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INDOOR AIR QUALITY IN 300 HOMES IN KINGSTON/HARRIMAN, TENNESSEE: Winter Phase Status Report

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ORNL/TM-10104

Health and Safety Research Division

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1. SUMMARY

Oak Ridge National Laboratory, in collaboration with the Harvard School of Public Health and sponsored by the Tennessee Valley Authority, the Electric Power Research Institute, and the Consumer Product Safety Commission, is conducting an indoor air quality study of 300 homes in the Kingston/Harriman area of East Tennessee. This city is one of six in the Harvard Air Pollution/Health Study to evaluate air quality and respiratory health. Measurements are made for a two-week period in each house during the winter season and again during the summer season. This report summarizes the status of the study at the end of the winter monitoring period which concluded in the spring of 1986. Homes were selected based on the participation of a school child in the concurrent Harvard Acute Health Study. Eight groups of houses were chosen based on the presence or absence of the following sources: cigarette smoking, woodstoves, and kerosene heaters.

A group of "core" monitoring that will be conducted in all six of the Harvard study cities includes: nitrogen dioxide, respirable particulate matter, water vapor, and air exchange rates. A detailed questionnaire about home characteristics and occupant behavior is also administered. These measurements were conducted in 319 homes in Kingston/Harriman during the winter monitoring.

Supplemental indoor air quality measurements were conducted for radon, formaldehyde, polynuclear aromatic hydrocarbons, and airborne mircoorganisms. Passive radon samplers were placed in the homes for approximately four months during the winter. Formaldehyde samplers were exposed concurrently with the "core" monitoring samplers.

Both vapor phase and particulate phase polynuclear aromatic hydrocarbons were monitored during the winter study. A passive dosimeter was used to obtain a ranking of houses by vapor levels. Particulates were extracted from filters that collected particulate matter over the one-week sampling period and analyzed for polynuclear aromatic hydrocarbons using luminescence techniques.

Viable bacteria and fungi were sampled in a subset of houses using an Anderson impactor. Both indoor and outdoor samples were collected. Samples were cultured on media plates and analyzed for colony-forming units. Classification of organisms was performed to identify the dominant growth.

Additional activities to further characterize the homes for energy use and weatherization were performed. Supplemental tracer experiments were performed to investigate the internal mixing in homes with and without combustion sources and central heating systems. For homeowners who agreed, a detailed energy survey was conducted by utility-trained auditors.

A supplemental investigation of 50 homes with kerosene heaters was conducted. Ten consecutive weeks of monitoring were performed in these homes using passive nitrogen dioxide samplers. Heater usage logs were also maintained. A subset of five houses was monitored in real-time for carbon and nitrogen oxides.

The status of the winter monitoring activities and plans for the summer phase monitoring are presented in the following chapters. A detailed appendix is included which describes the questionnaires, protocols, etc., used in the study.

2. BACKGROUND

An extensive characterization of the indoor air quality in 300 homes in Kingston/Harriman, Tennessee, has grown out of a joint interest by the Harvard School of Public Health (HSPH), the Tennessee Valley Authority (TVA), the Electric Power Research Institute (EPRI), the Consumer Product Safety Commission (CPSC), and Oak Ridge National Laboratory (ORNL) in maximizing the indoor air quality information that could be obtained from the Kingston/Harriman phase of the Harvard Air Pollution/Health Study[1] of air quality in six selected cities in the United States. Additional research has supplemented measurements being performed by the HSPH on air quality and respiratory health. Supplemental investigations included measurement of additional pollutants, characterization of weatherization status, and additional data analyses. Specific additional pollutant monitoring included radon, formaldehyde, polynuclear aromatic hydrocarbons, and airborne microorganisms.

The Air Pollution/Health Study is an epidemiological study that investigates the relationship between air quality and pulmonary function development and respiratory disease in children and adults living in six cities in the United States.[2] The cities are Kingston/Harriman, Tenn.; Portage, Wisconsin; St. Louis, Missouri; Steubenville, Ohio; Topeka, Kansas; and Watertown, Massachusetts. Traditionally, exposure data came from an ambient air monitoring station in each city, and the health data came from spirometry tests and a health questionnaire. At present, the focus of the study is shifting to the indoor environment. The new aspect of the study calls for measuring the air quality in 300 houses in each city, while acute respiratory health data are being collected on the participant child in each study house.

HSPH, under the sponsorship of the National Institute of Environmental Health Sciences (NIEHS), EPRI, and the Environmental Protection Agency (EPA), has been studying the effect of air quality on human health for about a decade. The program focuses on assessing the air quality in six cities in the United States that reflect a range of outdoor air quality. Recent results,

frequently indicating higher pollutant levels indoors than outdoors, have led to an appreciation of the importance of indoor air in determining the total human exposure to many pollutants. Based on this recognition of the importance of indoor exposures to total exposures, HSPH has embarked on a multiyear effort to monitor the indoor air quality of 300 homes in each of the six cities. These air quality measurements are limited to an assessment of nitrogen dioxide levels, respirable particulate levels, and water vapor levels and measurements of the air exchange rate during the air quality measurements. Respiratory symptoms of grade-school children will be obtained for each day and recorded by parents on calendar diaries. These data are collected monthly via mail and telephone by HSPH staff. Selection of homes for participation in the six-cities indoor air quality study is obtained from the new cohort of elementary school children. These children were all born in the late 1970's and were participants in the annual survey of pulmonary functions and chronic respiratory health conducted in the spring of 1984 and 1985.

One of the cities in the study is Kingston/Harriman, Tennessee. Homes in this area were monitored beginning in the fall of 1985. The measurements will cover two consecutive one-week periods in each house--once during the winter and again the next summer. ORNL is supporting the Harvard study by performing indoor air quality measurements in the Kingston/Harriman community. With the support of other sponsors, additional research aimed at supplementing information obtained in the HSPH study was conducted. Within the limitations that additional characterization of indoor air quality, weatherization, and energy usage not compromise the objectives of the Harvard study and not overly burden the participating homeowners, this study offered a valuable opportunity to gain additional indoor air quality information in a most cost-effective way. Much of the overhead expense of identifying and involving the study participants, characterizing their health, and making field visits to their homes was not required for the supplemental measurements. An additional valuable asset of this joint research is provided by the opportunity to investigate correlations between various components of this multifaceted study.

One unique aspect of the Kingston/Harriman phase of the six-cities study is an opportunity to investigate the interrelationships of wood and kerosene heater use, indoor air quality, and respiratory health in 300 homes. The protocol for the six-cities study calls for a design containing sample cells for homes with cigarette smoking, homes with gas stoves, homes with neither, and homes with both. Because there are relatively few homes in the Kingston/Harriman area with gas appliances, HSPH researchers agreed that this was an excellent opportunity to investigate the impact of wood burning and kerosene heater use by substituting these sources of fuel for the gas component in the study design. A substantial fraction of homes in the area use wood or kerosene either as the primary heating fuel or as a secondary source of heating. Wood use has become an important fuel source in many areas of the country. Its impact on electrical energy use and on indoor air quality is of interest to many utilities.

This report summarizes the status of the 300-Home Kingston/Harriman Indoor Air Quality Study at the end of the winter phase of monitoring. Plans for the summer monitoring phase are also presented. The report is organized by the major pollutants monitored. Reporting focuses on study protocols and summaries of winter monitoring activities. A minimum of results are presented since, for many pollutants, laboratory analyses are not yet complete.

3. STUDY DESIGN

As a follow-up to earlier research,[2] investigations of the indoor air quality in about 300 homes in each of the six cities are being conducted. The first of the cities to have measurements conducted in 300 homes was Watertown, Mass.[1] Kingston/Harriman was the second city selected for indoor air quality measurements. The study population was chosen in the spring of 1984 from the student population in the elementary schools in Kingston and Harriman. A letter and health survey were sent to the homes of children in the 2nd, 3rd and 4th grades. Of those that responded, 1,018 were selected as a new cohort for the respiratory health component of the study. In the fall of 1985, 692 letters were sent to the parents of the children indicating that permission would be sought to enter them in the indoor air quality phase of the study. A follow-up phone call was made to request a response. Of the 692 families to which letters were sent, 186 (27%) were unreachable, 129 (18%) declined to be in the study, and 377 (54%) were willing to participate in the study. By mid-November of 1985, 17 (2.5%) families had reconsidered and declined participation in the study, leaving a total of 360 families from which to choose for the air quality monitoring.

The sample was stratified on three different pollutant sources potentially present in the homes; smokers, kerosene heaters, and woodstoves. Table 3.1 identifies the eight groups into which the houses were classified. Table 3.2 shows the number of houses in each category. Table 3.2 also summarizes the number of weekly setup visits, by the eight categories, for the winter phase of the study. The group classifications are based on data provided by the study participants during initial participant selection activities. Our field experience during the winter visits indicates that there may be considerable misclassification. Most of the suspected classification error is related to the use of kerosene heaters.

Table 3.1. Group classification by presence of specific home characteristics

Group	Smoking	Kerosene Heater	Woodstove
1			
2			x
3		x	
4		x	x
5	x		
6	x		x
7	x	x	
8	x	x	x

Table 3.2. Distribution of houses in each group

Group	Targeted # Participants	# of Participants At Start of Study	# of Participants Sampled
1	45	46	40
2	45	72	66
3	45	53	46
4	45	21	20
5	45	41	36
6	45	56	48
7	45	41	36
8	45	30	27
TOTAL	360	360	319

Table 3.3. Summary of weekly initial setups by group code*

Week of	Group Code								
	1	2	3	4	5	6	7	8	Total
11/11/85	3	3	2	1	2	2	3	2	18
11/18/85	2	4	2	2	3	3	1	2	19
11/25/85	1	7	0	1	2	3	5	0	19
12/02/85	2	5	5	0	2	3	3	2	22
12/09/85	2	3	7	0	4	3	3	2	24
12/30/85	2	4	1	2	2	2	2	2	17
01/06/86	1	4	2	1	2	4	2	2	18
01/13/86**	3	4	3	4	3	3	4	4	28
01/20/86	4	4	2	1	1	3	3	2	20
01/27/86	3	3	2	0	2	6	4	2	21
02/03/86	1	2	5	2	2	4	2	2	20
02/10/86	4	6	1	1	4	4	1	3	24
02/17/86	3	4	3	1	3	4	1	1	20
02/24/86	2	6	5	2	3	3	1	1	23
03/03/86	5	5	4	2	0	1	0	0	17
03/10/86	2	3	2	0	1	0	1	0	9
TOTAL	40	66	46	20	36	48	36	27	319

*Excluding fall pilot study

**Winter visit to pilot group

The questionnaires administered during the initial visit to the home will be used to check for appropriate classification. Several owners of kerosene heaters have them for emergency use only; others have stopped using them but have not yet disposed of them.

The bulk of the sampling consists of monitoring the air in the houses for two consecutive weeks each in both the winter and the summer. A total of 319 houses were sampled during the winter phase. A group of approximately 30 houses of the 319 were sampled during a common two-week period in the fall and winter, and will be again sampled during the spring and summer. This group of houses, referred to as the pilot group, is an attempt to document seasonal changes in indoor air quality. The initial setup weeks for the pilot sampling are: fall - 10/14/85, winter - 1/13/86, spring - 4/14/86, and summer - 7/14/86.

Over the two-week sampling period, three visits are made to each house. The first is to set up the samplers, the second to exchange them, and third to remove the second week's samplers. Information sheets that explained the study objectives and other useful information were provided to the homeowners (see APPENDIX A). Questionnaires to characterize the housing parameters and occupant behavior were administered during the setup visit. These questionnaires are presented in APPENDIX B. Results of the Harvard questionnaire (APPENDIX B.1) will be included in the data base on all six cities, while the results of the supplementary questionnaire (APPENDIX B.2) will be maintained by ORNL. A floor plan was also drawn during the setup visit to determine spatial distribution of samplers.

Details of specific core sampling activities are described in a separate chapter. Sampling for formaldehyde and polynuclear aromatic hydrocarbons was performed during the first week of the two-week sampling period. Passive radon samplers were placed in most of the study houses during the first month of sampling and exchanged during March and April. Short-term sampling (two minutes) for airborne bacteria and fungi was performed in many of the houses during one of the three house visits. Details of this additional sampling are presented under respective chapters. During the second half of winter, a supplemental study to investigate in greater detail pollutant levels in homes with kerosene heaters was conducted in about 50 homes. A summary of this study is presented in the Kerosene Heater Study chapter. Study efforts related to energy use and weatherization are also presented. The protocols used for the winter monitoring phase are presented in APPENDIX C.

In an effort to keep study participants informed and interested in the study, we began devoting a portion of our quarterly INDOOR AIR STUDY Notes, a short newsletter sent to participants of ORNL field studies, to the Kingston/Harriman homeowners in the Indoor Air Quality/Health Study. Copies are included in APPENDIX D.

4. HSPH CORE ACTIVITIES

A specific set of indoor air quality measurements will be conducted in all six cities of the Harvard study. The core parameters that are being obtained in all six cities in the study are: nitrogen dioxide, particulate matter less than 2.5 μm in diameter (PM2.5), ventilation rate, water vapor, and house characteristics. Nitrogen dioxide and PM2.5 are also measured at the schools that the children attend, and PM2.5 is measured at selected outdoor locations.

Monitoring of the respiratory health of grade school children from 300 homes forms the basis of the Acute Health Study which complements the Indoor Air Quality Study in the Kingston/Harriman communities. Monitoring consists of a daily calendar of respiratory symptoms maintained by the child's parent plus a health questionnaire and respiratory testing. This research component is being performed entirely by HSPH; ORNL is not involved in this aspect of the study.

A brief summary of the winter phase "core" monitoring efforts follows. Details of the protocols used are provided in APPENDIX C.1. A copy of the questionnaire is presented in APPENDIX B.1. A sampling rack (see Fig. 4.1) is placed in each of three rooms in the study houses; the activity room (defined as the room where the child spends most of his non-sleeping time--usually a den, family room, or living room), the child's bedroom, and the kitchen.

Nitrogen dioxide levels are measured using passive Palmes-tube type samplers[3] exposed for one-week periods. Figure 4.2 is a photograph of the NO_2 samplers used in the study. Samplers are placed in three locations throughout each house, and one sampler is located outdoors. At the end of the sampling period, tubes are sealed and returned to HSPH for laboratory analysis. Field placements include 5% replicate samplers and 5% field blanks. See HSPH laboratory protocols for laboratory analysis protocols. A total of 2800 samplers were placed and returned to the laboratory for analysis during the winter study phase.

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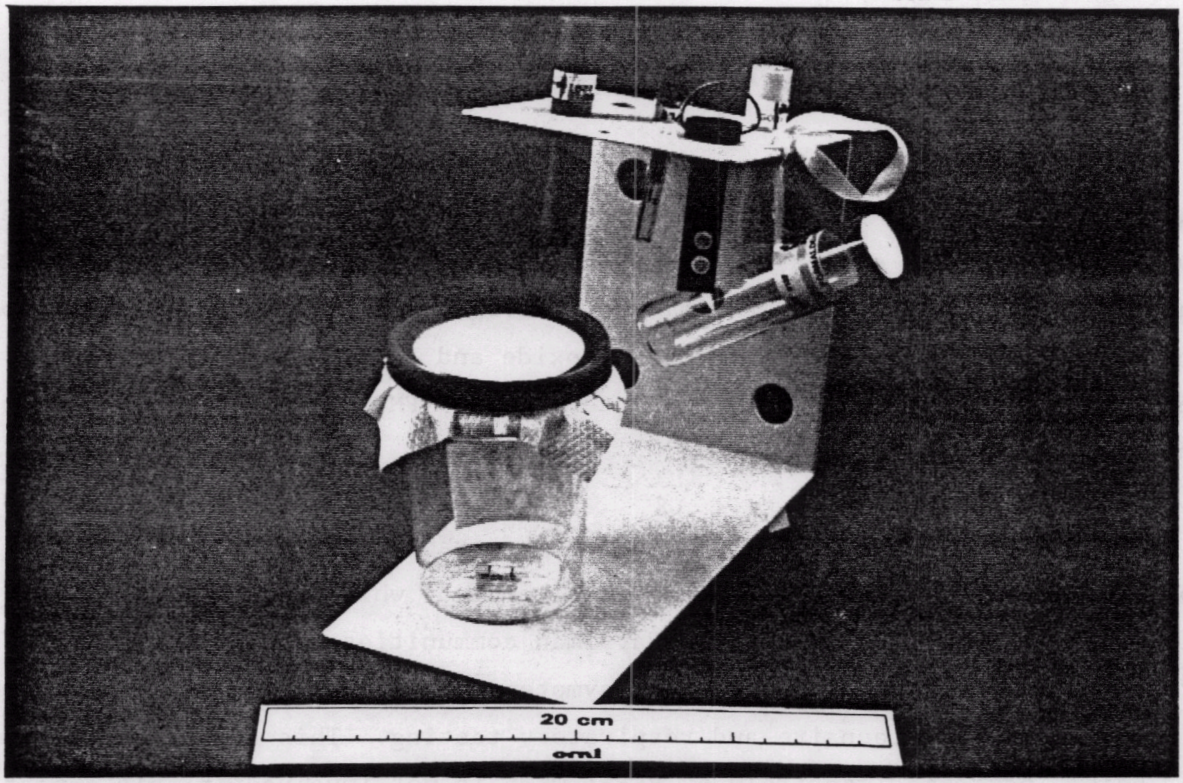

Fig. 4.1. Photograph of the sampling rack containing passive monitors that was placed in the activity room, child's bedroom, and kitchen.

ORNL PHOTO-1079-86

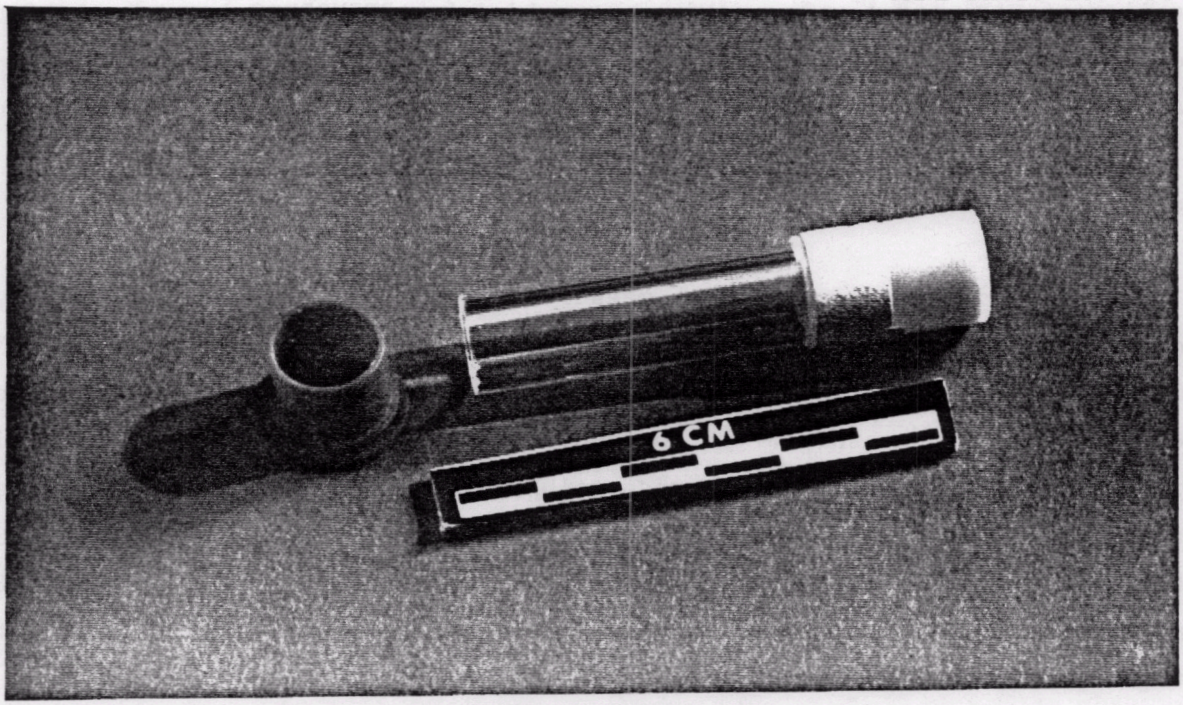

Fig. 4.2. Photograph of NO_2 sampler used in the study.

Water vapor samples are collected using passive diffusion tubes with molecular sieve sorbent to trap the water vapor.[4] Figure 4.3 is a photograph of the water vapor samplers used in the study. Weight gain of the molecular sieve is proportional to the integrated water vapor concentration. These sample tubes are exposed concurrent with the indoor NO_2 samplers and returned to HSPH as a package. Field placements include 5% replicate samplers and 5% field blanks. See HSPH laboratory protocols for laboratory analysis protocols. A total of 700 samplers were placed and returned to the laboratory for analysis during the winter study phase.

