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Project Summary

Nonoccupational Pesticide Exposure Study (NOPES)

Frederick W. Immerman and John L. Schaum

The Nonoccupational Pesticide Exposure Study was the first attempt to develop a methodology for measuring the potential exposure of specified populations to common pesticides. In this study, as in other studies utilizing the Total Exposure Assessment Methodology (TEAM), the exposures were related to actual use patterns. A selected list of 32 household pesticides were evaluated in two different cities during this study.

Air samples were collected over a 24-hour period in indoor, outdoor and personal microenvironments. In addition, limited water and dermal contact samples were collected for selected homes. The study households were selected from stratified random population samples in two urbanized areas. The samples were collected over several seasons in areas contrasting a relatively high and low use of pesticides. Dietary recall, activity pattern, and pesticide use data were collected through survey questionnaires.

The report discusses the results of the study with an emphasis on the various routes of exposure (air, water, dermal, and indirectly, food) and their relative contribution to total human exposure.

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

In 1984, Congress appropriated FY85 monies to the U.S. Environmental Protection Agency (EPA) to assess the level of pesticide exposure experienced by the general population. Occupational exposure of specific groups of pesticide users, such as farm workers and pest control operators, had been examined and characterized by previous studies. However, little was known about the general distribution of nonoccupational exposures to household pesticides. To begin to overcome this lack of knowledge, NOPES was designed to provide initial estimates of nonoccupational exposure levels and to address the nature of the variability in exposures.

NOPES was based on the Total Exposure Assessment Methodology (TEAM) approach to exposure estimation. The Agency began developing the TEAM approach in 1979 for measuring human exposure to various environmental contaminants. In a TEAM study, probability-based survey sampling procedures are combined with questionnaire data collection and modern personal monitoring techniques to obtain statistically defensible estimates of exposure levels in the general population. The initial application of this innovative approach (Wallace, 1987) was in the estimation of exposures to volatile organic compounds (VOCs).

NOPES had both methodological and analytical objectives. NOPES sought to apply the TEAM approach to a class of chemicals not previously addressed by

TEAM. Therefore, the primary methodological objective of NOPES was to develop monitoring instrumentation, laboratory procedures, and survey questionnaires for a TEAM study of pesticides. The overall analytical objective of NOPES was to estimate the levels of nonoccupational exposure to selected household pesticides through air, drinking water, food, and dermal contact.

Procedure

Work on the design phase of NOPES began in 1985. Southwest Research Institute (SwRI), of San Antonio, Texas, developed the methodology for collecting air samples and analyzing them for 32 selected pesticides and pesticide degradation products. Emphasis was placed on both identifying and quantitating the target compounds. Research Triangle Institute (RTI) of Research Triangle Park, North Carolina, developed the probability-based sampling design and the questionnaires needed to collect information about pesticide use and activity patterns. The questionnaires and monitoring and analysis procedures were tested in a pilot study conducted in Jacksonville, Florida in August and September 1985.

To permit assessment of regional and seasonal variations in exposure levels, the main NOPES data collection was conducted in three phases:

- Phase I: Summer 1986 in Jacksonville, Florida.
- Phase II: Spring 1987 in Jacksonville, Florida, and Springfield and Chicopee, Massachusetts.
- Phase III: Winter 1988 in Jacksonville, Florida, and Springfield and Chicopee, Massachusetts.

The findings of EPA's National Urban Pesticide Applicator Survey and earlier studies were used to select two study areas. Jacksonville was selected as representative of an area of the country with relatively high pesticide use, and the Springfield region was selected to represent an area of low to moderate pesticide use. In both study areas, some sample members were asked to participate in all seasons of the study, whereas others were recruited only for a single season. Monitoring some people in more than one season permitted assessment of whether the overall differences observed between seasons were due to true seasonal variations or due to random sampling variations. Short-term temporal variations were addressed by monitoring some respondents twice in the same season.

The following activities were performed for each sample member who agreed to participate in the study:

- A study questionnaire was administered.
- A personal air sampler was given to the participant to wear or keep in close proximity for 24 h.
- Two or more fixed-site air samplers were set up and run for 24 h. At least one sampler was run in the respondent's home, and at least one was run outside the home.
- At the end of the 24-h monitoring period, an activity log questionnaire was administered.

