Analytical Techniques

Every attempt was made to control sources of variability during sample collection. Time of day, pumps, and pump location were considered.

The basic sampling train consisted of an electric Millipore[R] miniature vacuum pump with a SKC sampling tube containing Chromosorb[R] 102 as the collecting medium. The sampling tubes were connected to the pump by a small piece of Tygon[R] tubing. Flow rates were measured using a Gilmont precision rotameter after the pump was turned on and again at the end of the sampling period. The rotameter was calibrated prior to the survey with a bubble meter. In instances where a slight drop in flow rate occurred, the beginning and ending flow rates were averaged to obtain a mean flow rate. The flow rates were appoximately 4.0 liters per minute for all samples.

The same pump was used in the same location in a given house throughout the evaluation. The pump and Chromosorb tube were located 3 ft off the floor in the center of the living room.

The following conditions were also recorded during the sampling period: inside temperature and relative humidity; outside high temperature, low temperature and barometric pressure; soil temperature and ambient temperature in the crawl space.

Samples were submitted to the USAF OEHL every 15 days for analysis. The filters, removed after 30, 60 and 90 days, were also submitted to the USAF OEHL for analysis. The samples were analyzed according to methods established by Thomas and Seiber (9) and Thomas et al (10).

Soxhlet extraction with hexane was used to recover chlordane from the filters.

C. Observations

1. Following completion of the sampling outlined in the study protocol, the Environmental Health Service at McConnell AFB performed additional sampling for chlordane. A polyurethane filter was installed in the five control houses. After seven days, the house was sampled and the filters removed. These samples and filters were also forwarded to the USAF OEHL for analysis.

2. The total sampling effort included 135 air samples and 20 filter samples.

IV. RESULTS

Table 1 shows a compilation of chlordane concentrations measured in the study houses and chlordane loading found on the polyurethane filters. The amount of chlordane on the filters was measured in milligrams of chlordane per gram of filter material (mg/G). Table 2 shows the environmental conditions under which the samples were collected.

V. DISCUSSION

The filter loading data from Table 1 clearly show that the polyurethane filter removes chlordane from the air being circulated through the housing units. However, the period of time filters should remain in place for optimum effectiveness is difficult to predict. Although the mean filter loading increased to 9.1 mg/G through the 60 days, mean loadings of 7.8 mg/G and 8.0 mg/G at 7 and 30 days, respectively, are not significantly different. The mean filter loading of 5.9 mg/G at 90 days is considerably less than the other filters and is unexplainable. The data show that the polyurethane filters continue to adsorb chlordane up to 60 days after installation. However, this should not be interpreted to mean that the effectiveness of the filter increases up to the 60 day point. The data essentially demonstrate that optimum filter effectiveness may be less than 7 days because of the insignificant increase in filter load after that time in place.

There appears to be little correlation between chlordane concentrations measured prior to filter installation versus the filter loading in the respective houses. Figure 1 shows a plot of these data. The correlation coefficient (r), which measures the strength of relationship between air concentration and filter load, was 0.2325. An r of 1.0 shows a perfect linear relationship between two variables and an $r = 0$ means the two variables are not correlated.

The preliminary filter evaluation done in February to March 82 yielded a mean recovery of 4.6 mg chlordane per gram of filter. These filters remained installed 9-27 days. The recovery from these filters was considerably less than the filters removed after 7 days in the latest study and may be a function of the ambient temperatures which were warmer during the filter protocol study, causing increased chlordane emission from the soil and greater filter loadings.

A direct relationship between air temperature in the crawl space and chlordane concentration was indicated in the control houses, see Figure 2. Correlation coefficients for the five control houses ranged from 0.72 to 0.93, with a mean correlation coefficient of 0.82. Ambient outside temperatures also show a direct relationship with airborne chlordane concentrations and is