ORNL PHOTO-1078-86

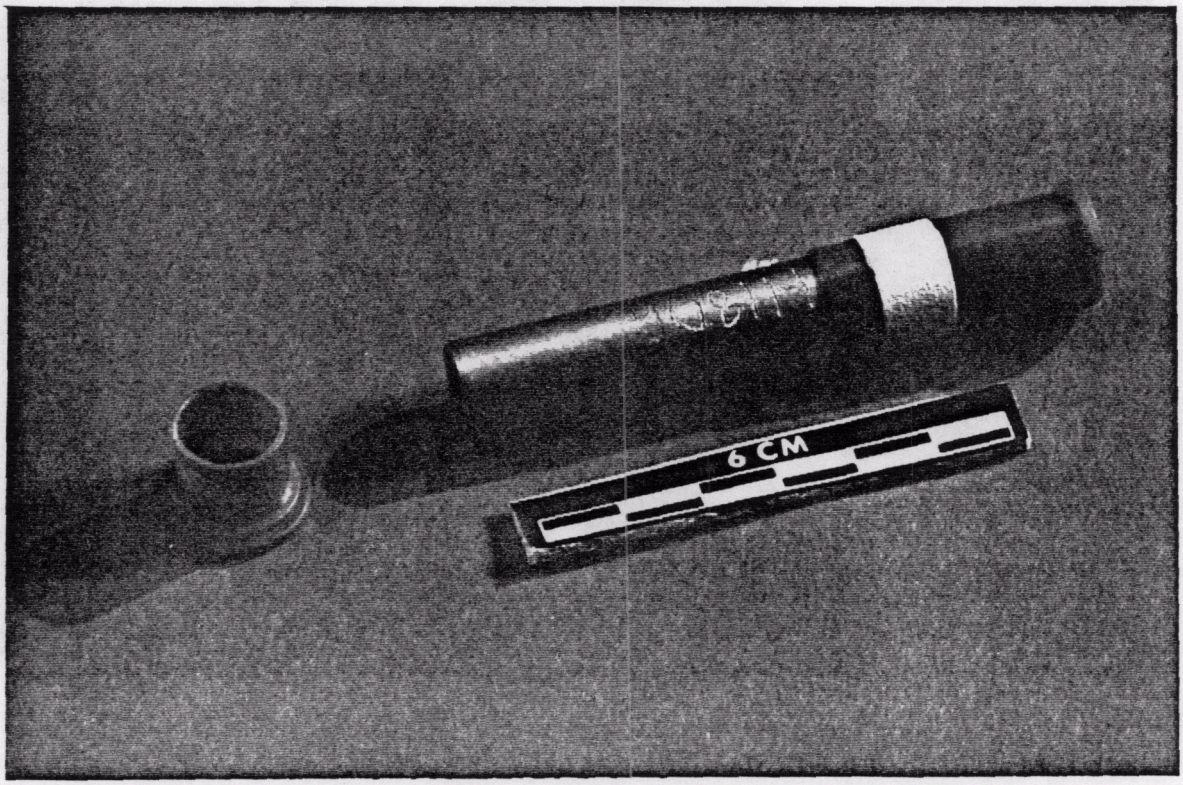

Fig. 4.3. Photograph of the water vapor monitors used in the study.

Particle samples are obtained using a quiet, compact, constant-flow pumping system developed by HSPH.[5] This unit has a 2.5-μm cut size and samples respirable size particles (PM2.5). Figure 4.4 shows one of the sampling units used in the study. One pumping unit supports two impactors. One sample was returned to HSPH for gravimetric and elemental analyses, and the other was used for organic analyses as described in the chapter on

polynuclear aromatic hydrocarbons. Each sampler collected particulate matter for approximately one week; operation was concurrent with the passive monitors. Air flow (4 L/min) was automatically switched between the two impactors every 15 min. An elapsed (sampling) time reading was obtained for each impactor. A total of 640 samplers were placed and returned to the laboratory for analysis during the winter study phase.

ORNL PHOTO-1083-86

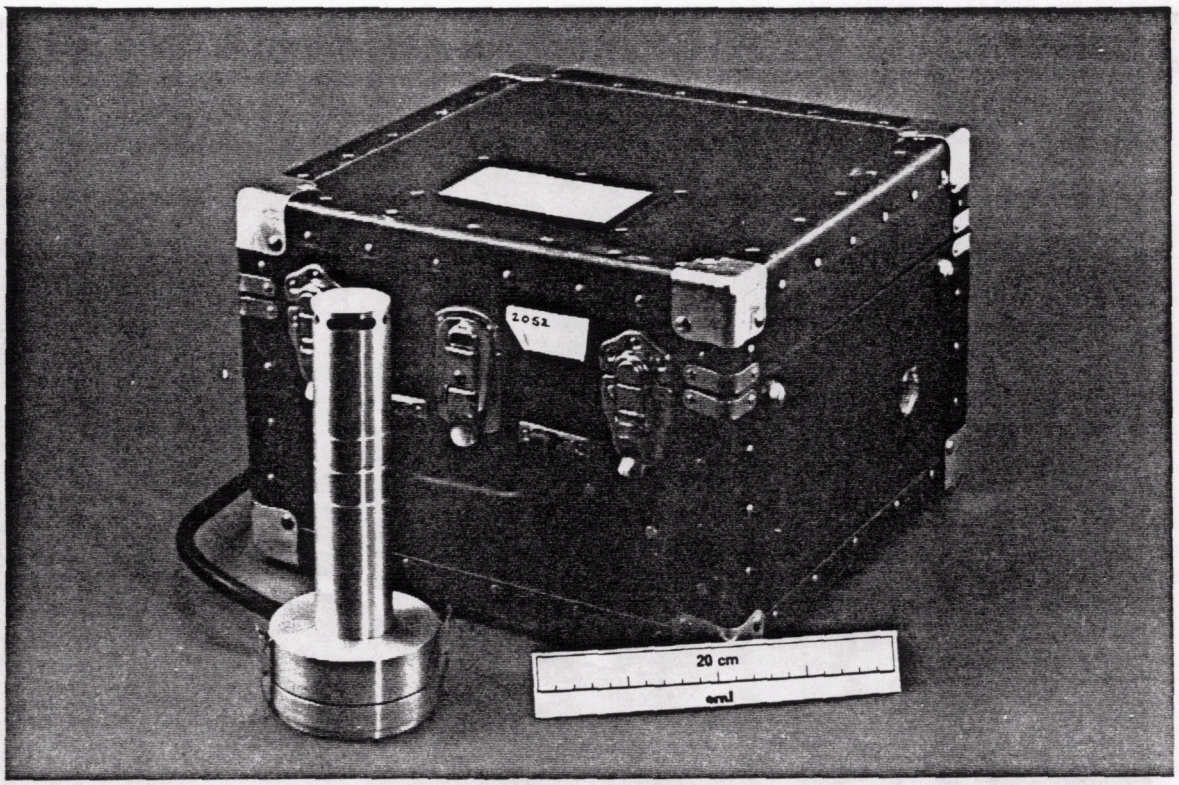

Fig. 4.4. Photograph of the particulate sampling unit used in the study.

Average air exchange rate measurements were obtained for each one-week period that pollutant monitors were exposed. The technique used is similar to that of Dietz et al. at Brookhaven National Laboratory.[6] Perfluorocarbon tracer (PFT) placement protocol was modified from APPENDIX C.1 to allow a study of pollutant mixing related to combustion sources as described in APPENDIX C.2. Passive collection tubes (CATS), co-located with the other passive samplers, were used to sample the amount of tracer in the air. Figure 4.5 is a photograph of the PFT sources and a CATS tube used in the study. Samplers were returned with the package to HSPH for desorption and analysis.

Field placements include 5% replicate samplers and 5% field blanks. See HSPH laboratory protocols for laboratory analysis protocols. A total of 2800 samplers were placed and returned to the laboratory for analysis during the winter study phase.

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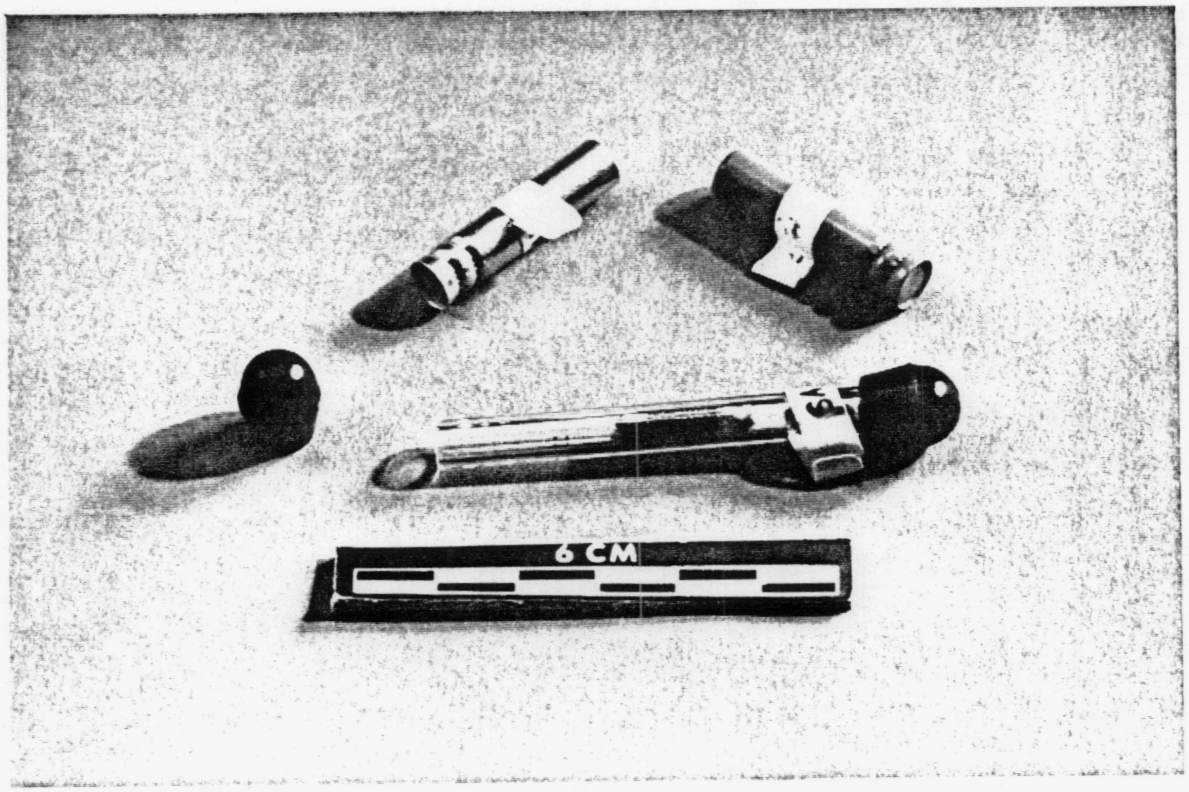

Fig. 4.5. Photograph of the PFT sources and CATS tube used in the study.

5. RADON

Radon is one of the indoor pollutants that have created the greatest concern over long-term health effects. Measurements of radon levels in 40 Oak Ridge area houses revealed elevated levels in approximately one-third of the homes.[7] One important finding of that study was the strong correlation between elevated levels and location of the homes. Elevated radon levels were much more likely to occur in homes located on the ridge surrounding Oak Ridge than in homes located in lower-lying areas. Some of the same geological structures are found in the Kingston/Harriman area. Locations of houses and radon monitoring results will be compared with a map of soil types and geological formations.

Measurements of radon levels were made in 250 houses during the winter phase of the study using passive track etch monitors from Terradex Corporation (Walnut Creek, Calif.) similar to those described by Alter and Fleischer.[8] Figure 5.1 is a photograph of the device used in the study. Good precision and correlation with a real-time radon monitor were obtained in a detailed assessment of these devices in an earlier work in a nearby community.[7] The vendor routinely calibrates the monitors in independently operated radon chambers as described in APPENDIX C.3.

The monitoring device was typically placed on top of the refrigerator (chosen as a common reference point in homes) for a period of three to five months. A total of 304 samplers (including replicates and basement samplers) were retrieved from homes during a spring exchange visit where new samplers were placed out for the summer phase. In 32 homes, a second monitor was placed in a basement. A few samplers were exposed as replicates or field blanks. A detailed evaluation of upstairs/downstairs ratios and sampler precision is provided by a concurrent study of radon in 70 homes throughout the Tennessee Valley.[9] Monitors were also placed in seven schools. Most samplers were placed during October or November and retrieved during March or April. Homes with setup visits for the one-week passive chemical monitors in October or November (about 100) had passive radon monitors concurrently placed. Special visits were made to the remaining homes to place the radon

samplers. A similar process was adopted during the spring exchange. Homes with final pick-up visits during March or April had a concurrent exchange of radon samplers. Special visits were made during April to the balance of the homes to exchange radon samplers.

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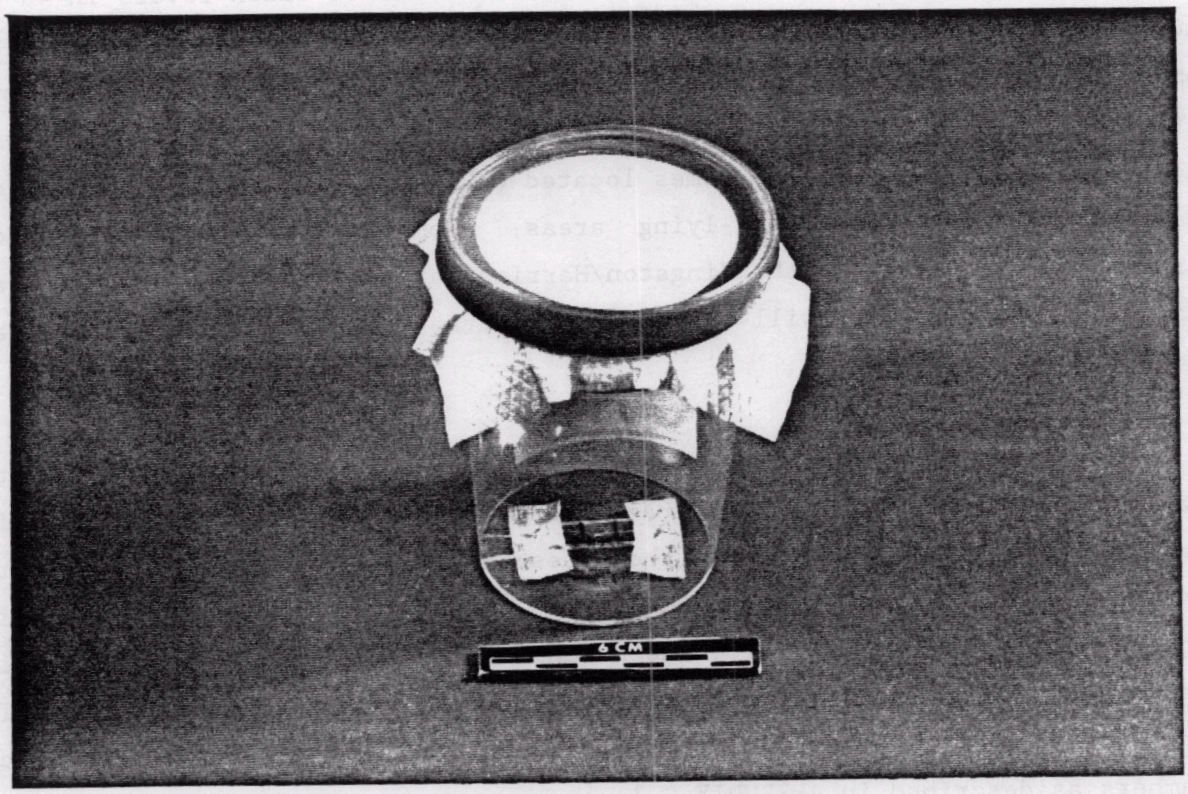

Fig. 5.1. Photograph of passive radon monitor used in the study.

6. FORMALDEHYDE

Formaldehyde measurements were made with passive integrating monitors similar to those developed by Lawrence Berkeley Laboratories and described by Geisling et al. (1982).[10] Figure 6.1 is a photograph of the formaldehyde samplers used in the study. The monitors used for the study are available commercially from Air Quality Research (Berkeley, Calif.). Samplers were returned to the vendor for formaldehyde analysis. Accuracy of the monitors is tested by the vendors as described in APPENDIX C.3.

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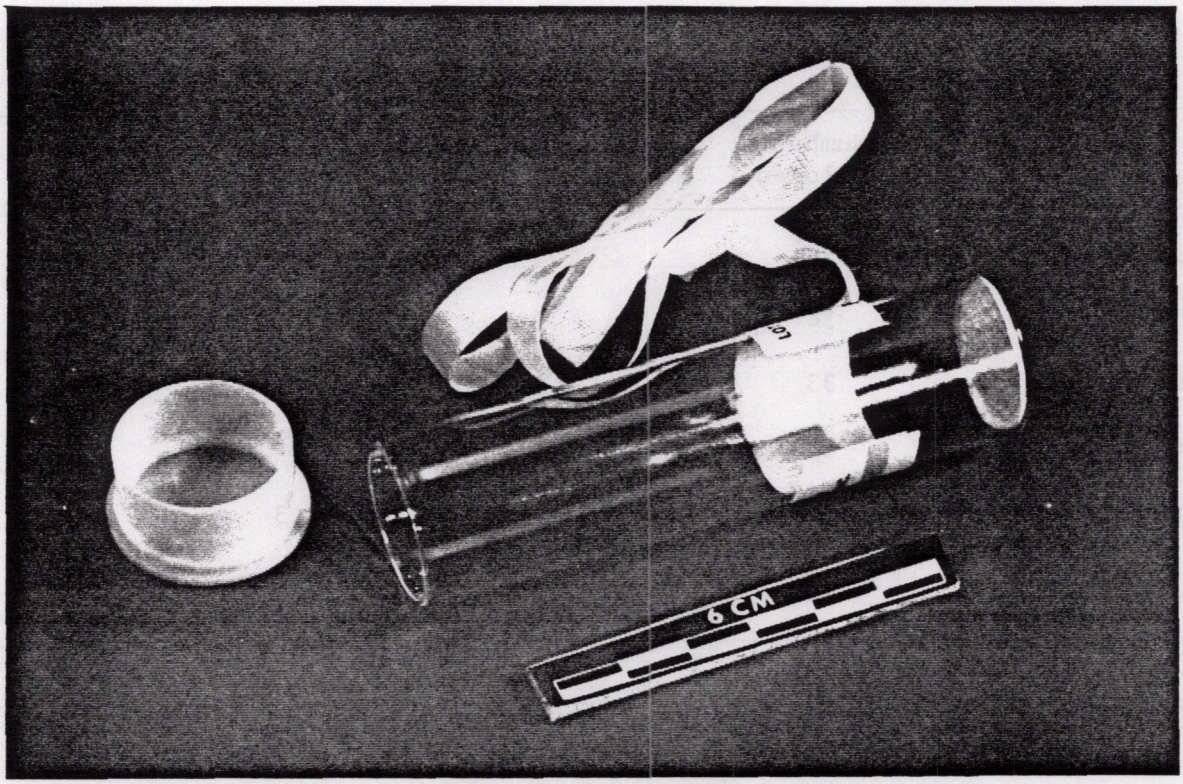

Fig. 6.1. Photograph of passive formaldehyde samplers used in the study.

The measurement period coincided with the first week of monitoring for NO_2 levels, water vapor, and PFT, and the formaldehyde monitors were co-located with these passive monitors. The monitors were generally deployed for one week in the activity room of the house. In addition to the activity room samplers, approximately 10% of the monitors were placed in the kitchen, 10%

were placed in the bedroom, 5% were placed as replicates, and 5% were returned to the vendor without exposure. Formaldehyde samplers were also placed in the seven schools. Approximately 10% of the homes had formaldehyde samplers during the second week of winter monitoring.

Table 6.1 summarizes placement of the monitors during the winter and also presents a summary of the formaldehyde levels obtained from the samplers analyzed. Data from replicate exposures are presented in Fig. 6.2. Analysis of variance in the results from replicate exposures suggests that the precision (defined as one standard deviation) was 3 ppb in a sample with a mean equal to 47 ppb (i.e., 7% CV).

Table 6.1. Placement of formaldehyde samplers

Location	Number Deployed	Number Analyzed	Mean ppb	Maximum ppb
Activity Rm	359*	247	42	114
Kitchen	34	23	45	88
Bedroom	33	23	45	74
Replicate	18	13	--	--
Unexposed	14	5	3	6
Total	458	311	--	--

*Includes approximately 10% sampling during second week of monitoring.

