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Project Summary

Field Evaluation of a High Volume Surface Sampler for Pesticides in Floor Dust

W. T. Budd, J. W. Roberts, and M. G. Ruby

House dust and the pollutants carried with it are potentially important contributors to total exposure through the pathways of inhalation, ingestion and skin penetration, especially for small children. Pesticides may be one of the more important contaminants of house dust. The full report describes a pilot study conducted as a part of the Non-Occupational Pesticide Exposure Study (NOPES), which provides preliminary information on the pesticide content of floor dust.

A high volume surface sampler (HVS2) for the collection of house dust and the semivolatile organics in house dust has been developed and tested in the laboratory. This study also served as a field test and initial validation study of the HVS2. The HVS2 is designed to collect more than 2 g of floor dust from a rug in an average clean residence in a few minutes. Such a large sample could be used in bioassays or analyzed for a variety of contaminants.

This study was conducted in nine houses in the Jacksonville, Florida Phase III segment of the NOPES study. Both the NOPES questionnaire and a supplemental questionnaire were administered in each household to develop information on pesticide usage and other variables that might be related to the floor dust samples. All samples were collected from carpeted surfaces.

The samples were collected and processed using previously published procedures. Both the HVS2 and the procedures were found to be generally satisfactory. An average of 3.2 m^2 (34 ft^2) was necessary to collect a 2 g sample. The total time for collecting a single sample, including sample processing, cleanup of the HVS2, and travel time, was approximately 4 hours.

The samples were analyzed for 33 pesticides by GC/ECD andGC/MS following the NOPES standard procedures. High concentrations of interfering compounds in some samples required substantial dilution before they could be analyzed. As a result, other analytes were diluted below their detection limit.

On average, 7.5 target pesticides were observed in the indoor air samples and 11.8 in the floor dust. The number observed in the floor dust ranged from 2 to 23. Thirteen of the pesticides were observed only in the floor dust. The most consistently observed pesticides were chlorpyrifos, with a median concentration of about 5 ppm in the dust, and chlordane, with a median concentration of approximately 6 ppm. The

median surface loading of chlorpyrifos was approximately 6 µg/m² and of chlordane, about 13 µg/m². No significant correlation between surface loading and dust concentration was seen for these or most other pesticides. Several pesticides were observed in floor dust which have not been in widespread use for many years.

Exploratory statistical analyses suggest that a relationship may exist between the measured concentrations of pesticides in the dust and in the air for some pesticides. A relationship was observed between the number of pesticides detected and the age of the house.

The HVS2's PUF plug adsorber was necessary for the accurate measurement of five pesticides. The source of the pesticides on the PUF plug (room air or blow off from the glass fiber filter) was not determined nor is it clear why these five pesticides are more likely to be found in the PUF plug. A supplemental experiment indicates a relationship between blowoff and vapor pressure.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Non-Occupational Pesticide Exposure Study (NOPES) was designed to gather information on total human exposure to selected pesticides among persons not occupationally exposed, using the Total Exposure Assessment Methodology. During Phase I and Phase II of NOPES, measurements were taken to permit estimates of human exposure through air, drinking water, and dermal contact. The full report describes a pilot study during the NOPES Phase III activities which provides preliminary information on possible human exposure to pesticides through the additional medium of household dust.

The importance of routes of exposure other than inhalation has been increasingly recognized in recent studies. The Health and Safety Plans for the Hyde Park disposal site in Niagara Falls, New York developed under a Superfund consent decree require the monitoring of homes for contamination of the house dust. However, prior to this study, no validated procedure existed to make such measurements.

The ingestion of pollutants deposited on soil and dust (particularly house dust) is expected to be especially important for very young children, because of their lower body weight and frequent hand-to-mouth activity. The toddler has only about one-fifth the body weight of an adult and ingests an estimated 2.5 times as much dust, which increases the potential health risk to the child by at least 12 times. Further, the risk to such children will be increased by the early stage of development of their organs, nervous system, and immune system. Estimates of the risks posed by pesticides and other semivolatile chemicals should therefore include an evaluation of the dust-mediated pathway.

Validation of a method for sampling surface dust is necessary if reliable measurements are to be made. The study reported here also served as a field test and initial validation study of a new surface dust sampling methodology, the High Volume Surface Sampler (HVS2), constructed by Cascade Stack Sampling Systems (CS3). The HVS2 was designed and developed (Roberts and Ruby, 1988) under EPA sponsorship as a way to collect removablesurface dust accumulations on indoor surfaces (e.g., rugs and floors) and outdoor fugitive dust surfaces (e.g., bare ground at a contaminated earth site).