Table 1

Concentration in Air $\mu g/m^3$

Sample Day

Group	1-2[1] Jun		16 Jun	1 Jul	16 Jul	30 Jul	16 Aug	31 Aug	14 Sep	Polyurethane Filter Loading mg/G
Control Houses										
2913 Andrews	5.3	3.4	14.3	16.4	25.7	26.1	22.7	18.4	14.9	9.7[2]
3033 Fairchild	7.2	4.8	8.5	5.9	6.9	12.0	23.8	19.5	11.1	7.0[2]
8229 Tinker	1.7	2.4	2.4	4.2	5.5	5.6	5.8	2.3	2.1	3.7[2]
3013 Westover	8.6	7.7	9.4	13.2	12.0	11.9	17.0	13.0	4.5	9.1[2]
2909 Westover	2.5	2.4	6.3	16.0	22.3	16.0	17.7	10.2	5.5	9.3[2]
Mean	4.6		8.2	11.1	14.5	14.3	17.4	12.7	7.6	7.8[2]
30-Day Filter Houses										
2917 Andrews	6.5	6.9	9.2	10.2	-	-	-	-	-	10.1
2916 Andrews	7.4	6.7	4.9	3.0	-	-	-	-	-	7.8
2928 Andrews	5.5	7.3	5.9	9.0	-	-	-	-	-	8.0
8416 Craig	5.9	6.5	6.9	5.9	-	-	-	-	-	6.7
8212 Cannon	7.2	8.1	6.3	9.6	-	-	-	-	-	7.4
Mean	6.8		6.6	7.5						8.0
60-Day Filter Houses										
2944 Fairchild	3.2	3.4	2.9	5.0	11.6	4.8	-	-	-	7.9
2908 Mitchell	5.2	6.0	6.4	16.0	14.8	11.8	-	-	-	13.6
2945 Fairchild	1.2	1.4	2.9	4.9	4.0	3.8	-	-	-	7.3
2920 Westover	4.4	4.8	3.7	10.0	8.4	10.0	-	-	-	8.4
2805 Westover	4.5	3.9	3.0	8.3	7.5	6.0	-	-	-	8.4
Mean	3.8		3.8	8.8	9.2	7.3				9.1
90-Day Filter Houses										
8101 Harmon	5.2	7.9	3.8	10.5	11.7	9.1	11.5	11.9	-	6.8
3101 Fairchild	11.3	9.2	9.0	9.9	10.6	9.4	10.9	10.8	-	8.7
8624 Ent	6.5	6.9	5.3	9.2	10.7	6.7	9.9	7.5	-	5.1
3024 Westover	5.1	5.1	4.0	10.1	10.1	0.00[3]	11.4	8.2	-	3.8
3032 Westover	2.3	2.5	1.3	2.2	6.0	5.8	6.1	7.6	-	4.9
Mean	6.2		4.7	8.4	9.8	[3]	10.0	9.2		5.9

[1]Samples on 1-2 June were all prefilter installation.
[2]Filters remained in control houses for 7 days in September.
[3]Suspected analytical error, mean value not calculated.

Table 2

Environmental Conditions

Sample Dates	1-2 Jun	16 Jun	1 Jul	16 Jul	30 Jul	16 Aug	31 Aug	14 Sep
Outside Air Temp (°F)								
Range	53-65	62-69	78-88	78-92	78-83	77-89	77-100	68-86
Mean	59	66	83	85	79	81	89	77
Ground Temp (°F)								
Range	63-70	66-70	68-70	64-75	66-75	68-81	63-75	61-75
Mean	67	68	69	70	71	75	69	68
Crawl Space Temp (°F)								
Range	63-68	66-72	70-73	66-77	66-77	68-82	64-79	59-73
Mean	64	68	71	72	71	75	72	66
Inside Air Temp (°F)								
Range	64-77	69-78	72-85	64-85	70-82	70-83	64-85	55-78
Mean	70	75	78	78	77	78	76	65
Inside Rel. Hum. (%)	74	66	66	65	64	68	72	70
Uncorrected Barometric Pressure (in. Hg)	28.55	28.57	28.56	28.46	28.68	28.65	28.56	28.58

NOTES: Ground, crawl space and inside air tempreatures were measured by survey personnel.
Inside relative humidity was calculated from sling psychrometer measurements.
Outside temperature and barometric pressure data were provided by the Base Weather Service.