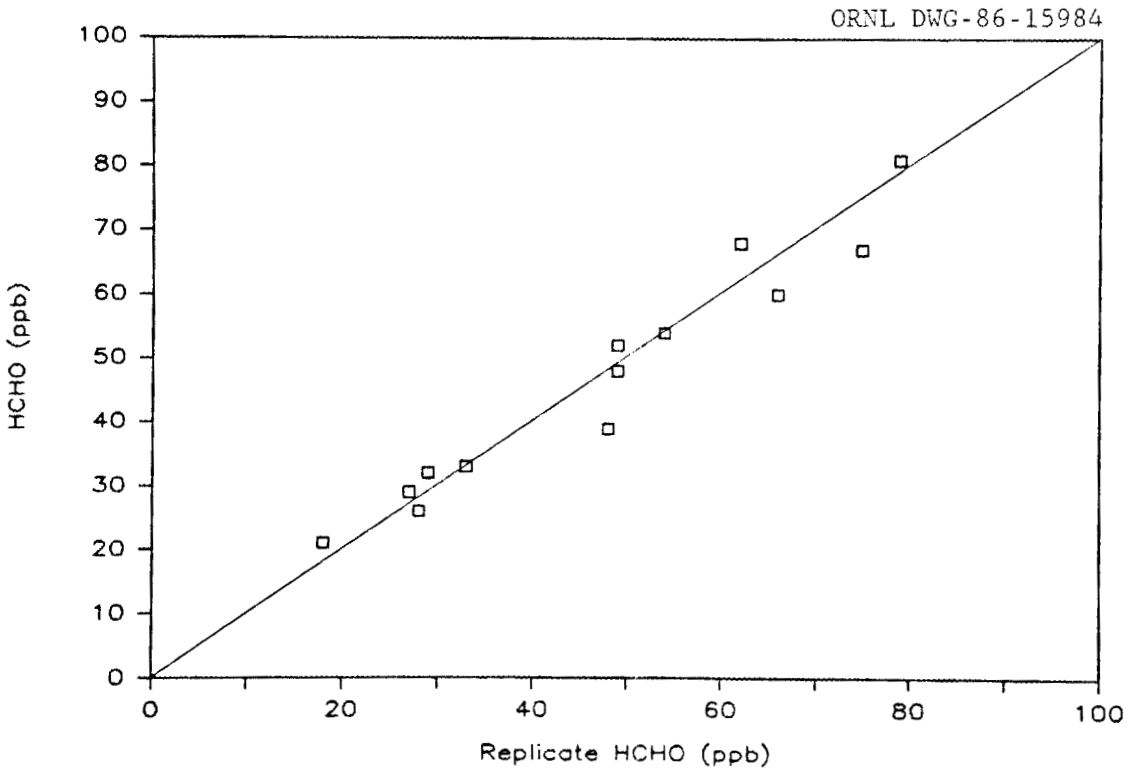

Fig. 6.2. Correlation of replicate field sampler results for formaldehyde (slope = 0.93, R^2 = 0.97). The mean absolute difference between replicates is 3.5 ppb, which represents 7% of the mean concentration.

7. POLYNUCLEAR AROMATIC HYDROCARBONS

One important class of potential indoor pollutants associated with the operation of woodburning stoves is polynuclear aromatic hydrocarbons (PNAs). Another indoor source of PNAs is cigarette smoking. A significant component of the supplemental indoor air quality measurements being conducted in the Kingston/Harriman study is a measurement of PNA material in air--both vapor phase and particulate phase--in the study homes. Particulate phase PNAs were sampled using the PM2.5 particle impactor developed by HSPH.[5] Filters were extracted and analyzed by synchronous luminescence (SL).[11] A subset of homes were monitored with a sorbent backup to the impactor to evaluate the extent of vapor phase loss from the filter. A subset of filter extracts are analyzed for specific PNAs using high pressure liquid chromatography (HPLC). A passive PNA dosimeter developed by ORNL[12] was used to rank the PNA vapor levels in homes. Dosimeters were analyzed using room temperature phosphorimetry.[13] Figure 7.1 is a photograph of the passive PNA dosimeters used in the study.

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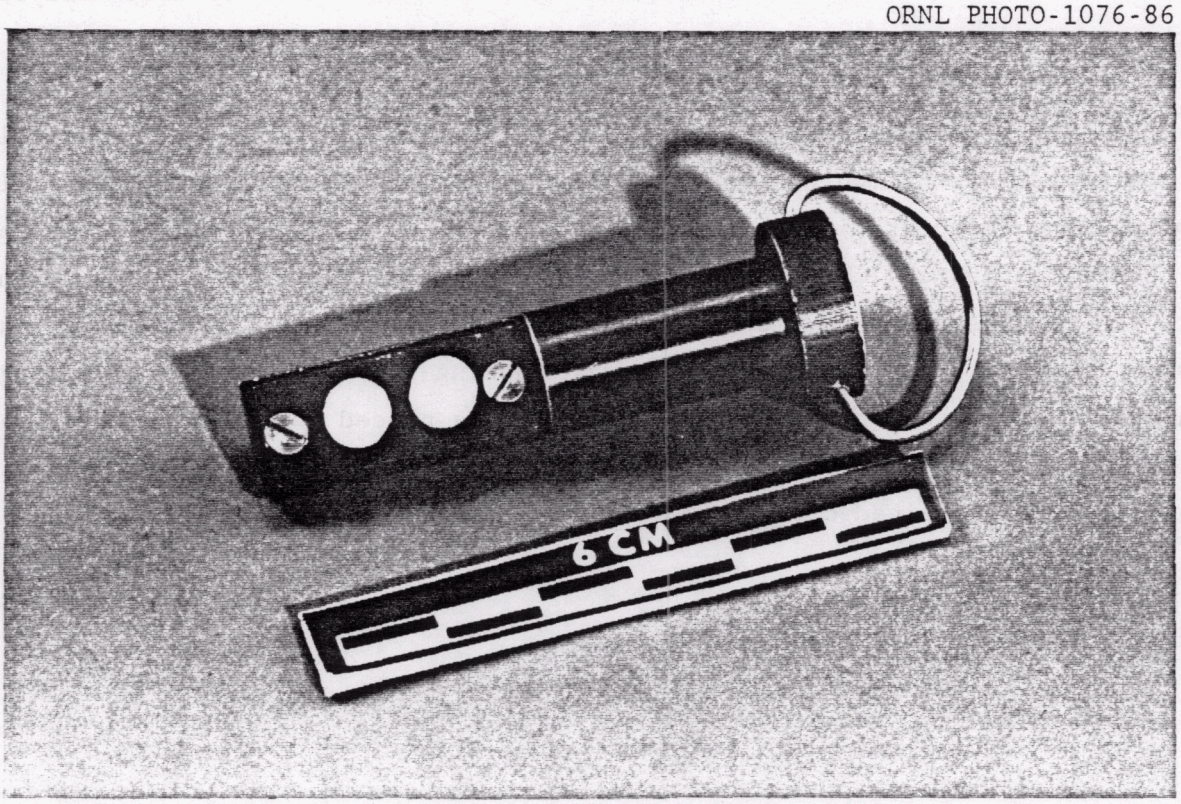

Fig. 7.1. Photograph of the passive PNA dosimeter used in the study.

SL and RTP are sensitive and selective methods for screening type analyses of airborne particulate PNA compounds and volatile PNAs. The data from these measurements are used to rank the overall level of PNAs in many environments including indoor air which is contaminated with smoke from woodburning stoves, kerosene heaters, or cigarette smoke. In a pilot study of 10 homes, the efficacy of using the ORNL dosimeter and SL technology to screen for PNA levels was tested.[14] Ranking indices from that study were compared to gas chromatographic (GC) analyses of the same samples and showed high positive correlations. The present study compares SL and RTP data to HPLC measurements obtained by analysis of volatile and particulate PNA collected from 300 homes in the Kingston/Harriman area of Tennessee. The use of HPLC for the analytical comparisons rather than GC was dictated largely by the 10- to 100-fold greater sensitivity of the combined HPLC-fluorescence detection apparatus when compared to GC sensitivity. This permits a more accurate measurement of the total priority pollutants present in the houses which contain relatively low levels of PNA in the indoor air. The improved accuracy of PNA measurement should provide a more rigorous comparison of the levels of PNA measured by SL and RTP with the levels of the 16 priority pollutants found by HPLC analysis of the particulate extract.

Sampling protocols are included in APPENDIX C.2. The PNA impactor sample was obtained by switching the 4 L/min pump between two impactors every 15 minutes. One impactor filter was returned to HSPH for analyses (see chapter on "CORE" activites) and the other Teflon-PTFE filter was weighed and extracted for PNA analysis. One passive PNA dosimeter was placed in the passive sample rack in the activity room during the first week of sampling. In a subset of houses, a second PNA dosimeter was placed in the activity room during the second week of sampling. Table 7.1 summarizes the number of PNA-related samples obtained during the winter sampling period.

Table 7.1. Summary of PNA sampling during winter monitoring period

	Activity room	Replicates	Blanks
Particulate filters	298	-	-
XAD-4 backup samples	23	-	-
PNA dosimeters	329*	54	34

*Includes second week samples from about 5% of houses.

The protocol for preparation, distribution, storage, analysis, and documentation of the ORNL dosimeters is included in APPENDIX C.3. The key elements of the protocol are summarized here. They include solvent cleaning of the dosimeters by ultrasonic agitation combined with sequential treatment using distilled H_2O, ethanol, and toluene. The assembled dosimeters, containing the filter paper substrate for absorption of volatile PNAs, were labeled with a 4-digit identification code. For quality control, dosimeters were tested for RTP response (i.e., possible contamination) one day after preparation and storage. Those dosimeters that showed no contamination were available for field use.

RTP measurements of adsorbed volatile PNA were made using a Perkin-Elmer MPF43A Fluorescence spectrophotometer. After field exposure, each substrate was excited with 300 nm and 343 nm light obtained from a Xenon lamp source, and the phosphorescence spectrum was measured between 400 nm and 660 nm. Thus, each dosimeter yields two sets of RTP data, one for excitation at 300 nm and one for excitation at 343 nm.

The particulate PNA protocol involved disassembling the impactors in the field office, placing the Teflon membrane filter and its holder in 2" x 2" slide trays for shipment to ORNL. The overall process required up to a week in transit. On arrival, the filters were removed from their holders and weighed using clean handling procedures. Weights were measured using a Metler AE 163 balance with internal calibration. The accuracy of weights was maintained by using National Bureau of Standards (NBS) reference weights

checked by trained instrument personnel from the ORNL Instrumentation and Control Division. Readability was accurate to the nearest 0.01 mg, and reproducibility was determined by repeated measurements to within 0.02 mg of the average value. After the weighing procedure the filters were transferred to 20-mL scintillation vials, sealed, and stored (+5°C in the dark) until extracted.

Methylenechloride was used as the extraction solvent. (This solvent was chosen because it was more efficient than benzene or cyclohexane and had lower acute toxic effects than acetonitrile.) The extracts containing small amounts of particulate matter were removed by filtration through 0.45-μm pore Nylon membranes.

In order to provide for an archival sample, an HPLC sample, and a sample for SL measurements, the filtered extracts were divided into three 5-mL aliquots. Coronene was added, as an internal standard to the 5-mL aliquot used for HPLC, and all samples were sealed and stored at -15°C until analyzed.

The HPLC analyses were performed on a modified Beckman Model 334 unit using an ODS reverse phase column and fluorescence detector. Results show that adaquate selectivity and sensitivity exist for both the 2- and 3-ring PNA and the larger ring PNA. Analyses of the winter samples are currently underway.

8. AIRBORNE MICROORGANISMS

High concentrations of airborne bacteria and fungi may result in a spectrum of symptoms including eye, nose, and throat irritation, headache, fatigue, sinus congestion, and upper respiratory irritation. Little information is available on indoor levels of these microorganisms in homes without occupant complaints.

An important component of the supplemental indoor air quality activities is an investigation of potentially pathogenic microbes in home environments. The primary objective of the winter phase studies was development of protocols and subsequent sampling to define the major bacterial and fungal components of household air. In addition to determining the total number of bacteria and fungi per unit volume of air, the resultant microbial populations were also qualitatively analyzed to determine the number and types of various genera comprising the total population.

Secondary objectives of the winter phase study were to determine, in a subset of homes, the content of airborne thermophilic actinomycetes and the Legionella content in both hot water systems and air. Because of the implication of free-living amoebae in humidifier fever, a few drip pans from refrigerator/freezers were also to be analyzed for the presence of such amoebae.

Determination of microbial content in household air was effected by using Anderson samplers. As recently described and recommended by Dr. Phillip Morey,[15] only the sixth stage of the sampler was used. Two-minute air samples were taken at a rate of 30 L/min. Trypticase soy (TSA) and malt extract (ME) agar plates were used for detection of bacterial and fungal genera, respectively. Malt extract agar plates were also used for detection of thermophilic actinomycetes. Figure 8.1 is a photograph of the sampling system used in the study.

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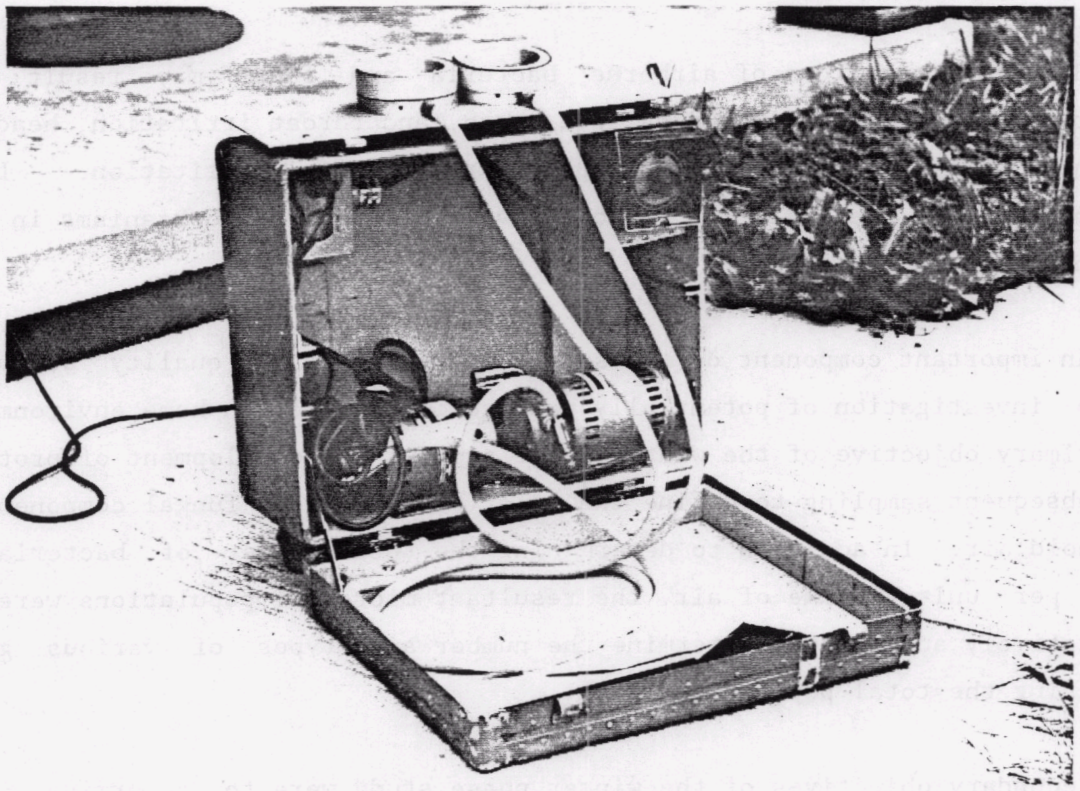

Fig. 8.1. Photograph of the sampling unit used to collect airborne microorganisms.

A set of TSA and ME plates were taken in the activity room and at an outside location at the study homes. During the winter phase of the study, 112 homes were sampled for bacteria and fungi. Additional TSA and ME plates were taken at a subset of homes to test the degree of replication and for content of thermophilic actinomycetes. The TSA and ME plates used for bacterial and fungal analysis were incubated for three days at 35°C and the ME plates used for thermophilic actinomycete detection were incubated for seven days at 55°C. The resultant colonies were counted using a colony counter and the genera determined by colony characteristics. Random bacterial colonies were also analyzed microscopically and, in the case of potential pathogens, enzymatically, to verify colony identification. Similarly, identification of random fungal colonies were confirmed by microscopic analysis of wet mount preparations.

For Legionella testing, hot water was collected from shower heads and, in a few cases, Litton-type high volume air samplers (HVAS) were used to collect air proximal to the showers during and immediately after discharging the hot water. The HVAS was operated for 30 minutes at a rate of 800 L/min. The shower water and air samples were quantitatively analyzed for Legionella by the direct fluorescent antibody (DFA) technique using fluorescein-labeled antisera specific for Legionella. To inhibit non-Legionella bacteria and thus enhance the culture of Legionella, samples positive for Legionella by the DFA test were plated on charcoal yeast agar with or without antibiotic, heat, or acid treatment.

A few samples of drip pan water from refrigerators/freezers, in which air blows over the drip pan water, were analyzed for free-living amoebae. Particulate matter from the drip pans was placed on non-nutrient agar plates seeded with a lawn of Eschericha coli. The plates were incubated at 35°C and examined microscopically for evidence of amoebic out-growths. Amoebae were classified by trophozoite and cyst morphology. Amoebae identified as Naegleria were placed in distilled water and observed microscopically for evidence of flagellation as a confirmation of their classification.

APPENDICES C.2 and C.3 contain a fuller description of the protocols used during the winter phase of the study.

Colony forming units (CFU) are identified by counting the number of colonies that are formed beneath the holes of the Anderson sampler. Results were adjusted to account for samplng holes with multiple CFUs according to Poisson statistics. During the winter sampling period, the total counts of microbes in household air were generally higher than those found in outside air. The following summary statistics are for a subset of data and do not include all houses sampled. The mean indoor fungal CFU/m^3 is 297 (n=85 plates) with a range of 0-4140, while the mean indoor bacterial CFU/m^3 is 980 (n=223 plates) with a range of 0-4200. The outdoor fungal CFU/m^3 is 55 (n=82 plates) with a range of 0-520, while the mean outdoor bacterial CFU/m^3 is 400 (n=106 plates) with a range of 0-4700. Approximately 4% of the indoor fungal samples were greater than 2000 CFU/m^3 and 14% of the indoor bacterial samples were greater than 2000 CFU/m^3.

The predominating bacterial genera found in home and outside air are Bacillus and Micrococcus. Staphylococcus were found in a few indoor air samples, but, as expected, have not been detected in outdoor air. The predominating fungal genera found in both indoor and outdoor air are Asperigillus, Penicillium, and Mucor. A greater diversity of fungal species is seen in household compared to outside air. Acetinomycetes were not detected in either indoor or outdoor samples. To date, the data suggest the home environment provides niches that will support a greater spectrum of microbial populations compared with the outside environment during the winter season.

Legionella were detected in some water samples and a few air samples by DFA analysis. However, while attempted, Legionella were not isolated from these samples on CYE. Two refrigerator drip pans were tested for free-living amoebae. Both were positive for Acanthamoebae.

9. ENERGY USE/WEATHERIZATION

One of the study objectives is to investigate relationships between various energy use related parameters and indoor pollutant levels. Several of the questions included in the HSPH questionnaire and the supplemental ORNL questionnaire (APPENDIX B.2) are directed toward this objective.

Occupants of about half of the houses included in the study have agreed to allow an energy audit by trained electric utility personnel. Representatives of the local utilities will visit these houses and evaluate the degree of weatherization and suitability of energy conservation measures. Also, they will examine the heating and cooling system.

Study participants were unexpectedly reluctant to participate in this aspect of the study. During the regular visit to each house, the field technician explained the purpose and nature of the energy audit and left a brochure and participation approval signature card. About 130 volunteers resulted from these efforts. Prior to the spring radon exchange visit, letters were sent to all study participants who had not yet volunteered for an audit. The letter explained that the energy surveys were free and that the homeowner was under no obligation to follow up with recommended conservation measures. During the subsequent spring radon exchange visit, the field technician answered any questions the homeowners had about the survey and emphasized that the information would be helpful in analyzing the indoor air quality data. About 40 additional volunteers resulted from this subsequent effort.

After obtaining written permission for an energy survey, these homeowners' names and telephone numbers were supplied to Dr. Jerome Harper with TVA who coordinated the energy survey visits. These visits are currently underway.

There were three frequently given reasons for refusal to participate:

1. The house is rented,
2. The audit has already been done, or
3. The homeowner does not wish to be bothered.

In response to reluctant responses, we informed the study participant that one of the purposes of our study was to examine possible correlations of indoor air quality with weatherization measures and that professionally administered energy audits of study houses would facilitate our efforts. In some cases, this was sufficient to overcome occupant reluctance. In cases where it was clearly the homeowner's desire not to be bothered, and not just a case of being unclear about our objectives, we respected their wishes not to participate.

Another component of this effort was to investigate the impact of wood and kerosene heaters on the internal mixing in a subset of homes with and without heaters and in homes with and without central (forced air) heating systems. These data will be especially important for modeling efforts that attempt to describe the behavior of pollutants generated in the houses and the resulting concentrations.