The HVS2 has been extensively tested in the laboratory. It is designed to collect several grams of dust in a few minutes from a rug or bare floor in an average house. Such a large sample could be used in bioassays or analyzed for a variety of contaminants by separate techniques. Because many of the environmental pollutants of most concern in the dust matrix are semivolatile organics, the HVS2 has been, and is here, carefully studied for its ability to capture these organic compounds.

This study involved nine houses in the Phase III Jacksonville NOPES set. The HVS2 was used to collect a sample of dust in each house. Analysis included the dust loading on the surface and the concentration of pesticides in the dust. The primary purposes of this study were to field test the HVS2 to validate the methodology, to obtain preliminary data on the amount and characteristics of dust in residences, and to obtain preliminary data on the species and concentration of pesticides in house dust.

The full report provides information on the practical aspects of field operations with the HVS2, the ability of the HVS2 to retain the collected pesticide material, the variation in dust loading observed in the nine houses, the loading and concentrations of pesticides in house dust in the nine houses, and a comparison of the concentrations in the air and in the dust.

Data Collection Methods

The sampling activities for this study were integrated with the NOPES Phase III sampling activities. The houses for floor dust sampling were obtained opportunistically from volunteers during one week of routine sampling activity. The standard NOPES samples were collected in each household, including indoor and outdoor air, in addition to the floor dust sample.

The selection of the floor area within the house to be sampled was determined primarily by convenience for sampling and the probability that a sufficiently large dust sample could be collected in a short period of time. No attempt was made to presurvey the entire house in order to select a representative area or an area where children would be likely to play. All the samples in this study are from carpeted surfaces.

The NOPES Study Questionnaire was administered in a personal interview. The Study Questionnaire requested demographic data for the individual respondent, any occupational exposure to pesticides, the potential for pesticide use in the home, and an inventory of all pesticides currently in the house. In the floor dust sample houses an additional questionnaire was administered. This questionnaire included queries on the type and frequency of floor cleaning, the number of cigarettes smoked in the household, and the frequency of fireplace or woodstove use, if one were present.

Floor dust sampling was carried out using the HVS2 and the sampling procedures described by Roberts and Ruby (1988). In brief, the HVS2 is a high-powered vacuum cleaner equipped with a nozzle that can be adjusted to a specific static pressure within the nozzle, a cyclone to separate the larger particles from the air stream immediately after their removal from the surface, a high efficiency quartz fiber filter for particles, and (optionally) a polyurethane foam (PUF) plug adsorber for semivolatile organic compounds.

The HVS2 has been shown to collect a consistent amount of the material on either a plush or level loop carpet, the two most commonly found residential carpets. With a standard test dust it will collect approximately 30% of the material in the test dust, which was less than 150 µm.

The recommended test procedures for the HVS2 (Roberts and Ruby, 1988) include calibration of the required measuring instruments, pretest preparation of the HVS2 and supplies, the procedures for sampling, and a procedure for clean up in the field between samples. The sampling procedure calls for laying out eight 46 by 137 cm (18 by 54 in.) rectangles, setting the HVS2 flowrate and nozzle pressure drop, sampling four of these rectangles, and then continuing the sampling of the additional rectangles until 2 g of material has been collected.

Field Operations

In addition to obtaining preliminary data on the amount and characteristics of dust in homes and preliminary data on the species and concentration of pesticides in house dust, this field study provided an opportunity to validate the High Volume Surface Sampler and to field test the sampling methodology. The latter included an evaluation of the practicality of the sampling, cleanup, and analysis procedures, the approximate times required to perform each of the tasks, a determination of the amount of sample that could be realistically collected in a normal range of houses, and an evaluation of the acceptability of the HVS2 by the residents of the sampled house.

Although the HVS2 weighs about 25 kg (55 pounds), it could be carried into the house by one person. After it was carried into the house, the floors were examined to locate areas where the 46 by 137 cm (18 by 54 in.) sample sections could be laid out. A folding frame was used as a template for marking the selected sampling areas with masking tape.