In some households, drinking water samples were collected for analyses. Dermal exposure during pesticide application events was estimated for a small number of respondents by analyzing cotton gloves worn during typical application events following the regular monitoring period.

In all phases, RTI recruited the sample households, administered the questionnaires, and statistically analyzed the questionnaire and chemical data. SwRI performed the environmental monitoring and laboratory analyses. In Phases I and II, Environmental Monitoring and Services, Inc. (EMSI), of Camarillo, California, provided overall program management and quality assurance. EPA assumed these functions in Phase III.

Results and Discussion

The second-stage (household screening) sample size was 1,501 housing units in Jacksonville and 2,472 housing units in Springfield/Chicopee. Screening information was obtained from 1,005 Jacksonville households and 1,774 Springfield households. Second-stage response rates, computed as the number of respondents divided by the number of eligible sample members, were relatively low for face-to-face household screening, ranging from 66% for the Jacksonville spring season to 84% for the Springfield/Chicopee winter season (Table 1). Second-stage nonresponse was due more to inability to contact household members during the time period allotted for screening (56% of nonresponding eligible sample members) than to refusals (32% of nonresponding eligible sample members).

Third-stage (personal monitoring) response rates varied by study area, season, and whether sample members were single-season or multiseason subjects. Nonresponse in the third stage was primarily due to refusals to participate (73% of nonresponding eligible sample members). The two most commonly cited reasons for refusing to participate were the amount of time required and the perceived burden associated with keeping the personal sampler nearby.

The overall response rates presented in Table 1 (45% for Jacksonville and 40% for Springfield/Chicopee) are comparable to the 44% response rate experienced in the New Jersey segment of the TEAM-VOC study (Wallace, 1987). Although these response rates are low relative to those experienced in traditional area-household surveys, they are typical of the rates experienced in personal monitoring studies. Low personal-monitoring response rates are believed to be primarily due to the respondent burden imposed by the monitoring systems and procedures.

Tables 2 and 3 present estimated arithmetic means for indoor, outdoor, and personal air concentrations for each season in Jacksonville and Springfield/Chicopee, respectively. Figures 1 and 2 present estimated cumulative frequency distributions as log-normal probability plots for personal air exposures for two of the study pesticides, chlorpyrifos and propoxur.

Mean outdoor air concentrations were almost always lower than mean indoor and personal concentrations. Mean personal air and indoor air concentrations were usually similar. Seasonal patterns were somewhat inconsistent. However, the pesticides found at higher concentrations in Jacksonville were highest in summer, followed by spring and then winter. For Springfield/Chicopee, the majority of the pesticides found at higher levels had higher concentrations in the spring than in the winter. For a majority of the pesticides, indoor and personal air concentrations were higher in Jacksonville than in Springfield/Chicopee, as expected. Differences between the sites were less consistent for outdoor air concentrations.

To assess the magnitude of short-term variability relative to measurement error and seasonal variations, absolute differences between pairs of indoor air

Table 1. Response Rates

	Jacksonville				Springfield/Chicopee		
	Summer '86	Spring '87	Winter '88	Total	Spring '87	Winter '88	Total
Second Stage							
Sample Size	401	550	550	1501	1422	1050	2472
Eligible	363	510	499	1372	1361	978	2339
Respondents	267	336	402	1005	956	818	1774
Response rate	74%	66%	81%	73%	70%	84%	76%
Third Stage							
First-time sample:							
Selected	125	79	95	299	92	73	165
Eligible	120	73	90	283	89	72	161
Respondents	65	53	55	173	49	37	86
Response rate	54%	73%	61%	61%	55%	51%	53%
Overall Response Rate[a]	40%	48%	49%	45%	39%	43%	40%
Followup sample:							
Selected	--	29	19	48	--	20	20
Eligible	--	29	19	48	--	20	20
Respondents	--	19	16	35	--	15	15
Response rate	--	66%	84%	73%	--	75%	75%
Total:							
Selected	125	108	114	347	92	93	185
Eligible	120	102	109	331	89	92	181
Respondents	65	72	71	208	49	52	101

[a]Overall response rate = (Second-stage response rate) * (third-stage response rate) for first time members of the sample.