PRE-FILTER INSTALLATION
CHLORDANE CONCENTRATION
VERSUS
FILTER CHLORDANE LOADING

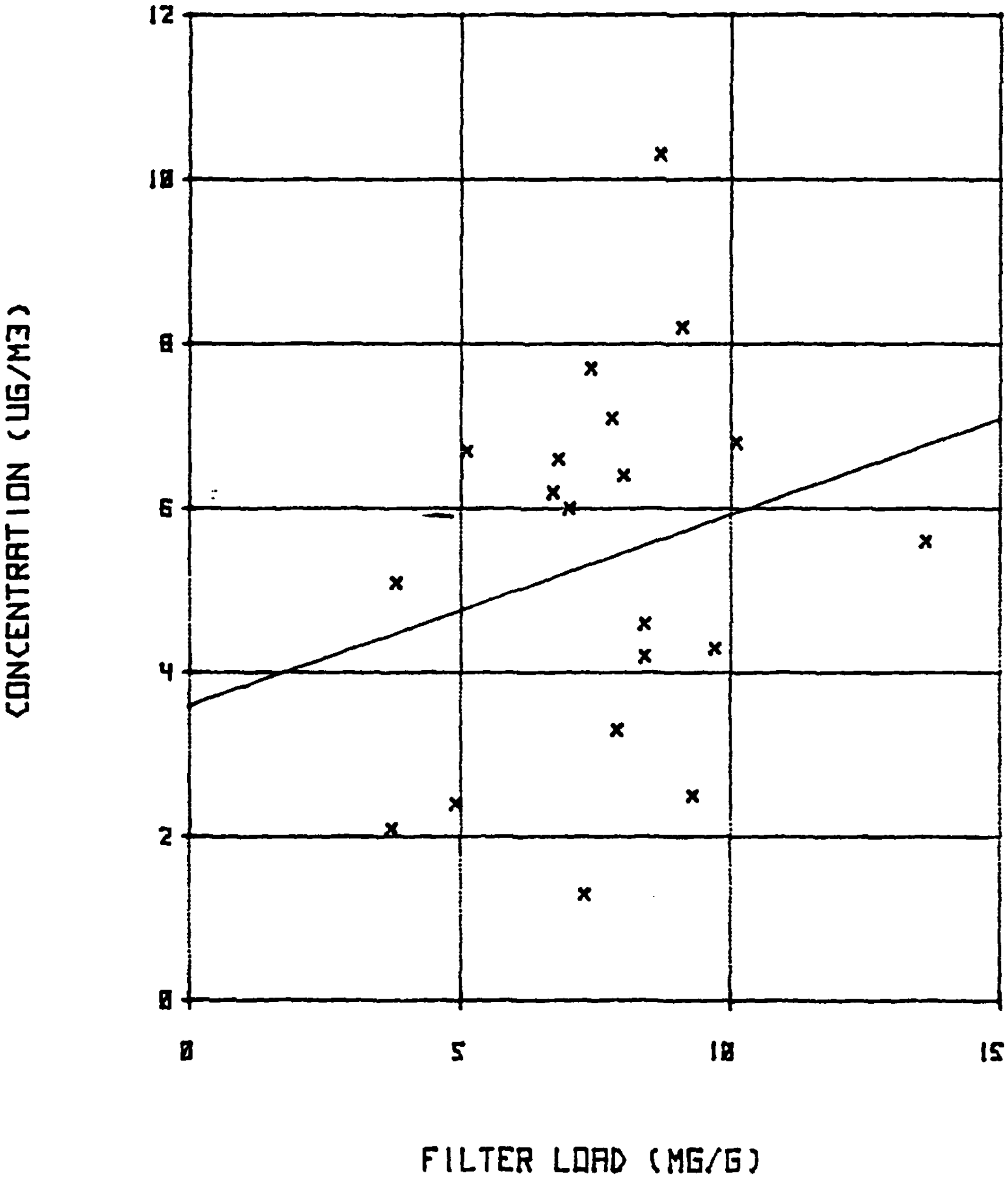

Figure 1

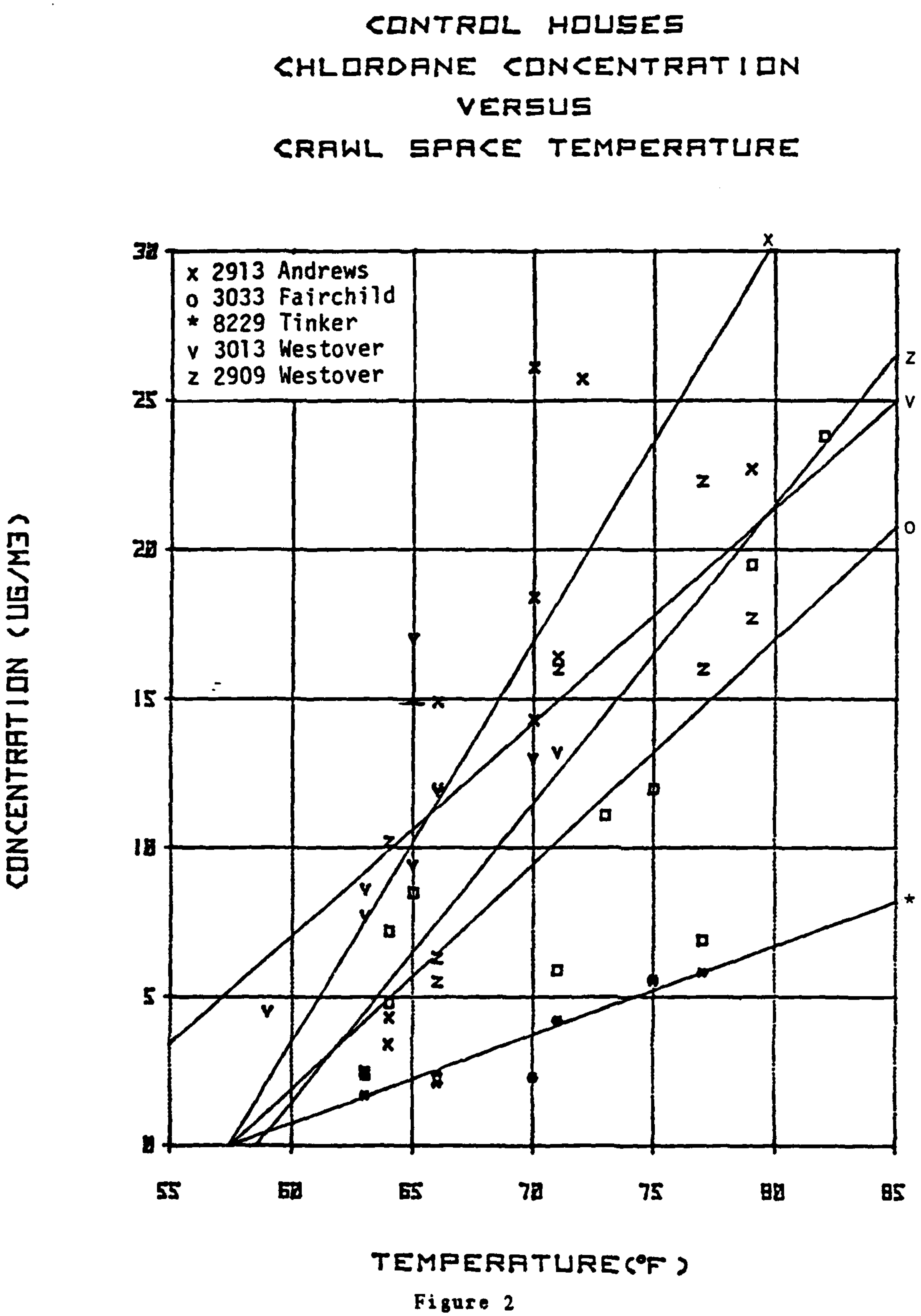
CONTROL HOUSES
CHLORDANE CONCENTRATION
VERSUS
CRAWL SPACE TEMPERATURE
x 2913 Andrews
o 3033 Fairchild
* 8229 Tinker
v 3013 Westover
z 2909 Westover
CONCENTRATION (UG/M3)
TEMPERATURE(°F)
0
5
10
15
20
25
30
55
60
65
70
75
80
85

Figure 2

to be expected because outside temperature greatly influences crawl space temperature. Previous air samples collected in the control houses further corroborate this relationship:

(1)	2913 Andrews	19 Feb 82	59°F	6 sample mean = 2.1 μg/m³
(2)	3033 Fairchild	18 Feb 82	49°F	6 sample mean = 3.5 μg/m³
(3)	8229 Tinker	19 Feb 82	44°F	6 sample mean = 1.0 μg/m³
(4)	3013 Westover	17 Feb 82	38°F	6 sample mean = 3.5 μg/m³
(5)	2909 Westover	22 Feb 82	73°F	6 sample mean = 2.8 μg/m³

The 73°F temperature for February was exceptionally warm for that time of year. It is suspected that ground and crawl space temperatures fluctuate much more slowly than ambient temperature; therefore, chlordane vaporization from treated surfaces would not increase enough during peak daytime temperature to show appreciable concentration increase.

Although the airborne concentration of chlordane in filtered houses continued to increase as the study progressed, chlordane levels measured in the control houses increased at a considerably greater rate than those in any of the filtered houses. This reinforces the filter load data and further demonstrates that polyurethane filters will remove airborne chlordane. However, the filters did not remove enough chlordane to maintain levels below 5 μg/m³. Samples collected with filters installed showed 76% (45 of 59) were greater than the NAS guideline.