To investigate the differences in internal mixing, we placed a second type of perfluorocarbon tracer in the room with the heater or in the kitchen if the house had no combustion heater. Sources of a second tracer type were placed in all houses. In a subset of houses, both tracer concentrations will be determined when the CATS (passive samplers) are analyzed by HSPH. With these data and the floor plans, an estimate of the mixing between zones can be obtained.

10. KEROSENE HEATER STUDY

Kerosene heaters can be an important source of combustion gases (principally carbon and nitrogen oxides) in the indoor environment. Considerable variability in emissions is expected based on the amount of usage by the homeowner. A supplemental investigation of air quality in 50 homes with kerosene heaters was begun during the winter monitoring phase. Nitrogen dioxide levels were monitored for up to 10 consecutive weeks in each of the 50 homes using the Palmes-type passive monitors that are used for the main component of the study. Concurrent information on respiratory symptoms of the participant child was obtained by the Acute Health Study group as part of their normal program. Real-time levels of several indoor pollutants were monitored in a subset of five houses using active sampling instrumentation. APPENDIX C.2 includes the instruction sheet, usage log, and questionnaire used for the kerosene heater study.

Beginning in January, each of the homeowners who agreed to participate in the kerosene heater study was provided with a package of 20 NO_2 samplers. Two samplers were co-located in the room (at least six feet from the heater) with the heater. Each week the homeowner would recap the previous week's samplers, record the date and time, and open a new set of samplers. During the spring visit to exchange radon samplers, the package of exposed NO_2 samplers was retrieved and shipped to HSPH for analyses.

A daily log of the hours of kerosene heater usage was maintained by the homeowner. In a subset of houses, an elapsed-time logger, which recorded the length of time when the temperature differential between two sensors, one over the heater and one in a distant portion of the room, was greater than a few degrees, was installed. These monitors had been developed by HSPH for use in monitoring gas stove usage. In some of the homes where elapsed-time loggers were installed, false recording of heater operation occurred due to thermal gradients, differential sunshine entry, difficult room geometries, etc. Care must be exercised in comparing the elapsed-time loggers with the homeowner recorded log. Recommendations will be made for protocol modifications and improvements to the loggers for future use with kerosene heaters.

Only two of the homeowners failed to participate for any of the ten-week period of the study and three others failed to complete usage logs (two provided subsequent estimates over the telephone). Approximately 375 house-weeks of monitoring were obtained. About 110 house-weeks of exposure were when there was no operation of the heater during the week. About 45 house-weeks of data were collected when there was greater than 100 h of heater operation during the week. Figure 10.1 shows the distribution of heater usage per week according to the homeowner usage log.

In a subset of five houses (four with heaters and one control), real-time data were obtained every 6 min from the following instruments:

- NO, NO_x chemilumiscent analyzer
- CO infrared analyzer
- CO_2 infrared analyzer
- SO_2 fluorescence analyzer
- Temperatures (room and near heater)

Measurements were made for one to two weeks in the homes with kerosene heaters during February and March. The control home without a kerosene heater was monitored during April. Considerable difficulity was encountered in identifying homeowners interested and willing to accommodate the size, noise, and traffic associated with this detailed real-time study. Much care was exercised to avoid causing anyone to cease participation in the larger study, as this was a prerequisite for our collaboration with the "core" HSPH activities. Consequently, we were considerably limited in our selection of homes, heater types, and other variables that would have been desirable to consider when making house selections. Three of the houses had radiant heaters, and one had a convective heater. Analysis of the field data, calibration data, and correlation with passive monitoring results will be conducted during the balance of the study.

ORNL DWG-86-15985

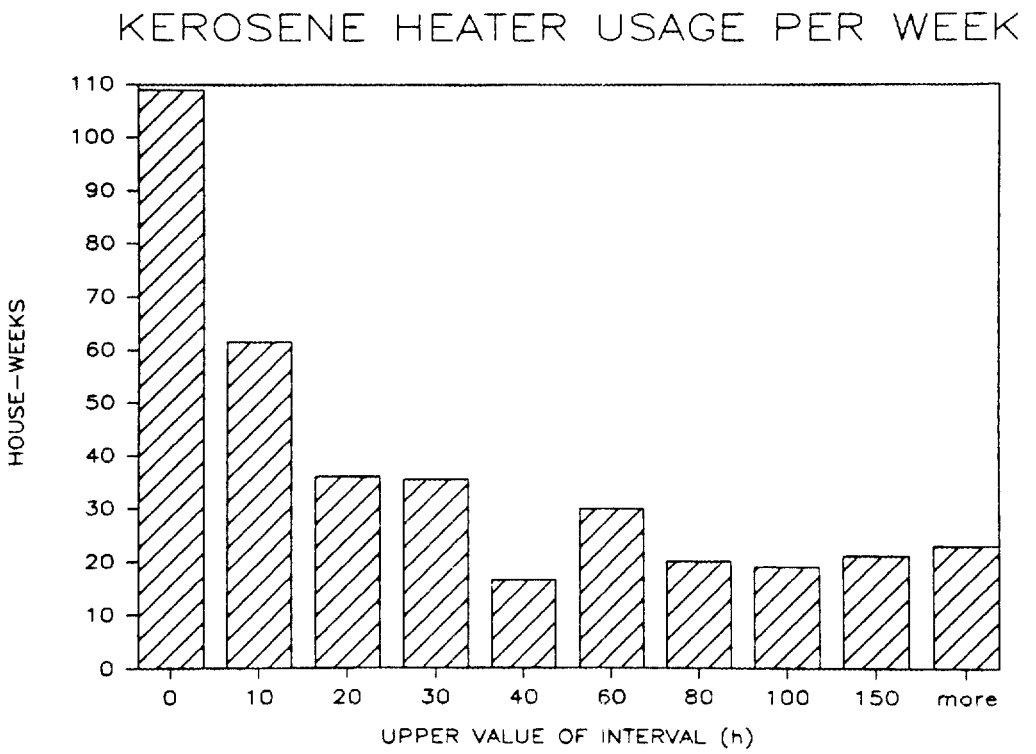

Fig. 10.1 Distribution of kerosene heater usage per week based on kerosene logs.

11. SUMMER PHASE PLANS

Most of the measurement activities conducted during the winter monitoring period will be continued during the summer monitoring phase of the study. Summer monitoring will occur from mid-May through August. Monitoring activities in the schools will terminate at the beginning of June. A spring series of measurements was conducted in the pilot homes (a subset of approximately 30 homes monitored during all four seasons) during April.

Most of the summer monitoring protocols will remain essentially unchanged from the winter phase measurements. Summer sampling protocols are presented in APPENDIX C.4. Significant changes are highlighted here.

Modifications to the "core" monitoring activities primarily relate to respirable particulate mass sampling. The sampling time will be changed from 16 h per day to 24 h per day to reflect the presumed increase in home exposures when school is out for the summer. Additional sampling will be performed with the PM2.5 samplers to increase replication statistics. A protocol for handling missing PFT sources has also been developed. A shortened questionnaire is administered during the summer to ascertain changes in house characteristics.

Radon samplers were exchanged during March and April. Samplers were placed on refrigerators in 286 homes. In a subset of 40 homes a radon sampler was also placed in the basement. Replicate samplers were placed in 31 homes. In addition, seven samplers were placed in schools. All radon samplers will be collected during August (except the schools).

Formaldehyde sampling protocols will remain essentially unchanged. The number of houses monitored for PNAs will be reduced and replication increased to improve our estimate of reproducibility. The biggest change between winter and summer monitoring activities is in the measurement of microorganisms. Sampling will be conducted in three tiers of homes. Measurement of airborne bacteria and fungi will be measured both indoors and outdoors at about 240 houses using a similar protocol to the one used for winter measurements.

In 40 of these homes more detailed monitoring will be conducted to assess emmissions from specific sources. A final subset of 10 homes will have even more detailed measurements with additional monitoring for nonviable organisms. Approximately half of the 10 homes will have at least one occupant with allergy symptoms. Measurements in these 10 homes will be conducted during the first two weeks of August and will be independent of normal monitoring visits.

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13. APPENDICES

A. Homeowner Information Sheets

B. Field Questionnaires

C. Protocols

D. ORNL INDOOR AIR STUDY Notes

APPENDIX A

Homeowner Information Sheets

- Kingston/Harriman Home Air Quality Survey Information Sheet
- Indoor Air Quality Study Fact Sheet for Oak Ridge National Laboratory Supplement

KINGSTON/HARRIMAN HOME AIR QUALITY SURVEY INFORMATION SHEET

Introduction

Most people think air pollution is mainly an outdoor problem. But few of us are aware of the fact that it can be an indoor problem as well. It is especially important to measure indoor air quality, as individuals typically spend over two-thirds or more of their time indoors.

During the upcoming year, over 300 homes in Kingston/Harriman will be taking part in an innovative research program designed to measure the concentrations of important pollutants inside homes together with the respiratory health effects these pollutants may or may not have on children. Similar measurements will also be made in the schools.

Who is doing the study?

Researchers in the Harvard Air Quality Group of the Department of Environmental Science and Physiology at the Harvard School of Public Health are conducting the study. We have been investigating the health effects of air pollution for over 10 years. Our research has importance for setting government standards for air quality and criteria for home appliances and heating equipment that might affect indoor air quality.

Who is paying for the study?

The study is sponsored by the National Institute of Environmental Health Sciences, the Electric Power Research Institute, and the U.S. Environmental Protection Agency.

Why is the study being done?

We know air quality varies widely in homes, but we do not know precisely all the factors that affect air quality and their importance. Nor do we know precisely what impact indoor air pollution may have on the health of children. This study will focus on the nature and extent of this impact. Its purpose is to gain a more precise knowledge of the interrelationships between indoor air pollution, outdoor air pollution, and respiratory health.

How were these households selected?

The 300 homes chosen were selected randomly from all the households in Kingston/Harriman. Kingston/Harriman is one of six areas in the United States selected for study. These areas were chosen to represent a cross-section of air quality found in the United States. Two of them are of relatively low air quality, two are relatively moderate, and two are relatively high. Kingston/Harriman is classified as moderate.

What will I have to do?

Participation in this study will involve: 1) noting on monthly calendars, which we will supply, any days on which your child has a respiratory illness; and 2) allowing us to set up a briefcase-sized air monitoring device and several small air monitoring tubes in your home for up to two weeks' time this winter and again next summer. These are quiet and relatively unobtrusive devices. We shall be calling you to make an appointment to show you the air monitoring equipment and to set it up in your home. We will also call you twice each month to ask you for health information noted on your calendars.

Who is the interviewer? Who will be the field technician?

All telephone contacts with you will be made by trained members of the Harvard Air Quality Group staff. And the persons visiting your home will be trained field technicians from the Harvard School of Public Health. All our interviewers and field technicians have identification and will be prepared to present it.

Who will receive the information on my home?

No one other than you and the research project staff. The data from all the homes in the study, once combined into statistical summaries and analyzed, will be presented in reports, scientific journals, books and maybe even in the news. But your name will *never* be linked to or associated with any of these results, *except* in a confidential report we will provide you with at the conclusion of the study of your home's findings. you with at the conclusion of the study.

What good will it do?

It can be expected that this air quality study will yield several lasting benefits: 1) a better understanding of the relationships between indoor and outdoor air pollution and health; 2) a greater public awareness of potential health hazards in the home; 3) a more rigorous and scientific basis for setting national policies and standards on air pollution; 4) improved standards for the design and construction of homes, home heating equipment and home appliances; and 5) improvements in preventive medicine.

What is in it for me?

The major benefit is that you will be contributing to a vital research project, and we expect you will find the experience to be interesting and valuable. Of more direct benefit is the report we will give you, after the last data collection, on the ventilation rates, energy conservation potential, and indoor air quality in your home; together with an explanation of what might be done to improve conditions, if warranted. You will also be able to learn how results from your home compare with the overall results from other (unidentified) homes in your area. And at the conclusion of this winter's air monitoring, we will send your family a small gift to thank you for your contribution to the study.

Where can I get more information?

Ask your interviewer or Field Technician, or you may call our Study Office collect at (617) 732-0830.

INDOOR AIR QUALITY STUDY FACT SHEET FOR OAK RIDGE NATIONAL LABORATORY SUPPLEMENT

Oak Ridge National Laboratory (ORNL) is working with the Harvard School of Public Health to increase the information that will be obtained from the Harvard Lung/Air Quality Study. This supplemental research is sponsored by the Tennessee Valley Authority, the Electric Power Research Institute, and the Consumer Product Safety Commission. We will be measuring levels of additional indoor pollutants and evaluating the impact of various energy using/conserving practices on indoor air quality. Most of the measurements will be made at the same time as measurements performed for the Harvard Lung/Air Quality Study. Monitoring will generally be conducted with passive sampling tubes or with small air pumps operated while field technicians are placing the small sampling tubes. Following is a list of the supplemental activities included in the ORNL research.

- Measure radon levels
- Measure formaldehyde levels
- Measure organic vapor and aerosol levels
- Measure bacteria and fungi levels
- Measure air mixing rates between zones of house
- Assess degree of weatherization of house

As part of our efforts to evaluate the relationship between indoor air quality and degree of weatherization, we would like to have TVA-trained energy auditors conduct a free survey of your home. These surveys will be the same as those conducted by TVA distributors throughout the Tennessee Valley area. With your approval, we will arrange for this free survey.

Upon completion of the study you will be provided with the indoor air quality information on your home. Specific homeowner identities will be maintained as confidential information.

Thank you for your participation in this research.

Please feel free to telephone for further information (376-0089 or 576-2712).

APPENDIX B

Questionnaires

- Home Characteristics Questionnaire
- ORNL Supplemental Questionnaire

COVER SHEET

HOME AIR QUALITY SURVEY

Home Characteristics Questionnaire

ADDRESS LABEL

DATE: _____ FIELD TECHNICIAN: _____

CONFIDENTIAL: Information provided in connection with this study will not be disclosed or used in any way that would permit identification of any individual.

HOME AIR QUALITY SURVEY

Home Characteristics Questionnaire

I. SETTING AND HOME TYPE

1. Which best describes this building? (Include all apartments, flats, etc., even if vacant.)

   [ ] a single family home detached from any other house
   [ ] a single family home attached to one or more houses
   [ ] a building for two or more families

   ——> How many living units (occupied and vacant) are at this address?
   [ ] number

   ——> How many stories (floors) are there in this building? (Include basement and attic.)
   [ ] number

   ——> On which floor or floors do the participants live? And how many rooms are there on each of the floors (exclude bathrooms)?

   Floor: _____ Number of Rooms: _____

   Floor: _____ Number of Rooms: _____

   Floor: _____ Number of Rooms: _____

   Floor: _____ Number of Rooms: _____

   ——> On which floor(s) are the Kitchen, Master Bedroom, Living Room?

   Kitchen: _____ Bedroom: _____

   Living Room: _____

NOTES: Detached means there is open space on all sides, or the house is joined only to a shed or garage. Attached means that the house is joined to another house or building by at least one wall which goes from ground to roof. Count all occupied and vacant living quarters in the house or building, but not stores or office space.

2. What type of garage, if any, do the participants have?

   [ ] NONE, DETACHED, OR SEPARATE CARPORT - SKIP TO QUESTION 3
   [ ] attached to one side
   [ ] underneath

   ——> On how many days during an average week is the garage used, that is that cars drive into and out of the garage?

   _____ days per week

3. Does this building have a basement?

[ ] NO - SKIP TO QUESTION 4
[ ] DON'T KNOW - SKIP TO QUESTION 4
[ ] yes

——> What type?
[ ] crawl space
[ ] partial basement
[ ] full basement

——> Is the basement directly underneath the floor(s) on which the participants live?

[ ] no
[ ] yes

4. How many exterior walls does the living unit have?

[ ] none
[ ] 1
[ ] 2
[ ] 3
[ ] 4

5. In what year did you move into this house or apartment?

[ ] 1979-84
[ ] 1975-78
[ ] 1970-74
[ ] 1960-69
[ ] 1950-59
[ ] 1949 or earlier
[ ] always lived here

6. In about what year was your home originally built?

[ ] 1979-84
[ ] 1975-78
[ ] 1970-74
[ ] 1960-69
[ ] 1950-59
[ ] 1940-49
[ ] 1939 or earlier
[ ] DON'T KNOW

7. What materials make up the exterior finish of the house (check all that apply)?

[ ] wood/clapboard
[ ] vinyl siding
[ ] aluminum siding
[ ] brick/double brick
[ ] tar shingles
[ ] stucco
[ ] concrete
[ ] stone
[ ] glass
[ ] other:_____
[ ] DON'T KNOW

8. Is there any insulation in the outside walls of this house?

[ ] NO - SKIP TO QUESTION 9
[ ] DON'T KNOW - SKIP TO QUESTION 9
[ ] yes

——> Are the outside walls completely insulated, or only partially insulated?

[ ] partially
[ ] completely

——> What kind of material was used to insulate the walls? In what year was it installed?

Type: _____ Date Installed: _____

Type: _____ Date Installed: _____

Type: _____ Date Installed: _____

9. Is the roof insulated?

[ ] NO - SKIP TO QUESTION 10
[ ] DON'T KNOW - SKIP TO QUESTION 10
[ ] yes

——> What kind of material was used to insulate the roof? In what year was it installed?

Type: _____ Date Installed: _____

Type: _____ Date Installed: _____

NOTES: Common types of insulation materials are: UFFI, fiberglass, polystyrene, cellulose and rock wool.

10. Check off which of the following, **permanent**, energy conservation devices are present? How extensively have they been implemented? (For example, of all the places they could be installed, what percentage of the places have them?)

TYPE	100%	75%	50%	25%
[ ] storm windows - exterior	[ ]	[ ]	[ ]	[ ]
[ ] storm windows - interior	[ ]	[ ]	[ ]	[ ]
[ ] double-pane windows	[ ]	[ ]	[ ]	[ ]
[ ] magnetic seal on doors	[ ]	[ ]	[ ]	[ ]
[ ] vestibule	[ ]	[ ]	[ ]	[ ]

11. Check off which of the following, **seasonal**, energy conservation devices are present? How extensively have they been implemented? (For example, of all the places they could be installed, what percentage of the places have them?)

TYPE	100%	75%	50%	25%
[ ] window plastic, quilts, blankets	[ ]	[ ]	[ ]	[ ]
[ ] caulking around windows	[ ]	[ ]	[ ]	[ ]
[ ] caulking around doors	[ ]	[ ]	[ ]	[ ]
[ ] weatherstripping on windows	[ ]	[ ]	[ ]	[ ]
[ ] weatherstripping on doors	[ ]	[ ]	[ ]	[ ]
[ ] storm doors - exterior	[ ]	[ ]	[ ]	[ ]

12. What percentage of the floor coverings in the home are wood, tile, linoleum and carpeting (excluding kitchen and bathrooms)?

TYPE	100%	75%	50%	25%	NONE
wood	[ ]	[ ]	[ ]	[ ]	[ ]
tile	[ ]	[ ]	[ ]	[ ]	[ ]
linoleum	[ ]	[ ]	[ ]	[ ]	[ ]
rug/carpeting	[ ]	[ ]	[ ]	[ ]	[ ]

NOTE: These should add to 100%

II. HEATING SYSTEMS AND FUELS

1. Is your home heated by any type of furnace system?

[ ] NO - SKIP TO QUESTION 11
[ ] yes

2. What basic type of furnace is it?

[ ] Steam or hot water furnace system
[ ] Central warm air furnace with ducts to rooms
[ ] Floor, wall or pipeless furnace

3. What type of fuel is used?

[ ] gas - NG
[ ] gas - LP
[ ] wood
[ ] oil
[ ] electric
[ ] kerosene
[ ] coal

4. Does the furnace have a flue damper?

[ ] NO
[ ] yes

5. Does the furnace have a pilot light?

[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> Is it turned off during non-heating season?
[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> On average, how many months per year is the pilot light kept on?
_____ months per year

6. INTERVIEWER CHECK:
[ ] RESIDENTS DO NOT HAVE A HOT AIR FURNACE - SKIP TO QUESTION 9
[ ] RESIDENTS HAVE HOT AIR FURNACE

7. Does the furnace have cool air return ducts?

[ ] no
[ ] yes

8. Does the furnace have air filters?

[ ] no
[ ] yes

9. Is the basement directly heated by furnace?

[ ] no
[ ] yes

10. Does the furnace system have a built-in humidifier?

[ ] no
[ ] yes

11. Is your home heated by any built-in electric units (installed in wall, ceiling or baseboard):

[ ] NO - SKIP TO QUESTION 12
[ ] yes
——> Does this provide the primary heat in the home?

[ ] no
[ ] yes

12. Do you use any space heaters to heat your home?

[ ] NO - SKIP TO QUESTION 16
[ ] yes

13. Do space heaters provide the primary heat for the home?

[ ] no
[ ] yes

14. How many space heaters do you have?

[ ] number

15. ASSIGN A UNIT # FOR EACH SPACE HEATER AND ASK FOR EACH UNIT:

And where is each located? What type of fuel does the space heater in (ROOM) use? (gas, kerosene, electricity)? Is this a portable or permanently installed unit? Does it have a flue?