measurements were computed for the five most prevalent pesticides. The mean absolute differences in replicate indoor air concentrations were computed for each study area and season and compared to the mean absolute differences between duplicate indoor air readings (Table 4). The mean absolute differences between seasons in multi season respondent indoor air concentrations were also computed and are presented in Table 4. The magnitude of the differences between estimated measurement error variability (duplicates), estimated short-term variability (replicates), and seasonal variability (multiseason respondents) varied considerably both within and between analytes. Because of the small sample size devoted to this aspect of the study and the magnitude of the variability observed, only qualitative conclusions are supported regarding the relative magnitudes of these components of variation. Measurement error variability is generally less than short-term variability, which itself is usually less than seasonal variability. Moreover, short-term and seasonal variability are generally more comparable than short-term and measurement error variability. The fact that the short-term and seasonal variations were generally comparable in magnitude suggests that the factors contributing to short-term variations may also be major components of seasonal variations.

Conclusions and Recommendations

Water sampling was by design only a small component of NOPES. Routine sampling of public water supplies by Jacksonville and Springfield prior to NOPES had not identified any contamination by the target compounds, and water samples collected and analyzed during the NOPES pilot study also did not contain detectable levels of any analytes. Therefore, a minimal sampling effort was believed to be sufficient for estimating water exposure to the target compounds.

The small sample sizes prevent estimation of weighted population exposure estimates from these data. However, the lack of detectable levels for most analytes and the relatively low levels occasionally detected for others suggest that exposure to the NOPES target compounds from water is minimal in the two study areas.

The dermal exposure component of NOPES was primarily a pilot study of a method for quantifying dermal exposure levels during acute exposure events. Chronic dermal exposure was not addressed. The number of events monitored was small, and events were not randomly selected, so estimated population exposure levels cannot be developed. However, analysis of the glove data does permit assessment of the method, and provides an initial impression of the relative importance of acute dermal exposure.

Dermal dose was estimated for all 16 target compound applications monitored in NOPES. It was computed by multiplying the glove concentration by the appropriate absorption factor and ranged from 0.02 µg to 16,000 µg. Daily air exposure doses were calculated as the mean personal air concentration estimates (ng/m³) from Tables 2 and 3 multiplied by 20 m³ per day of respired air. In only three of the 16 cases was the dermal dose less than the estimated daily air dose. The dermal dose was more than an order of magnitude greater than the daily air dose in more than half the cases.

Qualitative comparisons of the relative exposure contributions of air and food were possible for some of the target compounds. The relative air and food contributions were computed for daily exposures. Mean daily exposure from inhalation was estimated by multiplying the mean personal air concentration estimates (ng/m³) for each season (Tables 2 and 3) by 20 m³ air respired per day. These daily air exposure estimates were then compared to daily dietary exposure estimates. Only qualitative comparisons were supported by the data.

The NOPES air exposure data were evaluated with regard to potential chronic health effects. Both cancer and non-cancer risks were evaluated. No risks of major concern were identified.

Evaluation of NOPES results, in addition to providing important insights about the nature and magnitude of nonoccupational pesticide exposure, suggests a number of possible avenues for further research. Specific recommendations are:

1. Develop guidance for conducting exposure monitoring studies and associated methodologies for assessing human non-dietary exposure to pesticides in residential settings. These follow-up studies will be designed to permit a more comprehensive analysis of the health risks associated with

Table 2. *Weighted Arithmetic Mean Concentrations in Jacksonville Air[a] (ng/m³)*