It was necessary to use from 1 to 13 (average of 5) sampling areas to collect the required 2 g of sample. The sample areas contain 0.63 m^2 (6.8 ft^2). Because the amount of dust on the floor varied widely, it was difficult to estimate prior to sampling how many sample areas would be required. The sampling continued over additional sample sections until about 2 g of material were collected. On average, this required less than 7 minutes.

The HVS2 was cleaned between runs using brushes and a mixed solvent (50% acetone/50% hexane) rinse on the entire sampling train between the nozzle and the PUF plug holder.

The cyclone catch was weighed and then seived to less than 150 µm, using a shaker and sieves following ASTM standard method 422-63.

Results

Seven of the nine sample sites were single-family detached houses and the remaining two were mobile homes. In all but one house, most of the floors (other than kitchen and bathroom) were carpeted.

Dust Loading

The floor dust loadings at each site were determined by dividing the total sample collected in the cyclone and the fraction of that less than 150 µm by the total area sampled. The results are presented in Table 1. The two houses which have the greatest loading are also the two houses which were not using a vacuum. The ratio of the fine fraction to the total dust load is about 0.5, if the two high loading houses are not included.

Table 1. *Total and Fine Fraction Dust Loading by Household*

Household	*Total Dust load (g/m²)*	*Dust < 150 µm load (g/m²)*
1227-216	10.8	6.6
0753-039	4.2	3.0
1064-014	0.3	0.1
0490-026A	2.2	1.2
0490-026B	0.8	0.3
1440-016A	1.4	1.0
1440-016B	4.3	1.1
1647-001	0.8	0.3
1064-011	6.6	4.7
0966-021	33.7	23.3
0782-038	812.7	168.9

Pesticide Loadings and Concentrations in Air and Dust

The loading of the NOPES target pesticides was calculated by dividing the total mass of the pesticide by the area sampled. The concentration of the pesticide in the collected dust was calculated by dividing the total mass of pesticide by the mass of the fine fraction of the cyclone catch plus the mass on the quartz fiber filter. These results are presented in Table 2 for each household.

The data are reported as both a surface loading (ng/m^2) and as a concentration in the dust (ppb) as data have been reported by others using both measures. Previous work suggests surface loading may be better related to possible health effects. Davies et al. (1987) found a better correlation between lead surface loading and hand lead than between lead concentration in dust and hand lead.

The correlation between the concentration (ppb) and pesticide loading (ng/m^2) measures was significant (at the 99% level) and robust for only two pesticides, chlorothalonil and g-BHC. For the remainder that could be statistically tested, the coefficients were also generally near zero.

The total pesticide loading on the floor is understated by these data. First, the large particle size fraction (>150 µm diameter) was separated and was not submitted for analysis. Some pesticide materials may have been present in this segment of the floor dust. Second, the HVS2 does not collect 100% of the dust in a carpet. It is not known what fraction of the dust in the carpet is "available" for human uptake or how this relates to the fraction of dust which is collected by the HVS2. The HVS2 does collect a fraction which is approximately constant with loading and for different carpet materials.

An average of 7.5 target pesticides were identified in the indoor air at the nine sites, while an average of 11.8 pesticides were identified in the dust. The number observed in the floor dust ranged from 2 to 23. Thirteen pesticides were found only in the dust in these nine houses. Four of these (PCP, DDD, atrazine, and carbaryl) were not observed in indoor air in any of the samples taken during the Phase III Jacksonville segment of NOPES. In addition, six others (heptachlor epoxide, captan, methoxychlor, cis- and trans-permethrin, and DDT) were observed in indoor air of no more than four sites in the entire Jacksonville Phase III study. Conversely, of the six pesticides which were observed in samples from at least eight sites during this pilot study (heptachlor, chlorpyrifos, aldrin, dieldrin, chlordane, and ortho-phenylphenol), all but one were also observed in the air at most of those locations. The exception is aldrin, which was observed in the air at only two sites.

A summary of the median value (of the sites where that pesticide was observed) and maximum value for floor dust concentration in ppm and loadings in µg/m^2 of the most commonly observed pesticides is provided in Table 3.