The direct correlation between chlordane concentration and ambient temperature suggests that most of the crawl space houses at McConnell should have airborne chlordane concentrations below 5 μg/m³ during part of the year. Temperatures normally experienced at McConnell AFB are depicted in *Table 3*. Sampling data indicated most chlordane concentrations were less than 5 μg/m³ when ambient temperature were less than 60°F. Based upon this and Table 1, chlordane levels in the crawl space houses should be less than 5 μg/m³ from November through March. It is theorized that the installation of the polyurethane filter should keep chlordane levels safely below 5 μg/m³ from October through April.

There is a high probability that an annual TWA for most of the McConnell crawl space houses may be less than 5 μg/m³. However, there is insufficient sampling data throughout the year to calculate a TWA and sampling variability precludes making such projections for each house based solely upon temperature data and one or two samples. Also, the NAS has not specified whether the 5 μg/m³ guideline is a TWA or ceiling level. The NAS has stated that the "5 μg/m³ should be regarded as an interim guideline for exposures not exceeding 3 years." (3) This infers that a 3-year TWA could be applied.

The mechanism for chlordane intrusion into the crawl space housing at McConnell AFB is not fully understood. It is suspected that the chlordane contaminated air in the crawl space is penetrating the return air ventilation

Table 3

Temperature Data - McConnell AFB*

Month	Maximum Mean (°F)	Minimum Mean (°F)
Jan	41	21
Feb	46	26
Mar	54	33
Apr	67	46
May	77	56
Jun	87	66
Jul	91	70
Aug	90	69
Sep	81	60
Oct	72	50
Nov	54	35
Dec	44	26

*Data provided by Base Weather Service, McConnell AFB.

duct which is under negative pressure. The chlordane is then distributed throughout the unit. Or the chlordane may be penetrating the floor above the crawl space. Regardless, chlordane concentrations in the houses vary directly with the ambient outside and crawl space temperatures. This is opposed to previous USAF OEHL studies in houses built on concrete slabs where chlordane concentrations increased in the colder months. During cold weather, the heated air in the slab house ventilation ducts warmed the adjacent soil causing more chlordane to vaporize and infiltrate into poorly sealed ductwork. Conversely, the ventilation ducts, return and supply, in the crawl space are suspended immediately below the floor and are not in contact with the treated soil. Some of the wood sills and supports may also have been treated with the chlordane emulsion in 1979. Because an air buffer exists between treated surfaces and the ductwork, it is theorized that the heat transfer between the exterior of the duct to these surfaces is minimal; but the increased temperatures in the crawl space during the summer months is sufficient to heat the treated surfaces causing increased chlordane vaporization.

VI. CONCLUSIONS

A. Polyurethane filters installed in the place of the normal furnace filter removed chlordane from the air. The maximum filter loading was 13.6 mg/G, the average load was 7.7 mg/G.

B. The ideal filter installation time based upon optimum effectiveness could not be determined. The filter adsorbed an average of 7.8 mg/G after only 7 days in the system. The maximum filter loadings were found on the 60-day filters, but optimum filter effectiveness life may be less than 7 days.

C. The filter did not reduce airborne chlordane concentrations below 5 $\mu g/m^3$ in most of the study houses during the summer months.

D. Chlordane concentrations in the housing units increased directly with outside and crawl space temperatures.

E. The winter months should result in reduced chlordane concentrations in the crawl space houses at McConnell AFB. It is not realistic to predict concentrations on a house-by-house basis. However, most units should have chlordane levels less than 5 $\mu g/m^3$ for November through March.

F. Installation of polyurethane filters should result in most houses having concentrations less than 5 $\mu g/m^3$ from October through April.

G. A 3-year TWA may show that the NAS guideline is rarely exceeded by housing occupants. However, insufficient sample data exist to currently calculate such a TWA.

VII. RECOMMENDATIONS

A. As an interim precaution, polyurethane filters should be installed in all houses identified as having chlordane levels greater than 5 $\mu g/m^3$. Filters should be replaced every 30 days.

B. Engineering studies should be initiated immediately to explore techniques in eliminating chlordane intrusion into the crawl space houses at McConnell AFB. The following alternatives, alone or in combination, should be considered:

1. Seal the exposed crawl space soil. Concrete (poured or sprayed) or another hard sealant would be appropriate.

2. Replace the return air duct system in the crawl space with a duct which prevents infiltration of crawl space air.

3. Seal the return air registers in the house causing the house to act as a return air plenum. The return air should then be routed down to the basement where it could reenter the supply system. Thus, air flow through the crawl space is eliminated. Also, any vents between the basement and crawl space should be blocked.

4. Supply air ducts should be disassembled and thoroughly cleaned. Furnaces should also be cleaned.

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