In the last 7 days, on how many days have you used (EACH UNIT)? And on those days, for how many minutes or hours did you have it on?

Unit #	Location	Fuel	Portable	Flue	Frequency of use Days/Week	Hours/Day
1						
2						
3						
4						
5						

16. Do you use any fireplaces for heating your home?

[ ] NO - SKIP TO QUESTION 23
[ ] yes

17. Do fireplaces provide the primary heat for the home?

[ ] no
[ ] yes

18. ASSIGN A # FOR EACH FIREPLACE AND ASK FOR EACH:

And where is each located? What type of fuel do you burn in that fireplace?

In the last 7 days, on how many days have you used (EACH FIREPLACE)? And on those days, for how many minutes or hours did you use it?

Unit #	Location	Fuel Used	Frequency of use Days/Week	Hours/Day
1				
2				
3				
4				

19. Do the fireplaces have a separate source of outdoor air?

[ ] no
[ ] yes

20. Do the fireplaces have dampers?

[ ] NO - SKIP TO QUESTION 23
[ ] yes
——> Are the dampers open when the fireplaces are not in use?

[ ] always/usually
[ ] about half the time
[ ] occasionally
[ ] almost never/never

21. Do the fireplaces have recirculating air systems?

[ ] no
[ ] yes

22. Do the fireplaces have glass doors?

[ ] NO - SKIP TO QUESTION 23
[ ] yes
——> Is the glass door used when the fireplace is used?
[ ] always/usually
[ ] about half the time
[ ] occasionally
[ ] almost never/never

23. Do you use any coal or wood stoves to heat your home?

[ ] NO - SKIP TO QUESTION 27
[ ] yes

24. ASSIGN A # FOR EACH STOVE AND ASK FOR EACH:

What model of stove(s) do you have? Are they front- or side-loading? And where is each located? What type of fuel do you burn in that stove?

In the last 7 days, on how many days have you used (EACH STOVE)? And on those days, for how many minutes or hours did you use it?

Unit #	Model and Type	Location	Fuel Used	Frequency of use Days/Week	Hours/Day
1					
2					
3					
4					

25. Do wood/coal stoves provide the primary heat for the home?

[ ] no
[ ] yes

26. Are pans of water put on stove to increase humidity?

[ ] NO - SKIP TO QUESTION 27
[ ] yes

——> How much?
[ ] less than 1 gallon/day
[ ] more than 1 gallon/day

27. Do you use any type of solar heat?

[ ] no
[ ] yes

28. Do you have any heaters that are built into the kitchen stove?

[ ] NO - SKIP TO QUESTION 31
[ ] yes

29. Does the heater on the stove provide the primary heat for the home?

[ ] no
[ ] yes

30. Is the heater vented outside?

[ ] no
[ ] yes

31. Do you ever turn your oven on to heat your home?

[ ] NO - SKIP TO QUESTION 33
[ ] yes

32. Does the oven provide the primary heat for the home?

[ ] no
[ ] yes

33. Do you use any additional sources for heat?

[ ] NO - SKIP TO QUESTION 34
[ ] yes
——> What additional sources of heat do you use?

_____

34. Does the house have an air-to-air heat exchanger?

[ ] NO - SKIP TO QUESTION 35
[ ] yes
——> The the last 7 days, on how many days have you used it? And on those days, on average, for how many minutes or hours was it on?

DAYS: _____ TIME: _____

35. Does the heating system have a thermostat? IF MULTI-DWELLING UNIT: Can you control of the central heating setting?

[ ] NO - SKIP TO QUESTION 36
[ ] yes

——> Is the thermostat set to automatically adjust the temperature at different times of the day, or do you adjust the thermostat every day yourself?

[ ] automatic set-back
[ ] manual set-back

36. What is the usual temperature here during the day? How about early evening? How about during the night?

[ ] degrees F, in the daytime

[ ] degrees F, in the evening

[ ] degrees F, at night

III. COOKING AND WATER HEATING FUELS

1. Do you have a gas stove?

[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> What type of gas do you use?

[ ] gas - bottles, tank or liquid propane
[ ] gas from underground pipes serving the neighborhood

2. How many burners does your range have?

[ ] 1
[ ] 2
[ ] 3
[ ] 4
[ ] 5 or more

3. How does your range operate? Are the burners lit by constantly burning pilot lights or by an electronic ignition?

[ ] ELECTRONIC IGNITION - SKIP TO QUESTION 4
[ ] light by hand (pilot lights go out)
[ ] pilot lights - constantly burning

——> How many constantly burning pilot lights serve the range burners?
[ ] 1
[ ] 2
[ ] 4

4. How does your oven operate? Is it lit by a constantly burning pilot light, do you light the flame your self or is there an electronic ignition?

[ ] ELECTRONIC IGNITION - SKIP TO QUESTION 5
[ ] light by hand
[ ] pilot lights - constantly burning

——> Number of constantly burning pilot lights serving the oven?
[ ] 1
[ ] 2 or more

5. Is your oven self-cleaning?

[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> How often do you use the self-cleaning feature?
[ ] always/usually
[ ] about half the time
[ ] occasionally
[ ] almost never/never

6. Does your range have a hood (fan) ?

[ ] NO - SKIP TO QUESTION 7
[ ] yes

——> How the the fan work?
[ ] kitchen exhaust is vented to outside
[ ] the fan just recirculates indoor air
[ ] it has a charcoal filter

——> When you cook, how often is the fan turned on? Would you say usually, about half the time, occasionally, or almost never?

[ ] always, almost always, whenever stove is on
[ ] about half the time
[ ] occasionally
[ ] almost never/never

7. Does your kitchen have a separate ceiling fan that vents air to the outside?

[ ] NO - SKIP TO QUESTION 8
[ ] yes

——> When you cook, how often is the fan turned on? Would you say usually, about half the time, occasionally, or almost never?

[ ] always, almost always, whenever stove is on
[ ] about half the time
[ ] occasionally
[ ] almost never/never

8. In an average week, 7 days, on how many days would you and any other household members use the stove burners at all for preparing breakfast? For a typical meal, how many would you say are used at once? How long would the burners usually be on?

   On how many days per week would the oven be used for cooking breakfast? And for how many minutes would it be on?

   How about for lunch.....

   How about for dinner....

   Other than for preparing meals, on how many days per week would the stove burners usually be turned on? On an average day, could you estimate how many times they might be on at all at times other than meals? How about oven?

	STOVE			OVEN	
	Avg. # days per week	Avg. # burners per meal	Avg. Time on	Avg. # days per week	Avg. Time Cooking
Breakfast					
Lunch					
Dinner					
Other					

9. Which of the following appliances, if any, are used?

   [ ] microwave oven
   [ ] regular convection oven
   [ ] microwave convection oven
   [ ] toaster oven

10. Does the house have a gas water heater?

[ ] NO - SKIP TO QUESTION 11
[ ] yes
——> Water heater location: _____

——> Is there an air space where the vent pipe is connected to the heater?

[ ] no
[ ] yes

——> Does the water heater have a pilot light?

[ ] no
[ ] yes

——> Does the water heater have a flue damper?

[ ] no
[ ] yes

11. Does the house have a clothes dryer?

[ ] NO - SKIP TO NEXT SECTION
[ ] yes

——> Where is is located?

[ ] LIVING AREA
[ ] BASEMENT
[ ] OTHER

——> In an average week, on about how many days is the dryer used? And on the days that it is used, about how many loads of laundry are done each day?

Days: _____ Loads/day: _____

——> Is it a gas or an electric dryer?

[ ] ELECTRIC - SKIP TO NEXT SECTION
[ ] gas

——> Is the dryer vented?

[ ] no
[ ] yes, summer/winter (inside/outside) switch
[ ] yes, into living quarters
[ ] yes, into basement
[ ] yes, outside

IV. VENTILATION

1. Does the house have any air conditioning?

[ ] NO -SKIP TO QUESTION 2
[ ] yes

——> Type, operation and temperature setting:

[ ] central system

[ ] room units:

——> Location(s): _____

——> Operation:

Basic cooling:
[ ] evaporative
[ ] refrigeration

Air circulation:
[ ] recirculate inside air
[ ] vent in outside air
[ ] combination

——> In an average week, on about how many days is the air conditioner used? And on the days that it is used, about how many minutes or hours is it on?

Days: _____ Time: _____

2. Are there any air cleaning devices in the house?

[ ] NO - SKIP TO QUESTION 3
[ ] yes

——> Which types, how many, what brands, and where are they located?

TYPE	NUMBER	SIZE/BRAND NAME	LOCATION(s)
[ ] filter	_____	_____	_____
[ ] charcoal	_____	_____	_____
[ ] electrostatic precipitators	_____	_____	_____
[ ] ionizer	_____	_____	_____
[ ] others	_____	_____	_____

——> In an average week, on about how many days are they used? And on the days that they are used, for how many minutes or hours would you say they are on?

Days: _____ Time/day: _____

3. Are there any humidifiers?

[ ] NO -SKIP TO QUESTION 4
[ ] yes

——> Locations:_____

——> How do they operate?

[ ] automatically (settable level)
[ ] manually (on/off only)

——> Do the humidifiers produce hot steam or cold air mists?

[ ] steam
[ ] cold air

——> In an average week, on about how many days are they used? And on the days that they are used, for how many minutes or hours would you say they are on?

Days: _____ Time/day: _____

4. Do you have any dehumidifiers?

[ ] NO -SKIP TO QUESTION 5
[ ] yes

——> Locations:_____

——> In an average week, on about how many days are they used? And on the days that they are used, for how many minutes or hours would you say they are on?

Days: _____ Time/day: _____

5. Do you use an attic fan?

[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> How does it operate?

[ ] ventilates attic only
[ ] draws air through house

——> In an average week, on about how many days is it used? And on the days that they are used, for how many minutes or hours would you say it is on?

Days: _____ Time/day: _____

6. Are bedroom doors closed at all during the day or night?

[ ] NO - SKIP TO QUESTION 7
[ ] yes

——> Are the bedroom doors closed all or most of the time, just during the day or just during the night?

[ ] all or most of the time
[ ] during the day only
[ ] during the night only

7. Are kitchen doors closed at all during the day or night?

[ ] NO - SKIP TO NEXT SECTION
[ ] yes

——> Are the kitchen doors closed all or most of the time, just during the day or just during the night?

[ ] all or most of the time
[ ] during the day only
[ ] during the night only

V. PARTICIPANTS

1. How many adults 18 or older, live in this home? How many children, under 18 years old, live in this house?

   [ ] adults
   [ ] children (under 18 years old)

2. Who, if anyone, now smokes cigarettes, cigars or a pipe at home? (Anyone else?)

Name	Material & Brand(s)	Avg Amt per Day	Rooms Used

What does (EACH PERSON) smoke—cigarettes, cigars, or a pipe?

Which brands of cigarettes does (PERSON) usually smoke?

Could you estimate about how many cigarettes a day (PERSON) smokes at home?

Could you estimate how many minutes or hours a day (PERSON) usually smokes at home?

In what room or rooms does (person) smoke most often?

Home Characteristics Questionnaire

Watertown Supplement

I. WATER, HUMIDITY

1. What is your primary source of household water?

   [ ] an individual drilled well
   [ ] an individual dug well
   [ ] public system (city water department) - SKIP TO QUESTION 2
   [ ] some other source:_____ - SKIP TO QUESTION 2

   ——> How deep is the well?

   [ ] ft.

2. Does the house have any of the following (check all that apply):

   [ ] sump pump
   [ ] basement drain
   [ ] external perimeter drain

3. INTERVIEWER CHECK:
   [ ] BUILDING DOES NOT HAVE BASEMENT - SKIP TO QUESTION 5
   [ ] BUILDING HAS BASEMENT

4. Does water ever collect on basement floor?

   [ ] NO - SKIP TO QUESITON 5
   [ ] yes

   ——> Would you say water collects on the basement floor often or primarily when it rains heavily?

   [ ] often
   [ ] when it rains heavily

5. Has there ever been any water damage to the building?

[ ] NO - SKIP TO QUESTION 6
[ ] yes

——> Has there been any damage to the structure?

[ ] no
[ ] yes

——> Has there been any damage to the floor or the floor coverings?

[ ] no
[ ] yes

6. Has there ever been any mold or mildew on any surfaces inside the home?

[ ] NO - SKIP TO QUESTION 7
[ ] yes

——> In which rooms has any mold or mildew occurred?

_____

7. Are there noticeable static electric charges in the winter months?

[ ] no
[ ] yes

Site:_____

OBSERVE ONLY!

8. What is your assessment of the "dust control" effort attempted by the residents?

[ ] very cluttered home with minimal or no attempt at dust control
[ ] cluttered with obvious areas of increased dust, attempt at dust control infrequent and at irregular intervals, family tolerates some degree of debris accumulation
[ ] fair attempt at dust control but house looks lived in, average homes where dust control is only partially implemented
[ ] cleaner home with increased attempt at dust control but still having a "lived-in" appearance
[ ] excellent cleaning but with some areas of home where family has relaxed standards
[ ] extremely meticulous dust control

300-HOUSE STUDY
ORNL SUPPLEMENTAL QUESTIONNAIRE

1. House no. _____

2. Date _____

3. Person responsible _____

4. Direct door between garage and house _____

5. Percent of basement centrally conditioned _____ %

6. Do walls have vapor barriers (y/n) _____

7. Ductwork runs through

   a. Garage _____

   b. Unconditioned space _____

   c. Outer wall _____

8. Do you have a heat pump (y/n) _____ If so, is it a split system (y/n) _____

9. Usual temperature of house during cooling season _____ °F

10. If windows are opened during cooling season, number of windows opened _____ number days/week _____

11. Ceiling fans used how many _____ days/week during cooling season

    NOTE TO INTERVIEWER: Get answers to questions #12 and #13 from HSPH questionnaire.

12. Usual daytime temperature of house during heating season _____ °F

13. Usual nighttime temperature of house _____ °F during heating season

14. Is car left to idle/warm-up in garage (y/n) _____ during heating season

15. Ceiling fans used how many _____ days/week during heating season

16. If windows are opened during heating season, number of windows open _____ number days/week _____

17. Do you have pets (y/n) _____
list number of each kind
_____

18. Does your kitchen have particleboard or medium density fiberboard cabinets (y/n) _____. If yes, age _____ y

19. If yes, are the cabinets veneered with

    a. Vinyl (y/n) _____

    b. Wood (y/n) _____

20. What percent of your furnishings are primarily constructed of pressed-wood products _____ %

21. List rooms with paneled walls and the age of paneling in each.

    Room _____ Age (yrs) _____
    Room _____ Age (yrs) _____
    Room _____ Age (yrs) _____
    Room _____ Age (yrs) _____

22. Do you store chemicals in garage (y/n) _____
list: _____ _____ _____ _____ _____

23. Do you store chemicals in basement (y/n) _____
list: _____ _____ _____ _____ _____

24. Is your home used for hobbies or businesses that involve use of chemicals (y/n) _____
If yes, describe _____

25. Do you frequently use aerosol sprays or similar products in your home (y/n) _____
list: _____ _____ _____ _____ _____

26. Do you have a drip pan under refrigerator/freezer? _____
Does a fan blow air over it? _____

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APPENDIX C

C.1 Excerpts from Field Technician's Reference Manual

C.2 ORNL Field Sampling Protocols

C.3 Analyses Protocols

C.4 Summer Phase Protocols

APPENDIX C.1 Excerpts from Field Technician's Reference Manual

- Site Protocol
- Placement Protocol
- Floor Plan Measurement
- Questionnaire

Excerpts from

INDOOR AIR QUALITY/ACUTE HEALTH STUDY

FIELD TECHNICIAN'S REFERENCE MANUAL

Prepared by:

Peggy Reed
Field Operations
Coordinator

Vince McKay
Research Assistant

Leslie P. Fraumeni
St. Louis Field Manager

Harvard School of Public Health
Environmental Science and Physiology

IV SITE PROTOCOL

4.1 Equipment Checklist

Each Field Technician will be provided with a field case. It is the responsibility of the Field Technician to maintain the field case with proper supplies. Care should be taken to prevent loss or theft of case and contents. Each case should contain:

- Map
- Clipboard and Notepaper
- Pens
- Tape Measure
- Roll Counter
- Thumbtacks
- Extension Cord
- Spare Key for Pump Box
- Duct Tape
- Flashlight
- Calculator
- Compass
- Alligator Clips
- Extra Caps
- Spare Fuses

For each set-up visit the Field Technician will need

- Sample Holders (2-6/site)
- Outdoor NO2 Shelter and Nylon Ties
- PFT Source Packet
- Forms Package for Site
- Sample Package
- Rotameter
- Spare Pump Box
- Foam Pad for Pump Box
- Spare Forms

Each Field Technician is responsible for having a complete appointment book, weekly field log and business card. A checklist for equipment is included in the appendix.

4.2 Site Visit Supplies

Complete packages of forms and samples will be prepared in advance for each site visit. Obtain packages from the Field Manager and check all forms and sample packages for completeness prior to site visits. Sample packages contain a field card, impactor and passive samplers. Form packet includes coversheet, labels, appointment card, questionnaire, floor plan, and reminder card.

The Field Card contains the information for assigning samplers to sites in the home. One of the labels provided with the coversheet is affixed to the Field Card to denote which package was assigned to the site. The Field Card is used to record capping information pertaining to the passive samplers and elapsed time and rotameter information for the pump box. The Field Card is kept with the sample package and the sample package remains inside the pump box during the sample period. Sample packages must be returned to the field office promptly after sampling is complete.

Forms packets should be kept together until sampling at the site has been successfully completed. The coversheet is needed at each visit. Checklists for each site visit are included on the coversheets.

If the site has been visited previously, review all available documentation. For residents who have been difficult to keep appointments with call the residents in the evening or the morning before scheduled appointments to confirm date and time. If you arrive for a visit and do not find anyone at home, leave a missed appointment card on the resident's door asking them to call in to the office and leave a message.

The following sections roughly outline the recommended order of steps used to accomplish a site visit. The steps do not have to follow this order. Person al style and flexibility often determine the most comfortable flow.

4.3 Site Visits

4.3.1. Initial Contact

Introduce yourself to the residents. Getting acquainted with the family is usually best accomplished if the questionnaire is administered first. This affords the participants an opportunity to bring up questions in an informal atmosphere and allows you to explain the study's objectives and methods. Although the questionnaire is long do not rush through the questions. Finish the questionnaire in the first visit whenever possible. An adult to answer the questions may not be available after the initial set-up. If time is tight the floor plan and photo may be left to the next visit. Sitting with the family members is generally the best time to take out the tubes, explain their function and place them in holders.

There may be resistance to placing the black pump box in the home. Explain the importance of this monitoring equipment in the study. If the resident continues to resist, remove the equipment. The participants good will is important to all parts of the study. Record all problems on coversheet and notify the Field Manager as soon as possible.

4.3.2. Box Placement and Testing

View the general layout of the house. The ACTIVITY ROOM (AR) is defined as the room where the child in the study spends the most time. This room is usually the living room, den or study. It cannot be the kitchen or child's bedroom. Place the pump box in an non-obtrusive corner of the AR, under an end table or behind a chair. Place the impactor near where the tubes will be located. Tape down cords and wires. Put a 3-way cube tap in the outlet if it is already full or there is only one open outlet in the room. It may be necessary to run the sampling cord along the edge of a wall or under a sofa. All exposed cords MUST be taped down. THERE MUST BE NO CHANCE THAT THE OCCUPANTS CAN TRIP OR INJURE THEMSELVES ON EXPOSED WIRES. Note that the cords, sampling hose, and power cord must be extended through the hole on the left hand side of the box. Only pull out the length of cord and tube needed. Extra hose and wire should be pulled back into

the box. Plug in the pump and turn on the timer to activate the system. Be sure the outlet is not controlled by a wall switch.

The pumps needs a warm-up period of a least 10 minutes. The box lid should be closed for all flow checks. Check flows with a calibrated rotameter and RECORD the rotameter setting. Flows are checked by detaching the top of the impactor and replacing it with the cylinder connected to the rotameter. The rotameter must be in a stable vertical position. Use the center of the ball and read to the nearest mark. The flow reading should be within the limits indicated on the rotameter. Record the rotameter reading on the Field Card card.

If a volt check is needed attach the Digital Volt Meter (DVM) to the double prong outlet on the top of the green metallic flow control box inside the black case. Set the DVM dial on "V" position. The voltage reading may be - or + depending on how the DVM is connected. Insure that the voltage is within acceptable limits. Record the DVM readings on the site card. Should either the voltage or rotameter reading not be within acceptable limits replace the entire system and return suspect equipment to the office for further check out.

Setting the programmable timer is a critical step. The timer will be set so that the present day and the next seven days will have on/off times. All other days will have off times. The timer is designed with increments of four hours. The black tab in the out position denotes hours the samplers does not run The black tab in the depressed position or towards the center of the circle indicates hours the pump will be activated. The following are general guidelines for on and off sample times. Saturdays, Sundays, and school holidays are 24 hour per day sampling periods. School days will be sampled from 4 PM one day to 8AM the following morning. The timer will be off from 8 am to 4 pm. Two tabs should remain undepressed representing the time the child spends in school. On the days following that last day of sampling, the timer is left in the off position. Once the timer is set, the dial is turned in a clockwise direction to the closest approximation of the current time. This may or may not activate the timer given the sampling requirements for the current day.