Analyte	Indoor			Outdoor			Personal		
	Summer	Spring	Winter	Summer	Spring	Winter	Summer	Spring	Winter
Dichlorvos	134.5	86.2	24.5	0	0	3.2	147.6	40.2	21.4
alpha-BHC	1.2	1.2	1.1	0.0	0	0.0	0.9	0.8	0.7
Hexachlorobenzene	1.3	0.4	0.3	0.2	0	0	0.9	0.4	0.4
gamma-BHC	20.2	13.4	6.0	1.3	0.5	0.6	22.1	7.0	8.5
Chlorothalonil	5.3	2.2	6.7	0.2	0.3	0.6	0.5	0.0	2.5
Heptachlor	163.4	154.9	72.2	30.2	10.7	2.8	129.1	133.7	64.2
Ronnel	0.2	0	0	0.1	0	0	0.1	0	0.0
Chlorpyrifos	366.6	205.4	120.3	16.7	3.5	2.5	280.4	182.8	118.2
Aldrin	31.3	6.8	6.9	0.2	0	0.1	19.9	38.5	6.9
Dacthal	0.2	0	0.3	0	0	0	0.6	0	0.2
Heptachlor epoxide	0.5	0.8	0.8	0.7	0.1	0	0.6	0.5	0.1
Oxychlordane	5.2	0	6.5	0	0	0	0	0	0
Captan	1.9	2.2	0.1	0	0	0	0	0.1	0.1
Folpet	0.5	0.7	0.6	0.3	0.4	0	0.4	0.4	0.8
2,4-D ester[b]	1.8	0	2.5	0.0	0	0.8	0.7	0	3.5
Dieldrin	14.7	8.3	7.2	0.7	0.0	0.8	10.1	5.4	4.8
Methoxychlor	0.2	0.3	0.2	0	0	0.1	0.3	0.1	0.6
Dicofol	0	11.0	0	0	0	0	0	0	0
cis-Permethrin	0.5	1.9	1.3	0	0	0	0.1	1.3	0.8
trans-Permethrin	0.4	1.1	0.8	0	0	0	0.1	0.3	0.5
Chlordane	324.0	245.5	220.3	38.4	9.5	27.3	212.0	190.7	194.8
4,4'-DDT	--	1.0	0.5	--	0	0	--	0.5	0.4
4,4'-DDD	--	0	0	--	0	0	--	0	0
4,4'-DDE	--	0.6	0.2	--	0	0	--	0.5	0.8
ortho-Phenylphenol	96.0	70.4	59.0	1.2	0.0	0.1	79.7	55.6	39.7
Propoxur	528.5	222.3	162.5	10.2	0.8	2.5	315.6	141.1	142.8
Bendiocarb	85.7	5.5	3.4	0	0	0	51.4	4.4	3.5
Atrazine	0	0	0	0	0	0	0.3	0	0
Diazinon	420.7	109.2	85.7	12.6	1.1	13.8	321.6	112.7	89.0
Carbaryl	68.1	0.4	0	0.2	0	0	28.3	0.8	0
Malathion	20.8	14.9	20.4	0.3	0	0.2	9.2	10.1	16.8
Resmethrin	0.1	0	0	0	0	0	0.4	0	0

[a] A weighted mean of "0" means no detectable levels were observed. A weighted mean of "0.0" means that the weighted mean was less than 0.05.

[b] Methyl ester in summer, butoxyethyl ester in spring and winter.

exposure to pesticides from different routes.

2. Conduct prospective studies to estimate pesticide concentrations in household dust in order to explore the relationship between pesticide use and exposure, and the relative importance of the dust pathway to total human exposure, especially for infants and toddlers.

3. Refine the dermal exposure sampling and analytical methods required for quantifying dermal exposures and the estimation of acute and chronic pesticide exposures. These studies will attempt to estimate transfer coefficients between surface applications and the dermal and inhalation routes of exposure.

4. Improve the PUF sampling technique to reduce variability in matrix spike recoveries, evaluate analytical methodology for new compounds of interest, and prepare quality assurance standards on PUF media.

5. Conduct similar NOPES studies following revision of the population survey instruments. These revisions would incorporate improvements to the original survey design, develop more appropriate stratification variables, and permit the development of a survey data base with a larger regional or national

Table 3. *Weighted Arithmetic Mean Concentrations in Springfield/Chicopee Air[a] (ng/m³)*