The relatively fewer number but higher loadings of pesticides observed in four of the households (1064-011, 0966-021, 0782-038, and to a lesser extent 1647-

Table 2. *Concentration of Pesticides in Surface Dust*

Household	1227-216		0753-039		1064-014		0490-026A		0490-026B		1440-016A	
	ng/m2	ppb	ng/m2	ppb	ng/m2	ppb	ng/m2	ppb	ng/m2	ppb	ng/m2	ppb
Dichlorvos	399*	60*					85*	69*				
o-Phenylphenol	8730	1315	5778*	1896*	22*	360*	203*	165*	433	1368	171*	179*
Propoxur	13228	1992	2565*	842*	464	7600	276*	224*	160*	505*	167*	175*
Bendiocarb									< 40	< 100		
a-BHC							40*	32*	124	391		
HCB			21	7	1*	13*	4*	3*	5*	14*		
Atrazine							1111*	903*	167*	526*		
PCP									3017	9526		
g-BHC					1*	10*	255	207	594	1876	12*	13*
Diazinon	2646*	398*	22	7	635	10400	215*	175*	136*	428*	< 200	< 100
Chlorothalonil			17	5	9	152	213*	173*	1095	3458	12*	12*
Carbaryl					21*	340*	1984	1613	457*	1443*		
Heptachlor	254	38	249	82	13*	216*	1894	1540	3150	9947	112	118
Malathion												
Chlorpyrifos	76190	11474	17851	5857	427	7000	5758	4681	6947	21937	260	273
Aldrin	3810	574	10	3	55	908	12*	10*	226	713	13*	14*
Dacthal					3*	50*			14	43		
Heptachlor epoxide							43	35				
Oxychlordane												
Captan					71	1170	651**	529**	187	589		
Chlordane	1812	273	19550	6415	225	3680	18206	14800	31218	98584	3655	3838
Folpet									70	220		
2,4,D												
DDE			600	197	19	306	520	423	371	1173	234	246
Dieldrin	187	28	1440	472	32	524	414	336	5765	18205	176	185
DDT			4772**	1566**	4*	60*	330**	268**	1263	3988	27	28
DDD									372	1174		
Methoxychlor			1005**	330**			73**	59**	654	2066		
c-Permethrin												
t-permethrin												

(Continued)

Notes:
- * Value less than defined quantitation limit. Value is more uncertain than others.
- ** Value is more uncertain than others due to continuing calibration drift.
- < Pesticide confirmed as present in quartz fiber filter or PUF plug but not detected in cyclone due to high dilution required for analysis. Value shown is approximately detection limit of cyclone catch sample.

Blanks and analytes not listed are not detected or, more properly, "less than detection limit."

Table 2. *Continued*

Household	1440-016B		1647-001		1064-011		0966-021		0782-038	
	ng/m²	ppb	ng/m²	ppb	ng/m²	ppb	ng/m²	ppb	ng/m²	ppb
Dichlorvos										
o-Phenylphenol	233*	210*	<200	<800	<7000	<1000	<32000	<1000		
Propoxur	698	629	<100	<500			41540*	1786*		
Bendiocarb										
a-BHC										
HCB			<20	<90						
Atrazine										
PCP										
g-BHC	9*	8*								
Diazinon	254*	229*	<300	<1000			57413*	2469*		
Chlorothalonil										
Carbaryl					<9000	<2000	<39000	<2000		
Heptachlor	86	77	<20	<100	<700	<200	14729*	633*		
Malathion										
Chlorpyrifos	357	321	2073	8226	4431*	941*	59623	2564	193651	1147
Aldrin			263*	1045	1390*	295*	7747*	333*	11270*	67*
Dacthal	25	22								
Heptachlor epoxide			36*	143						
Oxychlordane										
Captan	74**	67*					<19000	<800		
Chlordane	7016	6314	1167*	4630	12965*	2753*	183894*	7908*		
Folpet										
2,4,D										
DDE	589	530					<3000	<100		
Dieldrin	254	229	352*	1398	3672*	780*	7433*	320*		
DDT	405	364					8990*	387*		
DDD										
Methoxychlor	6*	6*					5758*	248*		
c-Permethrin							21471*	923*		
t-permethrin							26254*	1129*		

Notes: * *Value less than defined quantitation limit. Value is more uncertain than others.*
** *Value is more uncertain than others due to continuing calibration drift.*
< *Pesticide confirmed as present in quartz fiber filter or PUF plug but not detected in cyclone due to high dilution required for analysis. Value shown is approximately detection limit of cyclone catch sample.*
Blanks and analytes not listed are not detected or, more properly, "less than detection limit."

001) illustrates one of the more difficult problems in the analysis of such multi-component samples. In order to measure the maximum compound, it was necessary to dilute the extract to the point that the effective detection limit was raised above the expected values of many of the other compounds.