After the timer is re-set to the present hour and day, RECORD the elapsed time indicator to the nearest tenth of an hour on the Field Card. The box should always be left latched and LOCKED.

4.3.3. Monitor Placement

Examine the household to determine the correct placement for the NO_2, H_2O, CAT and PFT tubes. Select proper adhesives, clips, or holders for each tube and location. The tube numbers are recorded on the Field Card indicating where tubes are to be located.

Check to make sure the entire ID on the tube corresponds with the ID number on the card. The tubes are also color-coded for quick checking:

Red - Kitchen

Blue - Bedroom

Yellow - Activity Room

Green - Outdoor

The tubes are uncapped and placed in holder. Caps are stored in sample case. RECORD the month, day, year and time uncapped on Field Card. Blanks are tubes which are not uncapped. The blank is always left in the child's bedroom near to the tube assigned to the bedroom. A replicate is a tube which is uncapped and left with the tubes in the Activity Room. Place the sample case with the caps and Field Card in the pump box before locking.

4.3.4. Change Visit

One week from the day sampling started return to the home for changing samples. For the particle monitor replace the impactor head, conduct flow checks, and reset the equipment. The passive monitors are capped and replace by new monitors.

Open the black box and record the elapsed time on the Field Card. Calculate the hours the sampler ran the previous week. If the sample is less than 120 hours, check the timer for correct setting and operation. It should indicate the current time and date. Check with the home owner to see if there were any prolonged power shortages. If the elapsed time is over 175 hours, the sample is suspect and the equipment should be replaced.

Change the impactor by disconnecting the black rubber hose at the impactor fitting and connecting the new impactor. Check the filter ID number on the new impactor corresponds with the filter ID number on the new Field Card. Perform flow check with rotameter and reset the timer. RECORD the elapsed time on the new Field Card.

All of the previous week's tubes should be capped and placed in the same case as the used impactor. The date and time of the capping should be written on the Field Card. The case complete with filled out Field Card, capped tubes and used impactor is returned to the office.

A new set of tubes will be placed in the home. Follow the same procedures in placing the tubes in the holders as the week before. Place caps and Field Card in pump box and lock the box.

4.3.5. Pick-up Visit

The pick-up visit is scheduled for two weeks after the initial set-up. RECORD the elapsed time, cap time and date on the Field Card. Remove the impactor and put it in the sample case. Store all cords and cables in the pump box. When the box is closed the hose and wire should not end up between the plastic box and timer dial. The dial must be free to turn. It will continue to run for up to 3-4 days on back up battery power.

Collect all of the tubes, cap them and document the date and time. Collect the holders and clips. The only equipment left in the house after the third visit is the sources. Use the third visit to make sure that all of your documentation is correct and complete. Return all equipment to the office.

4.3.6. Photographs

A photographic record of the homes provides a point of reference for interpreting data and serves as a reference for the general location of the site within the neighborhood. Record site ID on the marker board. Photograph the outside of the house with marker board included in the picture.

4.3.7. Floorplan

Sketch the basic floor plan of all living area floors. This includes only floors where monitors are placed. Mark where the samplers and sources have been placed with an "x" or an "s" depending on the type. Measure length, width and ceiling height for each floor. Record on floor plan form.

4.4 Follow-Up Paper Work

1. Reminder cards: Make sure that the resident is given an appointment card with the next two visits listed clearly. Make sure that the appointments for the next two visits are confirmed during the initial set-up. Do not postpone making these even if the resident is unsure of their schedule. It is important to fill in your weekly schedules early so that you know times that will be available for other visits.

2. Travel and expense forms: Reimbursement for all mileage and field work expenses must be made through standard Harvard University procedures. Fill out the reimbursement forms and hand them in to the office on a weekly basis. It often takes a long time for these forms to be processed. It is important that these forms be submitted as quickly as possible.

3. Time sheets: Time Sheets should be filled out and submitted to the Field Manager each week.

V PLACEMENT PROTOCOL

5.1 Introduction

Placement of monitors is an important factor in the successful implementation of the study. A monitor placed in a dead air space and one placed in a highly ventilated area such as near a window will give very different concentration values for the site. It is critical that all monitors are carefully and thoughtfully placed.

5.2 Particle Sample Placement

The particle sampler is being used to determine an average concentration of aerosol particles in the home. The impactor will collect a filter sample of particles less than 2.5 microns in diameter.

The pump box and impactor are placed in the activity room of the house. The box can be placed under a table or in a corner. Noise emitted by the pump box should be considered in determining the optimal location. The humming sound is known to vary from box to box. Vibration level is determined by the characteristics of the room especially floor coverings. Whenever possible place the box on a well-padded carpet. If only bare floor is available use a foam pad to dampen vibration. A small and uncluttered room may promote a "booming" effect because of amplification of the hum. Several different locations should be tried to alleviate this problem. Pump boxes with quieter noise level should be used in smaller homes. If the noise level seems to increase check the clear plastic exhaust tube between the pump and muffler. A kink in this tube may increase noise levels.

The impactor should be placed on a table or shelf in a well ventilated area. The impactor should be in the breathing zone of the child one to two meters from the floor.

5.3 NO2 Sampler Placement

NO2 will be measured using Palmes tubes to characterize concentrations both inside and outside the homes. Concentrations depend on source strength, volume, and air exchange rates. It is necessary to obtain measurements from several locations in the home.

Palmes tubes should be placed one to two meters off the floor in the sample holder. Care should be taken to avoid corners and windows. Three tubes are placed inside the home. One tube is placed in the kitchen no less than three meters from the stove. A second tube is placed in the bedroom of the child being monitored by the Acute Health Study. A third tube is placed in the activity room near the location of the impactor. Please note that the impactor is comparatively child proof and the tubes are not. Care should be taken to place the tubes out of reach of small children. Whenever possible use sample holders to place sampler.

One Palmes tube will be placed outside the home to sample ambient NO2 levels. Select a location for the outdoor sample on the north side of the house if possible. Avoid the north side if there is a gas dryer vent, stove exhaust vent, or if it borders a garage or driveway where

cars may idle. On a side not facing north, select a location shielded from direct sunlight. Use the plastic mounting strips and a NO2 shelter to place the tube outside. The NO2 shelter should be used whenever possible. The shelter serves as a protection from strong winds and rain. If necessary the tube may be clipped on a protected area of a porch.

5.4 H2O Monitor Placement

The water content in the indoor environment has many ramifications in studying concentrations of pollutants. The first-order decay of nitrogen dioxide concentrations is affected by humidity in the air. Humidity levels may also affect the susceptibility to respiratory illness.

The humidity level is assumed to be uniform within the house, with only short-term increases in humidity in kitchens, baths, or laundry areas. Only a single measure is necessary. The H2O tube is placed in the activity room sample holder.

5.5 PFT System Placement

The object of this system is to obtain an accurate measurement of air flow through the home. To achieve this measurement a source/receptor system has been devised. The PFT source is a perfluorocarbon tracer gas contained in a small cap. The receptor is a CAT containing an absorbent which collects PFT.

PFT sources may contaminate CATs if transported or stored in close proximity. Sources and collectors should be kept separated. PFT sources should be stored in two ziplock bags with an adsorbing charcoal packet in the inner bag.

Place 3 PFT sources (PMCH silver) in a bundle in the kitchen. Locate the bundle on top of a door jamb. If multiple doors are present in the kitchen, choose an interior doorway leading to the rest of the house. If there are no door jambs in the kitchen, sources may be placed under cabinets which are above stove level. The cabinets close to interior doorways are preferred.

CATs are placed in the kitchen and farthest used room from the kitchen. In a two floor house the second sampler will be on the second floor. The second CAT should not be placed in an unused room in the house. Whenever possible locate the other samplers with the CAT.

VI FLOOR PLAN MEASUREMENT

A floor plan is necessary to calculate the volume of the house and to document location of the samplers. Simple length, width, and height measurements for each floor on which the participants live is sufficient. The measurements should be accurate as the volume is a critical parameter. The following guidelines should be used to obtain estimates of the house.

Inspect the layout of the home, noting the overall shape. Sketch the floor plan and label each room (kitchen, activity room, basement, etc.). Mark the location of monitors and any gas-fired appliances. Note any closed off areas and attached garages. Mark the general area of the outside tube.

Straight-line measurements can be made very quickly using the Rolatape. Record length, width, and ceiling height of each box on the floor plan. If the first and second floors are the same size in your estimate, measure only the first floor. A diagram of the second floor can be made using the first floor measurements. Following are three sample floor plans. In sample floor plan "A" only three measurements are needed, length, width and ceiling height. This home is a simple box with no intrusions. In home "B" several additional measurements are required to allow for the intrusion of a closed stairway into the rectangle. In home "C" the irregular shape complicates the measurements. Divide the floor plan into simple boxes. Measure and label each box separately

Clearly mark the dimensions of the boxes. Accurate labeling is needed to calculate the volume. Any feature of the home that is unusual should be noted This includes wood or coal burning stoves, defective flues, dryer vents, kerosene heaters or excessively drafty doors and windows.

VII Questionnaire

The purpose of the Home Characteristic Questionnaire is to identify and catalog factors that may affect air quality in the study homes. It is the responsibility of the Field Technician to thoroughly understand the questionnaire and its objectives. The questions must be asked with scientific objectivity and professional standards. Read the Home Characteristic Questionnaire description carefully to understand the object of each question. Please speak with the Field Manager if there is any confusion.

During the interview it is important to maintain a professional approach. Studies of survey research methods have shown the interviewer can bias the respondent's answers. Maintaining some distance minimizes the bias and helps maintain a sense of confidentiality and respect for the participant's privacy. Some questions about cooking and clothes washing can be perceived as intrusive if not asked in the proper manner. Two questions are particularly sensitive to bias if not asked properly. One question concerns smoking and the other pertains to the use of the oven for heat.

It is suggested that the interview takes place at the beginning of the first home visit. This allows the technician to explain the study and establish a rapport with the family. Save the "interviewer check" questions to the end when it is more convenient to examine the windows and check the basement.

APPENDIX C.2 ORNL Field Sampling Protocols

- PFT Placement Protocol
- Radon (Track-Etch) Sampling Protocol
- Radon Progeny (MOD) Sampling Protocol
- Formaldehyde Sampling Protocol
- PNA Vapor Sampling Protocol
- Dual Impactor Sampling Protocol
- XAD-4 Sorbent Tube Sampling Protocol
- Biogens Sampling Protocol
- Supplemental Questions, Energy Audit Approval, and Kerosene Heater/Woodstove Usage
- Kerosene Heater Study

PFT PLACEMENT PROTOCOL

1. Place bundle of 3 silver PFT sources in KITCHEN per HSPH protocol (unless KITCHEN is room with wood stove or kerosene heater, then swith sources for KITCHEN and ACTIVITY RM)

2. Place bundle of 3 red PFT sources in room with combustion sources or in ACTIVITY RM if code is 1 or 5 (BE SURE TO DOCUMENT PLACEMENT)

3. Be sure that one of the CATS is placed in the room with the red PFT sources

4. Use HSPH protocol for other aspects of PFT/CAT placement and data recording

RADON (Track-Etch) SAMPLING PROTOCOL

1. Use Radon Scheduling Sheets to schedule visits unless setup is a component of a normal IAQ setup. Record directions and best time to call for subsequent use by field teams.

2. Use Radon Sampler Placement Sheets to record sampler number, house (child) ID, and date placed.

3. Assemble cup, ensuring that the cup is not cracked and that the red ring seals the white filter to the mouth of the cup.

4. Place cup with red ring on top of refrigerator. Failing that, place cup in open location agreeable to home's occupants (document placement).

5. Place a second cup in homes with occupied space substantially underground (up to 10% of homes).

6. In 2% of randomly selected homes, place a replicate cup side-by-side on refrigerator.

7. Return Scheduling Sheets to Field Manager when finished.

8. Return Placement Sheets to data file drawer when finished.

RADON PROGENY (MOD) SAMPLING PROTOCOL

1. When feasible (i.e., when MODs are available and when your timing allows), place a MOD on or next to the particle sampler

2. Record data on field data sheet

3. BE SURE TO CHECK WITH HOMEOWNER ABOUT ACCEPTABLITY OF NOISE LEVEL. SHOW THEM HOW TO TURN PUMP OFF IF NOISE BECOMES UNACCEPTABLE.

4. Either first or second week of monitoring is acceptable for this measurement

5. Return MOD head to laboratory when finished

FORMALDEHYDE SAMPLING PROTOCOL

1. Measurements will be conducted in ACTIVITY RM during setup week in all houses

2. Measurements will be duplicated in ACTIVITY RM in 5% of houses during setup week

3. Measurements will be conducted in KITCHEN in 10% of houses during setup week

4. Measurements will be conducted in BEDROOM in 10% of houses during setup week

5. Measurements will be repeated in ACTIVITY RM in 10% of houses during second week to assess week-to-week variability

6. Place HCHO sampler in rack with HSPH passive samplers

7. Record data on ORNL data sheet

PNA VAPOR SAMPLING PROTOCOL

1. Measurements will be conducted in ACTIVITY RM during first week in all houses

2. Measurements will be duplicated in ACTIVITY RM in 10% of houses during first week

3. When ACTIVITY RM and room with combustion source are different, put sample in both locations

4. Measurements will be repeated in ACTIVITY RM in 10% of houses during second week to assess week-to-week variability

5. Place PNA sampler in rack with HSPH passive samplers

6. Record data on ORNL data sheet

DUAL IMPACTOR SAMPLING PROTOCOL

Perform sampling with dual impactors and pump with a time-share unit during first week's visit to each house. Exchange pumps during changeover and use a single impactor and pump without a time-share unit during second week.

Use a dual impactor setup in one of the second-week homes to provide a measure of week-to-week variation (choose one house from codes 2-8)

SETUP

1. Connect HSPH impactor to pump tube labeled "C" and ORNL impactor to other tube
2. Set time-share timing tabs alternately on and off (switch every 15 min)
3. Set main timer and complete setup per normal HSPH protocol
4. Record data for both timers on field data sheets (HSPH and ORNL sheets)

PICKUP

1. Note sampling times on data sheet
2. Exchange sample pumps for second week
3. Return impactors to field office

NOTE: If a time share unit is used to sample with a single impactor, put all tabs depressed on TSU and connect single impactor to "C" tube.

XAD-4 SORBENT TUBE SAMPLING PROTOCOL

Codes 2-4: Two (2) houses per week until a total of 24 houses are sampled

Codes 5-8: Three (3) houses per week until a total of 36 houses are sampled

SETUP

Place pump with single impactor and XAD sorbent beside normal dual impactor setup (there will be two black boxes and three impactors).

1. Remove caps from tubes and save for pickup — record sample ID on ORNL data sheet

2. Insert the tubes into Y holder with direction of air flow through long sorbant bed then through short sorbant bed (direction of arrow)

3. Position tube holder inside box away from pump to keep tubes cooler during sampling

4. Finish set up of box in normal manner, set timer the same as HSPH sampler, and note data on data sheets

PICKUP

1. Note sampling times on data sheet

2. Remove tubes from sample line inside box

3. Cap and return with impactor

NOTE: Tube ends are sharp and can cut. Handle carefully.

BIOGENS SAMPLING PROTOCOL

Measurements will be conducted during changeover week in as many houses as feasible.

Water sample

1. Use 1 L screw cap bottles
2. Turn hot water of shower on and off abruptly several times during collection to dislodge sediment
3. Put sample ID on ORNL data sheet

Anderson impactors

1. Choose one outdoor and one indoor sampling site (normally ACTIVITY RM.)
2. Keep case upright to open cover (it will set level with cover open)
3. Pull top tray with impactors out and place on top of box
4. Remove cover of impactor and media plate, insert media and replace impactor cover—TSA agar for bacteria in one sampler and ME agar for fungi in the other sampler
5. Press start button, pump will automatically stop in 2 minutes
6. Record data on data sheet
7. When pump shuts off (as soon as feasible) remove media and cover dish
8. Disinfect impactors with alcohol
9. When time and supplies allow, take a second indoor sample at same location—TSA agar will duplicate bacteria sample and ME will be used to measure thermophilic actinomycites

NOTES: Lightly grease O-ring seals twice per week with stopcock grease to help seal during sampling.

Return samplers to lab (WGD) once per week for flow calibration.

Keep spare marking pen in supplies in case agar plates need to be labeled.

SUPPLEMENTAL QUESTIONS, ENERGY AUDIT APPROVAL, AND KEROSENE HEATER/WOOD STOVE USAGE

1. During setups, complete supplemental questions for ORNL monitoring

2. During setups, give homeowner approval card for TVA energy audit. May be picked up during later visit if homeowner wishes. Note on data sheet when completed.

3. Brief homeowner on desired information on wood stove and kerosene heater usage during setup. Leave usage form with homeowner.

4. During pickup, complete wood stove and kerosene heater usage log as much as possible.

House Number _____

Name: _____

_____ I agree to participate in an energy audit. Please forward my name, address, and phone number to the appropriate utility representative.

_____ I do not agree to participate in an energy audit.

Signature: _____ Date _____

TX 5270
(11-85) Power Distributor: _____

Kerosene-Heater Study

Instruction List

1. Save this information packet...you will need it to record information on it on a regular basis.

2. Remove two (2) tubes from the bag marked "NEW."

3. Record the I. D. Number printed on the tube onto the "Data Sheet" (page 2) as well as the Time and Date the tubes are uncapped.

4. Remove the red cap from the tube and save it. Slide the tube into one of the clip-holders provided.

5. Place 2 tubes in the room where the kerosene heater is operating.

6. Place the tubes as follows...
   - 2-6 feet from the floor
   - at least 6 feet away from the heater
   - at least 6 inches from wall

7. Leave the tubes out for one week (e.g., Sunday to Sunday)

8. Record the daily usage in house of kerosene heater. Use the "Daily Usage Log" (page 3).

9. Recap the tubes after one week and record the Time and Date on page 2 and place the tubes in the bag marked "USED."

10. Repeat the process for each week of the Study until the packages are picked up in mid-March.

Data Sheet

Week 1:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 2:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 3:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 4:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 5:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 6:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 7:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 8:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 9:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm
Week 10:	ID Number 1: _____	ID Number 2: _____
	Date Uncapped _____	Date Uncapped _____
	Time Uncapped _____ am/pm	Time Uncapped _____ am/pm
	Date Capped _____	Date Capped _____
	Time Capped _____ am/pm	Time Capped _____ am/pm

Kerosene Heater
Daily Usage Log

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 2:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 3:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 4:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 5:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 6:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 7:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 8:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 9:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___
Week 10:	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___	hours used ___

KEROSENE STUDY

QUESTIONNAIRE

Last Name _____ I.D. # _____

1. What is the name of the kerosene heater? _____

2. What is the model? _____

3. What is the BTU output? _____

4. In what room is the kerosene heater used? _____

5. How far (in feet) are the sample tubes from the kerosene heater? _____

6. About when was the last time you changed the wick? _____

7. When burning, is the flame in the kerosene heater _____ blue? _____ white?

8. Is the kerosene heater the convective type (i.e., round) or the radiant type (i.e., square)? _____

9. Picked up tubes? ____ yes ____ no

   Picked up usage log? ____ yes ____ no

   Picked up T.E. cups? ____ yes ____ no

APPENDIX C.3 Analyses Protocols

- SF Track-Etch Radon Detectors (Terradex)
- PF-1 Passive Formaldehyde Monitor (AQR)
- Polynuclear Aromatic Hydrocarbons
- Microorganisms

TERRADEX CORPORATION

FEBRUARY 1986

CALIBRATION OF TRACK ETCH RADON DETECTORS

BY

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February 18, 1986

INTRODUCTION

The latest group of **Track Etch** radon detectors have been systematically exposed and returned to Terradex for analysis. The 640 detectors from batches 21 and 23 were exposed to amounts of radon ranging from 118 to 1406 pCi/l-days. To insure accuracy, the exposures were carried out by three independent testing agencies. These were the U.S. Department of Energy's Technical Measurements Center operated by Bendix Field Engineering Corporation in Grand Junction, Colorado; the U.S. Bureau of Mines in Denver; and the U.S. Department of Energy's Environmental Measurements Lab in New York City. These exposures and subsequent analyses represent the first conclusive results we have for batch 23 and statistical improvement of our calibration coefficient for batch 21.

EXPOSURE

In each of the 16 runs 40 detectors were exposed simultaneously to radon concentrations ranging from 74.3 to 225.1 pCi/l. Table 1 lists the radon concentration and duration of exposure for each run. The exposure is a product of these two factors. In each run, the 40 detectors used consisted of eight sets of five identically composed detectors, one set from batches 21 and 23 in each of the four configurations: F, M, SF, SM.