Analyte	Indoor		Outdoor		Personal	
	Spring	Winter	Spring	Winter	Spring	Winter
Dichlorvos	4.3	1.5	0	0	3.7	2.1
alpha-BHC	0.2	0	0	0	0.0	0
Hexachlorobenzene	0	0.1	0	0	0	0.0
gamma-BHC	0.5	9.5	0	0	0.7	5.4
Chlorothalonil	0.1	0.1	0.4	0.8	0.8	0.1
Heptachlor	31.3	3.6	0.3	0.1	34.7	4.6
Ronnel	0.2	0.0	0	0	0.1	0.0
Chlorpyrifos	9.8	5.1	13.9	0.0	7.5	5.9
Aldrin	0	0.3	0	0	0	0.2
Dacthal	1.6	0.3	0.9	0	2.6	0.3
Heptachlor epoxide	0	0	0	0	0	0
Oxychlordane	0	0	0	0	0	0
Captan	0.1	0.0	0	0	0.1	0
Folpet	0.7	0	0.5	0	0.7	0.0
2,4-D butoxyethyl ester	2.1	0	0	0	0	0
Dieldrin	1.0	4.2	0	0	0.8	0.7
Methoxychlor	0	0	0	0	0	0
Dicofol	0	0	0	0	7.0	0
cis-Permethrin	0	0	0	0	0	0
trans-Permethrin	0	0	0	0	0	0
Chlordane	199.3	34.8	3.1	2.0	252.9	35.9
4,4'-DDT	0.0	0.5	0	0.2	0.9	0.7
4,4'-DDD	0	0.0	0	0	0	0
4,4'-DDE	0.9	0.6	0	0	4.9	0.5
ortho-Phenylphenol	44.5	22.8	1.6	0	43.4	27.3
Propoxur	26.7	17.0	0.8	0.1	16.2	11.3
Bendiocarb	0.2	0.4	0	0	0.3	0.2
Atrazine	0	0	0	0	0	0
Diazinon	48.4	2.5	8.2	9.2	10.1	1.4
Carbaryl	0.3	0	0	0	0.1	0
Malathion	5.0	0	0.8	0	0.5	0
Resmethrin	0	0	0	0	0	0

[a] *A weighted mean of "0" means no detectable levels were observed. A weighted mean of "0.0" means that the weighted mean was less than 0.05.*

application. The survey instruments would incorporate more detailed activity pattern information and pesticide use applications. The data would be combined with limited monitoring data and used to validate a proposed human exposure model specifically designed to estimate exposures to several of the NOPES pesticides.

References

Wallace, L. A., 1987, *The Total Exposure Assessment Methodology (TEAM) Study: Summary and Analysis: Volume 1.* EPA/600/6-87/002. U.S. Environmental Protection Agency, Washington, DC 192 pp.

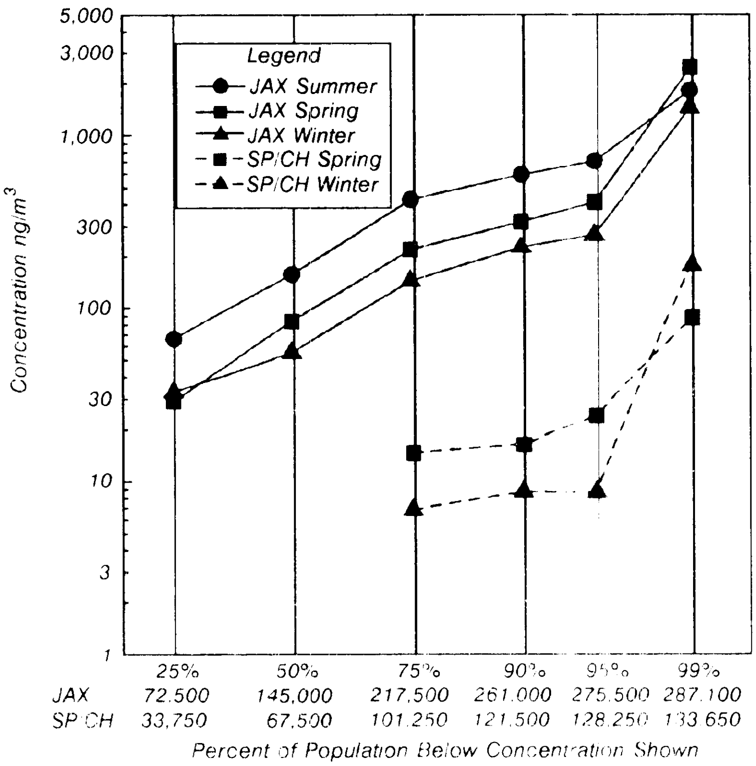

Figure 1. *Chlorpyrifos weighted cumulative frequency distribution for personal air concentrations.*