Some of the pesticides were observed on the quartz fiber filter or the PUF plug in samples from these four households even though the compound was not reported in the (diluted) cyclone catch extract. The concentrations of these pesticides have been reported in Table 2 as less than the detection limit for the cyclone catch plus the observed value on the filters.

Conclusions and Recommendations

The use of the HVS2 in this nine-home pilot study has shown it to be an effective and efficient way to collect household floor dust samples of sufficient size to permit detailed chemical analysis. Experience with the HVS2 suggested some minor modifications to the device to make it more maneuverable. Additional study should be undertaken to determine the variability of recovery efficiency of the HVS2 with samples of real house dust. The operating procedures and sampling documentation were found to be workable and complete, although additional comments on the availability of a portable hood for use during cleanup should be added.

Analytical procedures were generally satisfactory. However, high concentrations of pesticides in some samples required substantial dilution before they

Table 3. Summary of Dust and Pesticide Data

Analyte	Median		Maximum	
Dust < 150 µm	1.2 g/m²	--	169 g/m²	--
o-Phenylphenol	0.2 µg/m²	1.3 ppm	8.7 µg/m²	1.9 ppm
Propoxur	0.4	0.6	41.5	7.6
Diazinon	0.2	0.4	57.4	10.4
Heptachlor	0.3	0.1	14.7	9.9
Chlorpyrifos	5.6	4.7	193.7	21.9
Aldrin	0.3	0.3	11.3	1.0
Chlordane	12.9	6.3	183.9	98.6
DDT	0.4	0.4	9.0	4.0
DDE	0.5	0.3	0.6	1.2
Dieldrin	0.4	0.5	7.4	18.2

could be analyzed. As a result, other analytes were diluted below their detection limit. A cleanup procedure should be developed for the cyclone catch that would remove interfering compounds, allowing accurate measurement of all the target compounds.

Several pesticides were observed that have not been in widespread use for many years. It is not known if these were long-lived residues from earlier indoor applications, recent applications of old pesticide material, or material tracked in from outside areas which were treated in years past.

A relationship was observed between the number of pesticides in the samples and the age of the house. No relationship was found with any of the other physical or socio-economic variables. A significant correlation was observed between surface loading (e.g., µg/m²) and dust concentration (e.g., ppmb) for only two pesticides. For other pesticides the correlation coefficient was generally small as well as not significant.

When a pesticide was present in both the air and dust samples, simple statistical tests suggest, with a high degree of confidence, that a relationship may exist between the air concentration and the concentration in the dust for some pesticides. The sample size was not sufficient to quantify the relationship or to identify which pesticides could be so related.

A PUF plug filter was necessary for accurate measurement of alpha-BHC, HCB, gamma-BHC, heptachlor, and aldrin. The source of pesticides found on the PUF plug could be either the indoor air drawn through the HVS2 or pesticide material blown off the dust in the cyclone or on the quartz fiber filter. It was not possible to refute either alternative with the data available. A supplemental study did show that blowoff could occur over time and was a function of vapor pressure, especially over the short term. Further study will be necessary to determine if the PUF plug, or a lower pressure drop alternative, is necessary to retain these pesticides and other semi-volatile compounds.

This work leaves a number of questions about household exposure to pesticides unanswered. Although this study has demonstrated the presence of a wide variety of pesticides in household dust in significant concentrations, it is not clear that this material presents any risk to residents. However, preliminary studies do suggest that the dust-mediated pathway may be a significant route of exposure, especially for very young children. A series of studies should be conducted to determine the sources of these pesticides and the mechanism of transfer, if any, from the dust to residents. Specifically, 1) longitudinal studies should be made of pesticide application events, 2) studies should be made of surrounding soils to evaluate "track-in" as a source for the pesticide materials, and 3) studies of pesticide materials on residents, or dirt and surrogates on very young children, should be conducted to determine the amount and manner of transfer from house dust to residents.

References

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W. T. Budd, J. W. Roberts, and M. G. Ruby are with Environmetrics, Seattle, WA 89103.
***Robert G. Lewis** is the EPA Project Officer (see below).*
The complete report, entitled "Field Evaluation of a High Volume Surface Sampler for Pesticides in Floor Dust," (Order No. PB 90-192 006/AS; Cost: $ 17.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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U.S. Environmental Protection Agency
Research Triangle Park NC 27711

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