TABLE 1

EXPOSURE CONDITIONS FOR CALIBRATION OF TRACK ETCH RADON DETECTORS
February, 1986

		Run #	Radon Concentration (pCi/l)	Duration (days)	Radon Exposure (pCi/l)-days
Bendix	11/11/85	1	200.9	7.0	1406.3
	11/12/85	2	199.6	3.0	598.8
	2/05/86	3	-	-	1195.9
	2/03/86	4	-	-	776.4
U.S. B of M	11/24/85	1	153.8	3.72	572.1
	11/31/85	2	225.1	3.00	675.4
	12/06/85	3	223.8	3.96	886.7
	12/13/85	4	220.1	3.33	732.9
EML	8/30/85	1	129.6	6.66	864
	8/30/85	2	146.5	4.66	683
	8/30/85	3	105.3	3.0	316
	8/30/85	4	113.4	1.04	118
	12/09/85	1	83.3	2.73	227
	12/11/85	2	83.2	4.73	394
	12/13/85	3	78.5	6.74	529
	12/16/85	4	74.3	9.74	724

RESULTS

After routine processing a calibration coefficient for each batch/configuration combination is calculated. This is done by first calculating the average track density of the five identically composed detectors and then dividing this average by the exposure reported to us by the independent testing agency. The calibration coefficients from all 16 runs are then averaged to produce the coefficients which we use to determine the exposure of our commercially available detectors. Table 2 lists the coefficient calculated for each of the 16 runs in each of the 8 batch/configuration combinations.

Table 2. CALCULATION OF CALIBRATION COEFFICIENT (February, 1986)

	BENDIX				U.S.B. of M.				ENVIRONMENTAL MEASUREMENTS LABORATORY							
Date	11/11	11/12	2/5	2/3	11/24	11/31	12/6	12/13	8/30	8/30	8/30	8/30	12/9	12/11	12/13	12/16
Run #	#1	#2	#3	#4	#1	#2	#3	#4	#1	#2	#3	#4	#1	#2	#3	#4
Configuration & Batch #																
FI 21	.0546	.0493	.0596	.0571	.0565	.0623	.0638	.0560	.0474	.0437		.0415	.0409	.0429	.0397	.0398
ME 21	.0387	.0385	.0360	.0338	.0487	.0487	.0503	.0409	.0320	.0288		.0132	.0219	.0255	.0299	.0299
FI 23	.0636	.0569	.0714	.0632	.0752	.0673	.0918	.0716	.0788	.0821	.0482	.0419	.0439	.0418	.0433	.0456
ME 23	.0503	.0451	.0438	.0378	.0586	.0541	.0572	.0552	.0379	.0340	.0209	.0142	.0261	.0299	.0338	.0342
SF 21	.0183	.0177	.0174	.0172	.0190	.0214	.0208	.0209	.0188	.0163	.0158	.0161	.0169	.0170	.0193	.0187
SM 21	.0174	.0181	.0187	.0166	.0205	.0188	.0211	.0214	.0145	.0157	.0138	.0136	.0154	.0159	.0178	.0165
SF 23	.0190	.0184	.0212	.0201	.0222	.0226	.0223	.0248	.0177	.0175	.0182	.0205	.0206	.0221	.0191	.0206
SM 23	.0221	.0202	.0239	.0182	.0279	.0229	.0227	.0212	.0177	.0167	.0188	.0156	.0181	.0185	.0179	.0167

CONCLUSION

The final step involves averaging the coefficients for each of the 16 runs and calculating the standard deviation of this mean. The table below lists the batch/configuration combination with the corresponding calibration coefficient and its associated error estimate.

CALIBRATION COEFFICIENTS

February 1986

Configurations	$\bar{X}$	$\pm\ \delta\bar{X}$*
FI21	0.0503	4.3%
ME21	0.0345	7.5%
FI23	0.0617	6.6%
ME23	0.0396	8.4%
SF21	0.0182	2.4%
SM21	0.0174	3.5%
SF23	0.0204	2.5%
SM23	0.0199	4.1%

* $\delta\bar{X}$ = standard deviation of the mean.

Terradex is committed to maintaining its outstanding record of accuracy despite the pressures of increasing volume and interest.

AIR QUALITY RESEARCH, INC.
INTERNATIONAL

13.74

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February 1985

OPERATING CHARACTERISTICS OF THE PF-1 PASSIVE FORMALDEHYDE MONITOR

The PF-1 Passive Formaldehyde Monitor allows rapid, simple and inexpensive screening of ppm-ppb levels of airborne formaldehyde in homes and offices. The following is a summary of the operating characteristics of the PF-1.

Conditions for Sampling

The PF-1 monitor samples formaldehyde for periods up to one week in indoor environments. The monitor is suspended from the ceiling using the attached ribbon and tack. When the cap is removed the PF-1 begins to sample formaldehyde in the air. Preprinted labels are provided so that sampling information can be recorded and attached to each monitor. Two monitor and other necessary items are provided in a mailing kit.

Analytical Method

AQRI analyzes the entrapped formaldehyde using the commonly-used chromotropic acid method. The specific procedure is a modification of the method standardized by the National Institute for Occupational Safety and Health (NIOSH P & CAM 125) and is available upon request. For laboratories performing their own analyses AQR can provide "spikes" and blanks for quality assurance programs.

Product Performance

A fraction of each lot of PF-1 monitors is exposed to a carefully controlled test atmosphere of formaldehyde gas for one week. The air concentration of formaldehyde is nominally 0.1 ppm and the relative humidity is 50%. PF-1 monitors are also tested to verify that "blanks" are acceptably low. Monitors demonstrating acceptable performance as detailed below are released.

Accuracy and Precision

Monitors are released for use when the-two sided tolerance limits for that lot indicate that there is a 95% probability that at least 75% of the monitors produce results within ± 25% of the known air concentration obtained simultaneously from reference bubblers. Because tolerance limits combine both the mean and the variance in a single statistic, specific values of these parameters (mean and variance) vary from lot to lot. However, both the bias (observed minus true concentration) and the relative standard deviation for a given lot are typically less than 10%.

If a group of PF-1 monitors were exposed to the same formaldehyde concentration, the mean air concentration observed for the group would typically be within 10% of the true concentration.

Range of Quantitation

Range for a one week exposure: 0.025-1.0 ppm

Blanks

Monitors are released for use when blank values for packaged monitors are found to contain less than 0.01 ppm equivalents of formaldehyde (assumes a one-week exposure). Measured blank values are available upon request for each lot of PF-1 monitors.

Typical equivalent air concentration of blank:

0.005-0.007 ppm

Stability

Established shelf life of PF-1 monitors prior to exposure:

6 months

Established stability of exposed PF-1 monitors prior to analysis:

1 month

Relative Humidity Range

Minimum range of relative humidity over which the PF-1 monitor can detect formaldehyde concentrations of 0.1 ppm (under combined conditions of high humidity and high formaldehyde concentration the sampling period should be shortened to five days):

30 - 80% RH

Interferences

There are no known interferences at this time. A small number of compounds interfere with the chromotropic acid analysis applied to the PF-1 monitor, but these compounds are seldom encountered in indoor environments and are not expected to be collected by the selective trapping agent employed in the PF-1 monitor.

Protocol

For

Polynuclear Aromatic Compounds Measurements in the Kingston-Harriman 300-House Study

by

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Submitted to

U.S. Consumer Product Safety Commission

INTRODUCTION

There is increasing interest in monitoring the exposure of people to polynuclear aromatic (PNA) compounds emitted in indoor environments from the combustion of fuels and from various domestic activities and as cooking and cigarette smoking. Health assessment studies could be costly because these studies require extensive and long-term monitoring and analysis programs involving large numbers and the use of sophisticated analytical techniques, such as high-performance liquid chromatography (HPLC) and gas chromatography/mass spectrometry (GC/MS). In many situations, a screening phase to identify crtical problem areas can reduce the cost of monitoring programs and help select a high PNA concentraction groups that should be considered for more extensive study.

The primary objective of this task is to evaluate the efficacy of a screening method based on synchronous luminescence (SL) for PNA compounds in air sample extracts, and to assess the use of a passive PNA monitor developed at ORNL to detect PNA vapors and aerosals. The experimental protocol for this project is presented in the following section.

I. Sampling Protocol

Samples will be obtained using two different sampling methods. PNA badges developed at ORNL will be used as a passive sampling device for polynuclear aromatic hydrocarbons. Sample extracts from the Harvard particulate samplers will also be obtained. The badges will be co-located with the other passive samplers on a rack designed to hold the suite of passive samplers. In a subset (5%) of homes where the main activity area being sampled is not located near the combustion source (e.g., the woodstove. A second passive sampler will be located near the source.

In the sampling protocol for the other planned samples two consecutive weeks of sampling will take place with the samplers being changed at the end of the first week. New samplers will be put in place for the second week. The PNA samples and the concurrent particulate samples will only be taken during one of the sampling weeks. All 300 homes will be sampled with at least the PNA badge/particulate sampler combination during the winter season.

In a subset of up to 20% of the houses sampled, the Harvard particulate sampler will be backed up with two XAD-4 tubes in parallel to trap any vapor phase PNAs that may escape the particulate samplers. Preliminary tests have shown that using two tubes in parallel does not degrade the flow characteristics of the samplers. The particulate samplers operate at a flow rate of four liters per minute. Scoping studies will be performed to determine if these are any effects related to sample volume and flow through the tubes such as loss of the lighter PNA compounds.

II. Extract Protocol

Samples received for analysis will be extracted as soon as possible after arrival to minimize evaporation losses and chemical degradation.

Two types of extraction procedure will be used. (1) The teflon filters from teh air flow sampling will be extracted with methylene chloride and ultrasonic agitation. This solution will evaporate and the residue will be disolved in a standard volume of methanol for storage and analysis. (2) The XAD-4 tubes will be attached to a syringe for washing with methanol and then methylene chloride. The combined extracts are dried, disolved in a standard volume of methanol for storage and analysis.

I. Analytical Protocols

The Synchronous Luminescence (SL) Technique:

Conventional luminescence spectroscopy utilizes either a fixed emission or excitation wavelength. With synchronous excitation spectroscopy, the luminescence signal is recorded while both emission and excitation monochromators are simultaneously scanned; the wavelength interval, $\Delta\lambda$, between the two monochromators is kept constant throughout the measurement. Improved selectivity without loss of simplicity in experimental protocol is the main advantage of this method. In general, the spectral structure of the composite mixture is more resolved because the spectra of the individual components are simplified and the bandwidth narrowed. The decrease of spectral overlap from various components in the mixture is another attribute of the synchronous technique.

The concept of synchronous excitation can be applied both to fluorescence, i.e., synchronous fluorimetry (SF), and to phosphorescence, e.g., synchronous phosphorimetry (SP). In the case of SF, the Stokes shift, i.e., the wavelength difference between the 0-0 bands in emission and absorption, determines the optimum value of $\Delta\lambda$, which is often set at 3 nm. For SP, it is the singlet-triplet energy difference that determines the optimum value of $\Delta\lambda$.

The SL Analytical Protocol

In this work we use a three step protocol in order to obtain a ranking index, based on SL, of air sample extracts. The first step is serial dilution of the samples. The second step is obtaining SL spectra of the diluted samples. The third step consists of ranking the samples.

The computer program developed to calculate ranking index for SL receives, as inputs, the peak height intensities of a previously determined number of emission bands or the integrated spectral area, the sensitivity factor of the detector, the dilution factor of the sample, and peak height of a given band of a known standard reference sample. These peak height intensities are then corrected to the reference standard, normalized to the unity sensitivity scale of the spectrometer and original dilution of the sample, and summed. The ranking program can also correct for spectral artifacts such as filter effects and energy transfer commonly encountered in luminescence measurements. The summed value of the peak height for each sample is stored in a one-dimensional array and used as a basis for ranking. Because most of the PNA compounds fluoresce, the rationale of this ranking protocol is based upon the idea that the higher the total peak height of the SL bands, the more concentrated the samples are in PNA species. The SL

ranking index is a relative number proportional to the total peak height of the major SL emission bands. The relative standard deviations of the data obtained were typically ± 5%.

Values of SL and RTP obtained from extracts from the Harvard air samplers will be compared to HPLC data to establish the correlation statistics.

II. Room Temperature Phosphorescence (RTP) Technique using the PNA Passive Monitor

The PNA Passive Monitor

The PNA dosimeter is a self-contained, badge-size passive monitor. The device is lightweight (~20 g) and can be conveniently worn by a person or placed at a stationary location. The monitor consists of a holder, a filter paper substrate, and an interchangeable diffusion chamber. The heart of the dosimeter is the sample collection cellulosic substrate treated with a heavy-atom chemical such as thallium acetate or lead acetate. The monitoring procedure is based on the measurement of the quantity of the PNAs transfered to the substrate surface via molecular diffusion in air. The mass M, of PNA compounds collected at the sorbent surface is given by:

The RTP Technique

The RTP method is a relatively new approach based on the detection of phosphorescence from organic compounds adsorbed on various solid substrates such as filter paper, silica gel, and sodium acetate[6]. At room temperature, phosphorescence of organic compounds is normally a very weak emission that is difficult to detect in liquid solutions or in the gas phase. This is due to the fact that the phosphorescence is almost totally quenched by collisions in liquid and gas samples, or is deactivated by intramolecular vibrations and rotations. The conventional phosphorescence technique, therefore, typically requires low temperature equipment and frozen solvents to reduce the probability of these quenching processes so that the phosphorescence signal may be more easily detected. Unlike conventional phosphorimetry, the RTP technique does not use cryogenic technology. This feature is one of the main attributes of this method for routine applications and field measurements.

The unique feature of this dosimeter is the dual use of the heavy-atom chemical as the sorbent agent and as the RTP inducer. The paper substrate of the dosimeter is treated with a heavy-atom chemical that enhances the RPT emissions of the PNA compunds. This process, known as external heavy-atom perturbation, provides an invaluable aid to RTP detection.

Draft Protocols for Biogen Sampling of the Kingston-Harriman Homes

R. L. Tyndall

1. Sampler Selection

1.1 N6-Andersen: The Andersen viable impactor will be used for collection of airborne particles in the home environments. A modified single stage version of the Andersen sampler [referred to as NIOSH-6 (N6) Andersen sampler] will be used in place of the original multistage impactor. In the N6 Andersen sampler a Petri dish containing culture media is placed on top of the instrument base plate.

1.2 Litton-type High Volume Sampler: The utility of the Litton-type sampler is recognized. The sampler may be used where airborne concentrations of microorganisms is expected to be very low, such as with *Legionella*. Constraints in using this sampler in a large number of houses is recognized.

2. Sampler Calibration

The N6 Andersen samplers are calibrated to air flow rates recommended by the manufacturer (28 liters per min). Air flow rate through samplers are checked on a weekly basis using a rotameter. The Litton-type samplers are calibrated by the manufacturer and are used at an air collection rate of 800 liters per minute.

3. Sampler Disinfection

For use in the field the N6 Andersen sampler is decontaminated by immersion in 70% ethanol. Excess ethanol is drained away and the sieve plate allowed to dry before its next use. The Litton-type High Volume sampler is flushed through with ethanol and sterile, distilled water prior to use. The last rinse is retained and compared with test samples

for proper interpretation of results.

4. Culture Media

Most of the media used is for the detection of three classes of microorganisms, namely fungi, bacteria, and thermophilic actinomycetes. These media are recommended because they provide good general support for growth of microorganisms. In addition, more specific media is required for the growth of *Legionella* and for the identification of free-living amoebae.

4.1 Media for General Detection and Enumeration of Fungi: Malt extract agar - ingredients per liter of distilled water:

Malt extract	20 g
Peptone	1 g
Dextrose	20 g
Agar	20 g

4.2 Media for General Detection and Enumeration of Bacteria and Thermophilic Actinomycetes: Ingredients per liter distilled water: Trypticase soy agar - 40 g

4.3 Additional Media: Charcoal yeast extract agar plates (Gibco Co.) are used for attempted isolation of *Legionella* from high volume air samples or in the N6 Andersen sampler. Nonnutrient agar plates seeded with a lawn of *E. coli* are used for isolation of free-living amoebae.

4.4 Incubation: Malt extract agar plates are incubated for 2 to 5 days at 35°C. Trypticase soy agar plates for bacteria are incubated for 2 days at 35°C. Trypticase soy agar for thermoactinomycete isolation are incubated at 50°C for 3-7 days. Duplicate counts at single impaction sites on plates from the N6 Andersen sampler

plates are avoided as are the counting of colonies that grow at sites other than the 400 impaction locations.

5. Quality Assurance

Culture media is checked for sterility and ability to support the growth of the organisms being collected. These include *Cladosporium*, *Alternaria*, *Mucor*, *Fusarium*, *Aspergillus*, *Staphylococcus*, *Micrococcus*, *Streptomycetes*, *Escherichia*, and *Bacillus*. Culture plates are also inserted into the sampler (with pump off) and then checked for sterility. Random bacterial colonies are also analyzed microscopically and, in the case of potential pathogens, enzymatically, to verify colony identification. Similarly, identification of random fungal and actinomycetes colonies are confirmed by microscopic analysis of wet mount preparations.

6. Sampling Locations

Duplicate, two-minute samples on TSA plates will be taken in the activity room of the test home for determining bacterial profile and degree of replication. Duplicate two-minute samples on ME plates will also be taken in the activity room for determining fungal and actinomycete content of the indoor air. One two-minute sample on TSA and ME plates will be taken of the outside air for comparison with inside air. In a subset of homes two-minute samples on both TSA and ME plates will be taken at the air discharge of central air conditioning ducts, humidifiers and refrigerator drip pans for comparison of these microbial populations with that of the general indoor air samples obtained from the activity room. Water from humidifiers will also be analyzed for microbial flora including *Legionella* and free-living

amoebae. Either ten or thirty-minute air samples using the Litton-type high volume or N6 Andersen sampler, respectively, will be taken proximal to a running hot water shower or faucet. Hot water from shower heads or faucets will be taken for *Legionella* and general microbial analysis and refrigerator drip pan water will be analyzed for free-living amoebae and bacterial content.

7. Identification of Microorganisms

The following microorganisms will be identified and enumerated (CFU per m^3):

Acremonium spp.
Alternaria spp.
Aspergillus spp.
Aureobasidium spp.
Chaetomium spp.
Cladosporium spp.
Mucor spp.
Penicillium spp.
Fusarium spp.
Other predominant fungi
Thermoactinomycete spp.
Acanthamoebae spp.
Naegleria spp.
Bacillus spp.
Staphylococcus aureus
Staphylococcus epidermidis
Other *Staphylococcus* spp.
Streptococcus salivarius
Other *Streptococcus* spp.
Corynebacterium spp.
Actinetobacter spp.
Pseudomonas spp.
Flavobacter spp.
Legionella spp.
Micrococcus spp.
Other predominant bacteria

APPENDIX C.4 Summer Phase Protocols

DUAL IMPACTOR SAMPLING PROTOCOL
(Summer)

The field protocol for the summer is the same as the winter's, except that no second week samples will be taken.

XAD-4SORBERNT TUBE SAMPLING PROTOCOL
(Summer)

Same as the winter protocol except for the following:

Codes 1-4: One (1) house per week

Codes 5-8: Three (3) houses per week, with one (1) of the three having a replicate setup

SETUP

1. The Y holder is connected directly to the impactor with a short length of teflon tubing with silicon joints

2. The XAD tubes and hosing are to be taped to the impactor to prevent crimping and damage to the tubes

PICKUP

1. Cap the tubes and return them in the impactor box or ORNL bag

2. Throw away the piece of teflon tubing with the joints

PNA VAPOR SAMPLING PROTOCOL
(Summer)

1. Ten (10) of the smokers' and six (6) of the non-smokers' houses will be monitored during the first week in the ACTIVITY RM

2. Four (4) of the ten smokers' houses will have triplicate measurements made at the same location

3. Six (6) of the smokers' houses will have a single PNA cell

4. Two (2) of the six non-smokers' houses will have the triplicate measurements

5. Four (4) of the non-smokers' will have a single PNA cell

6. Blanks will be placed in two (2) houses at random

7. PNA samplers will be placed in rack with HSPH passive samplers

8. Data will be recorded on the ORNL data sheet

FORMALDEHYDE SAMPLING PROTOCOL
(Summer)

The field protocol for the summer is the same as the winter's, but four (4) houses will have second week formaldehyde samplers.

PFT PLACEMENT PROTOCOL
(Summer)

1. Check to see that all sources are still present, if otherwise ask the family if their whereabouts are known

   - If a silver source is known to have been removed from the house, replace it with another silver source, record its ID number on the coversheet

   - If a silver source's whereabouts cannot be determined, replace the missing one or ones with black source(s) and record its ID number on the coversheet

   - Sources are to be replaced on a one to one basis

   - If a red source(s) is missing do not replace it, simply write a comment on the cover sheet.