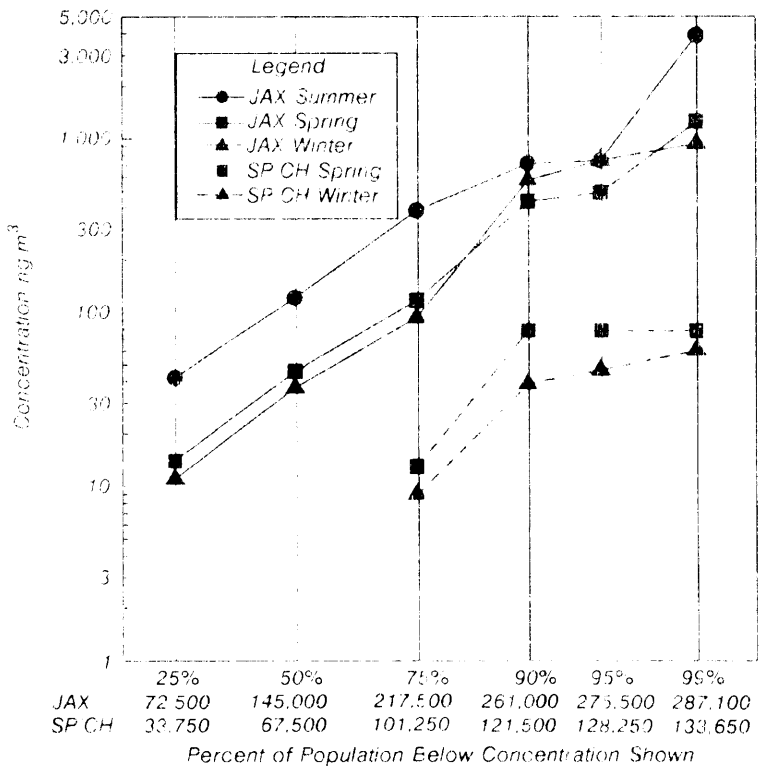

Figure 2. *Propoxur weighted cumulative frequency distribution for personal air concentrations.*

Table 4. *Duplicate, Replicate and Seasonal Indoor Air Concentration Differences (ng/m^3)*

	Duplicates			Replicates			Multiseason Respondents		
	Mean Conc.[a]	Mean Abs. Diff.[b]	No. of Pairs	Mean Conc.[a]	Mean Abs. Diff.[b]	No. of Pairs	Mean Conc. Over Seasons[c]	Mean Abs. Diff. Between Seasons[d]	No. of Pairs
Chlordane									
Jacksonville									
Summer	55	2	6	271	98	8			
Spring	505	40	10	249	55	10	369	343	19
Winter	145	60	9	129	22	9	242	114	16
Springfield									
Spring	51	38	8	64	43	10			
Winter	54	12	7	140	32	10	32	29	15
Chlorpyrifos									
Jacksonville									
Summer	247	38	6	362	169	8			
Spring	268	8	10	162	101	10	259	276	19
Winter	187	17	9	152	198	9	122	114	16
Springfield									
Spring	63	16	8	34	14	10			
Winter	18	1	7	5	2	10	13	11	15
Heptachlor									
Jacksonville									
Summer	13	3	6	157	41	8			
Spring	142	14	10	114	75	10	218	223	19
Winter	43	3	9	64	22	9	124	108	16
Springfield									
Spring	5	4	8	20	11	10			
Winter	7	< 1	7	26	3	10	10	15	15
ortho-Phenylphenol									
Jacksonville									
Summer	81	29	4	91	46	5			
Spring	101	33	10	96	145	10	75	72	17
Winter	51	6	9	82	87	9	80	117	16
Springfield									
Spring	107	39	8	26	22	10			
Winter	54	12	7	46	23	10	34	38	15
Propoxur									
Jacksonville									
Summer	142	28	4	289	138	5			
Spring	378	13	10	168	137	10	529	629	17
Winter	92	10	9	51	30	9	197	184	16
Springfield									
Spring	48	36	8	64	18	10			
Winter	10	4	7	17	12	10	52	77	15

[a] Unweighted mean of all matched pair data.
[b] Unweighted mean of the absolute differences between matched pairs.
[c] Unweighted mean of data for two seasons from multiseason respondents. Values on the rows labelled 'Spring' are means for combined summer and spring data; rows labelled 'Winter' are for combined spring and winter data.
[d] Values on rows labelled 'Spring' are the unweighted mean absolute differences between summer and spring concentrations; values on rows labelled 'Winter' are for mean absolute differences between spring and winter concentrations.

Frederick W. Immerman is with Research Triangle Institute, Research Triangle Park, NC 27709 and John L. Schaum is with the Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, DC 20460.
Andrew E. Bond *is the EPA Project Officer (see below).*
The complete report, entitled "Nonoccupational Pesticide Exposure Study (NOPES)," (Order No. PB 90-152 224/AS; Cost: $31.00, 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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