2. Check to see that all of the sources still contain their fluid

   - If a silver source is found to be empty, replace it and record the new source's ID number

   - If a red source is found to be empty, do not replace it, simply write a comment on the coversheet

3. Comments should be used liberally to flag any changes in the status or location of the sources

4. The CATs should be placed in the same locations as they were in the winter, if the placements are different record the fact on the coversheet

5. Retrieve all Pft's during the final pickup visit

OCCUPANT BEHAVIOUR QUESTIONNAIRE

1. The questionnaire is to be issued at the pickup visit

2. The questions pertaining to combustion may be omitted

3. If more than three questionnaires per week are not given due to an absent occupant, outstanding questionnaires may be issued over the phone

HSPH REPLICATE PM2.5 STUDY

1. A second pump will be placed in the STUDY BR with an HSPH impactor

2. One (1) replicate will be made in houses with code 1-4 per week (non-smokers) and two (2) replicates will be made in houses with codes 5-8 per week (smokers)

3. The replicates will be run for both weeks

HARVARD SUMMER SAMPLE CHECKLIST

1. The questionnaire may be issued at any time
2. The questionnaire may also be issued over the phone

DRAFT June 11, 1986 DRAFT

300-HOME KINGSTON/HARRIMAN STUDY

MICROBIOLOGICAL MONITORING

SUMMER PROTOCOLS

Technical Contact: R. L. Tyndall (FTS-624-0686)

The protocols for microbial sampling of the 240 homes (I), the 40 homes (II) and the 10 homes (III) will utilize three initial isolation media. Trypticase soy agar (TSA) is used for isolation of the aerobic bacteria. Charcoal yeast extract (CYE) agar is used for isolation of Legionella. Fungi are isolated using malt extract agar (ME). Approximately 240 homes will be monitored for fungi and bacteria.

I. The protocol for sampling of the 240 homes is as follows:

1. Duplicate (i.e., simultaneous) 2 minute air samples on TSA plates and duplicate 2 minute air samples on ME plates will be taken in the activity room of 120 homes.
2. Duplicate 2 minute air samples on ME plates plus additional 2 minute air samples on ME and TSA plates will be taken in the activity room of 120 homes.
3. Two minute air samples on one ME and one TSA plate will be taken at an outside location at 200 homes.
4. Duplicate 2 minute air samples on ME and TSA plates will also be taken at an outside location at 40 homes.
5. A TSA or ME plate will be inserted into the sampler once each day without turning on the pump. This will serve as a control plate for evidence of background or operator contamination.
6. Hot water from all locations, preferably from shower heads will be collected.
7. Air temperature and humidity as well as hot water temperature will be taken.

This protocol allows for sampling for bacteria, fungi, and thermophilic actinomycetes in 240 homes and duplication of the bacterial and fungal plates in 120 of the homes. Duplication of fungal and bacterial plates is also effected in the outside sampling of 40 of the homes. The fungal plates

(ME) are incubated at 25-30°C and colonies identified according to genus. The bacterial (TSA) and actinomycete (ME) plates are incubated at 35° and 50°C, respectively, with colonies identified according to genus. The water samples are examined by the direct fluorescent antibody test (DFA) for quantitation of Legionella.

II. Twenty of the forty houses will be selected on the basis of high total microbial content or presence of potential pathogens, as indicated by results of the winter sampling and/or available time during the spring sampling. Twenty of the forty homes will be randomly chosen.

The protocol for sampling of the subset of 40 homes for possible microbial sources is as follows:

1. As a subset of the 240 homes the 40 homes will be sampled as described in protocol I.
2. A fifteen minute air sample (Anderson) using duplicate ME plates will be taken for presence of thermophilic actinomycetes.
3. 1 TSA, 2 ME and 1 CYE plate each will be used in 2 min air sample (Anderson) of various sources of microbial aerosols. These include: AC duct outlets; refrigerator drip pan outlets; humdifiers; dehumidifiers, if aerosol producing; window AC units; whirlpools, saunas, hot tubs and water-damage areas. In addition, duplicate CYE plates will be used to take 10 min samples adjacent to running hot water faucets or showers.

Potential sources of indoor microbial aerosols will be sampled as indicated:

Equipment Needed: Water sampling bottle, thermometer, quad-pod (for wall AC units), extra-long tubing (for wall AC units), and a

Plexiglas shield to direct air from the various sources to the air sampler.

Refrigerators: The plate holder should be placed immediately adjacent to the vent located on the bottom front of the refrigerator. Disinfect Plexiglas shield and place it over the plate holders with the open face of the shield flush with the vent face. Use tape to seal up vent area to either side of shield. Open the refrigerator door until you hear the fan cycle on and begin sampling for two minutes. Use one TSA, one CYE and two ME plates. Record house ID and location onto data sheet and plates.

Shower Heads: Turn on hot water to shower head and collect first liter of water in a sampling bottle. Let water run until steam begins to build up and begin sampling for a ten-minute interval with duplicate CYE plates. When adequate steam in bathroom has been built up, turn off hot water. In large bathrooms, the plate holder may be placed on the tub sill with the shower curtain behind it to prevent undue dilution of the steam.

HVAC: If unit is on when entering home, turn the AC and HVAC fan off. In either case, record the status of the usage just prior to sampling onto the data sheet. Disinfect shield and place it over floor vent (if present) with open side facing forward, shunting air over the plate holder placed adjacent to the vent. If the vent is located in the walls, use quad-pod with extra-long

tubing to raise plate holder to an adjacent position. Turn on HVAC fan and AC unit and begin sampling for two minutes. Use one TSA and CYE plate and two ME plates and record house ID and location onto data sheets and plates.

AC Wall Units: Follow the same procedure as HVAC, using the quad-pod to position holder in an appropriate position.

Humidifiers, Dehumidifiers, Whirl Pools, Saunas, Hot Tubs and Water Damage Areas: Place sampler proximal to any obvious or suspected aerosols or to water damage area and sample using the type and number of plates as indicated for the refrigerator and HVAC sampling.

The plates will be incubated and resultant colonies characterized as indicated for the protocol I sampling. In addition any colonies indicative of pathogenic bacteria or fungi will be transferred to fresh media for further speciation and possible typing.

Also, when possible, water samples will be obtained from the appliances and the total bacteria population determined by the standard plate count method. Duplicate ME plates will also be incubated at 50° for detection of thermophilic actinomycetes. Microbial pathogens will be concomitantly quantitated on the same plates and transferred to fresh media for further speciation and possible typing. The water samples will also be tested for the presence of free-living amoebae. If possible, the temperature of the

water will also be measured.

When practical, the manufacturer, model number, age, general condition and origin of the water for the appliances will be noted and recorded.

III. The protocol for sampling ten of the 240 house subset will include testing for nonviable biogens. Approximately one half of these 10 test houses will be selected, partly on the basis of known allergy problems in one or more of the occupants.

1. Sample each house using both protocols I and II.
2. Water samples will be obtained from potential sources if possible.
3. In addition, impinger and/or Litton-type high-volume samplers will be used to take 30 minute air samples in locations indicated in protocols I and II. Allergens present in the air will be collected and deposited in 150-300 ml of sterile water as indicated in the following descriptions.

The Sci-Med Model M-3A Litton-type high-volume air sampler is designed to collect paticulate matter continuously from a large air sample (maximum of 1×10^3 L/min) and deposit it into a small amount of liquid. This effects a concentration factor on the order of 1×10^5 during a 1/2-h sampling period.

The Greenberg-Smith impinger air sampler is a simple vacuum-driven device capable of processing air at approximately 25 L/min. The "inhaled" air is passed through sterile filtered water so that the particulates remain in the water phase. A second reservoir is connected in series with the first; most particles inadvertently carried through the first reservoir will be collected in the second. In our experience, bacteria are rarely found in the second reservoir even when the first is positive, indicating that the

first reservoir generally traps the majority of the particulate matter. In these tests, the samplers will be run for 30 minutes, processing approximately 0.75×10^3 L of air. After sampling, the two 150-mL water reservoirs are combined and analyzed for allergens.

4. The collectate is centrifuged to concentrate the allergens preparatory to analysis by the direct fluorescent antibody (DFA) technique. Waters in which the airborne allergens were deposited will be centrifuged at 2000 x g for 45 min at room temperature to concentrate suspended particulates. Aliquots of the centrifugates will be examined using DFA with antisera prepared against allergens of interest. Sub-samples (0.010 mL) will be pipetted into predesignated 7-mm-diam wells on toxoplasmosis slides. Negative controls will be fluorescein-conjugated sera prepared from the preimmunization sera of rabbits later immunized with the allergens. Samples will be viewed using epifluorescence microscopy.

5. Antisera to two classes of allergens will be used in the DFA test. One class of allergens will be fungal and the other will be chosen in consultation with CPSC staff.

Fungal antisera will be obtained by immunizatiion of New Zealand white rabbits with a mixture of mycellium and spores of Aspergillus, Mucor and Penicillium. The serum will be conjugated with fluorescein isothiocyamate. The fluorescein tagged antisera will be reacted with the allergens previously deposited in measured amounts onto the toxoplasmosis slides. The average number of fluorescent pieces of fungi or spores per microscopic field will be determined and the concentration of allergen per cubic meter of air will be ascertained. The specificity of the technique derives not

solely from the antisera but also relies on only counting fluorescent debris indicative of fungal morphology.

APPENDIX D

Indoor Air Quality Notes

- Number 2 - January 1986
- Number 3 - April 1986

OAK RIDGE NATIONAL LABORATORY

ornl INDOOR AIR STUDY *NOTES*

Number 2 Health and Safety Research Division January 1986

INDOOR AIR STUDY *NOTES* is our attempt to keep study participants informed of the progress, logistics, and results of our various indoor air quality field studies. *NOTES* will be issued quarterly while our studies are under way. This quarter we are distributing *NOTES* to a new study group (see 300-home Kingston/Harriman item below). Should you have comments or suggestions, please let us know. We hope you find our *NOTES* useful and informative.

FOUR-STATE TENNESSEE VALLEY IAQ STUDY

WINTER SCHEDULE for home visits: Chattanooga - placement week of January 6, pick-up week of January 13; Birmingham - placement week of January 27, pick-up week of February 3; Huntsville/Florence/Tupelo - placement week of February 24, pick-up week of March 3. Homes in Oak Ridge area are tentatively scheduled for sample placement on January 16 and sample pick-up on January 23.

SPRING SCHEDULE for home visits: Chattanooga - placement week of April 7, pick-up week of April 14; Birmingham - placement week of April 28, pick-up week of May 5; Huntsville/*lorence/Tupelo - placement week of May 26, pick-up week of June 2. Homes in Oak Ridge area are tentatively scheduled for sample placement on April 17 and sample pick-up on April 24.

SCHEDULES ARE TENTATIVE at present. We will call to schedule specific times to visit your home. We will try to contact you if our projected arrival time differs from the scheduled time by more than 30 minutes. If you plan to be away during the week scheduled for your city, please inform us so that we can adjust if possible.

STUDY STAFF: Ken Monar, Jeff Quillen, Mike Capacci, Charles Clark, Charles Dudney, and Alan Hawthorne. You can contact us at (615) 574-6829 or (615) 576-2712. Students with the University of Alabama Birmingham will be assisting with measurements in the Birmingham area.

PRELIMINARY SUMMARY RESULTS of our first quarter of measurements will be presented in our next quarter's issue of *NOTES*. We hope you will find this preview interesting.

CITIES INCLUDED in our Indoor Air Quality (IAQ) study are: Oak Ridge, Tennessee (6 homes); Chattanooga, Tennessee (9 homes); Rossville, Georgia (5 homes); Birmingham, Alabama (20 homes plus 10 energy efficient homes); Huntsville, Alabama (8 homes); Florence, Alabama (8 homes); and Tupelo, Mississippi (4 homes).

THANKS FOR PROMPT and accurate return of the second week samplers for nitrogen dioxide. Please remember to record both the time and date when you close the samplers. This monitoring helps us evaluate the variation in concentration from one week to the next.

ENERGY AUDITS will be scheduled by representatives of either TVA or Alabama Power Co. for those homeowners who agreed to such a survey. If you have not returned the energy audit request (the bottom of last quarter's *NOTES*), please fill it in and return it or call us collect about the surveys. We would like to complete this phase of the study in time to correlate results with our indoor air quality measurements.

DO YOUR HEATING/COOLING DUCTS leak? Conditioned air (i.e., heated or cooled) can escape through openings in duct work which runs through unconditioned living spaces (e.g., garages, outside heat pumps). Pollutants in garages may also enter living spaces via this route. We plan to perform a simple test to evaluate the difference in air exchange rates when the central fan of the heating system is operating and again when it is off in a subset of study homes. Study staff will be contacting you to describe the measurement and to see if you would be willing to participate in this additional measurement.

MEASUREMENTS IN THE 10 new "energy efficient" homes in the Birmingham area will begin with the winter quarter measurements and extend for four subsequent quarters.

NOTES is prepared by Measurement Applications Group, Health and Safety Research Division, Oak Ridge National Laboratory, which is operated by Martin Maietta Energy Systems, Inc., for the U.S. Department of Energy, under Contract No. DE-AC05-84OR21400.

KINGSTON/HARRIMAN IAQ STUDY

OAK RIDGE NATIONAL LABORATORY is working with the Harvard School of Public Health to measure indoor air quality in 300 homes in the Kingston/Harriman area of East Tennessee. This effort will support the Harvard Lung/Air Quality Study, which will measure indoor air quality in 300 homes in each of six cities in the United States. In addition to the "core" series of measurements (nitrogen dioxide, respirable particulate matter, water vapor, and air exchange rates), we will be conducting supplemental research sponsored by the Tennessee Valley Authority, the Electric Power Research Institute, and the Consumer Product Safety Commission. We will be measuring levels of additional indoor pollutants and evaluating the impact of various energy using/conserving practices on indoor air quality. Most of the measurements will be made at the same time as measurements performed for the Harvard Lung/Air Quality Study. Monitoring will generally be conducted with passive sampling tubes or with small air pumps operated while field technicians are placing the sampling tubes. Following is a list of the supplemental activities included in the ORNL research.

- Measure radon levels
- Measure formaldehyde levels
- Measure organic vapor and aerosol levels
- Measure bacteria and fungi levels
- Measure air mixing between zones of house
- Assess degree of weatherization of house

WHY ARE WE CONDUCTING THIS STUDY? There are several reasons for conducting a study of indoor air quality. One objective is to obtain an estimate of the distribution of indoor pollutant levels in homes. Another objective is to see if there is a relationship between respiratory health and levels of selected indoor pollutants. The relationship between various housing characteristics and indoor air quality is also of considerable interest.

RESEARCHERS AT THE HARVARD School of Public Health will contact homeowners on a regular basis to obtain respiratory symptom data from the Health Calendars being kept on the school children. If you have questions about this aspect of the study, you should contact them directly.

AS PART OF OUR EFFORTS to evaluate the relationship between indoor air quality and degree of weatherization, we would like to have TVA-trained energy auditors conduct a free survey of your home. These surveys will be the same as those conducted by TVA distributors throughout the Tennessee Valley area. With your approval, we will arrange for this free survey. You will be asked to fill in an energy survey request card during the field team's initial visit.

UPON COMPLETION of the study you will be provided with the indoor air quality information on your home. Specific homeowner identities will be maintained as confidential information. We hope you will find this information interesting and valuable.

RADON SAMPLING CUPS will remain in each house throughout the winter monitoring period. During March, the winter samplers will be exchanged and replaced with a summer sampler, which will be picked up at the end of the summer monitoring period.

THE SMALL SILVER AND RED PELLETS used to measure the exchange rate between indoor and outdoor air are to remain in the houses until the end of the summer monitoring period. If you have had a problem with the sources staying in place, please secure the sources with tape or give us a call (or you may store them in a safe place until we return for the summer monitoring).

IF YOU HAVE NOT YET HAD two weeks of monitoring in your home during the winter phase of the study, we should be visiting you in the near future. We are performing measurements in about 20 new homes each week and will have visited all houses by the end of February.

A REPEAT MONITORING PERIOD of two weeks will be conducted in each home during the summer phase of the study. Measurements will be conducted between the beginning of May and the end of August.

THE CONSUMER PRODUCT SAFETY COMMISSION is supporting additional monitoring for nitrogen dioxide in homes with actively used kerosene heaters. A major component of the study will be weekly measurement of levels using a series of sampling tubes provided to the homeowner. If you use a kerosene heater at least a few times per week and are interested in participating in this extra monitoring, please give us a call (collect, if a long-distance call) for additional information.

STUDY STAFF: Celeste Daffron, Chuck Orebaugh, Marty Cohen, Ken Monar, Larry Bull, Charles Dudney, and Alan Hawthorne. Please feel free to contact us at any time (376-0089 or 576-2712).

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OAK RIDGE NATIONAL LABORATORY

ornl **INDOOR AIR STUDY** *NOTES*

Number 3 Health and Safety Research Division April 1986

INDOOR AIR STUDY *NOTES* is our attempt to keep study participants informed of the progress, logistics, and results of our various indoor air quality field studies. *NOTES* will be issued quarterly while our studies are under way. Two major studies are now being conducted: a 70-home study in four states throughout the Tennessee Valley (see below) and a 300-home study in Kingston/Harriman, Tennessee (see back page). Should you have comments or suggestions, please let us know.

FOUR-STATE TENNESSEE VALLEY IAQ STUDY

SPRING SCHEDULE for home visits: Chattanooga - placement week of April 7, pick-up week of April 14; Birmingham - placement week of April 28, pick-up week of May 5; Huntsville/Florence/Tupelo - placement week of May 26, pick-up week of June 2. Homes in Oak Ridge area are tentatively scheduled for sample placement on May 12 and sample pick-up on May 19.

A FINAL VISIT to retrieve our passive radon monitors (plastic cups) will be made approximately 12 weeks after the spring visit. If you are planning to be away on vacation (it's that time of the year!), please let our field team know so they can adjust schedules if possible.

SCHEDULES ARE TENTATIVE at present. We will call to schedule specific times to visit your home. We will try to contact you if our projected arrival time differs from the scheduled time by more than 30 minutes.

STUDY STAFF: Ken Monar, Jeff Quillen, Mike Capacci, Charles Clark, Ray Foley, Charles Dudney, and Alan Hawthorne. You can contact us at (615) 574-6829 or (615) 576-2712. Students with the University of Alabama, Birmingham, will be assisting with measurements in the Birmingham area.

THANKS FOR YOUR FAVORABLE response for energy surveys by utility trained personnel. More than 90% of the participants agreed to an audit. This information will be most valuable to us when we analyze the study data.

WHEN WILL WE get a final report on the study? is a question many of you have asked. Following the final quarter of monitoring, we will be analyzing the data and preparing a final report to the study sponsors. Around the beginning of 1987 the report will be issued and a copy sent to you along with a detailed list of specific information on your house. We will also provide some additional information that will be helpful to you in interpreting what various pollutant levels mean. As always, homeowner identity and addresses will be maintained in confidence.

PRELIMINARY DATA for several of the pollutants monitored during the first quarter are shown in the table below (excludes energy efficient houses in Birmingham - data from upstairs location).

Average first quarter pollutant concentrations by city

City	Pollutant			
	Radon (pCi/L)	Radon Progeny (WL)	Nitrogen Dioxide (ppb)	Formaldehyde (ppm)
Oak Ridge	2.81	0.010	5.1	0.115
Hixson	1.38	0.014	4.3	0.097
Chattanooga	1.49	0.006	4.8	0.049
Rossville	1.81	0.010	5.1	0.075
Huntsville	15.3	0.039	3.7	0.065
Florence	2.01	0.019	3.9	0.106
Tupelo	0.65	0.007	1.9	0.152
Birmingham	1.28	0.009	8.2	0.070

GUIDELINES FOR GENERALLY ACCEPTABLE levels of the various pollutants are: Radon less than 4 pCi/L, radon progeny less than 0.02 WL, nitrogen dioxide less than 50 ppb (EPA annual outdoor standard), and formaldehyde less than 0.1 ppm. A few homes were significantly above the guidelines for radon exposure, and we have notified the participants and provided additional information. Each participant will be sent two pamphlets prepared by the Environmental Protection Agency, *A CITIZEN'S GUIDE TO RADON: What It Is and What to Do about It* and *RADON REDUCTION METHODS: A Homeowner's Guide*, as soon as they are available for distribution.

SHORT-TERM MEASUREMENTS of air exchange between indoor and outdoor air were made in 20 homes in Birmingham and 20 homes in the other study cities during the winter quarter of monitoring. Measurements will be repeated during the summer in 20 of these houses to assess seasonal differences. Special thanks go to those homeowners participating in this study.

(*continued on back*)

THE WINTER SAMPLING PHASE of the Harvard/ORNL Indoor Air Quality Study was successfully completed during March. All of our staff involved in the study wish to express sincere appreciation to study participants for their cooperation, especially in scheduling. Much valuable data are being obtained on residential indoor air quality, and we hope you take pride in being an important part of this contribution. We look forward to providing you with specific information on your home following completion of the study and data analysis.

THE SUMMER MONITORING PHASE will begin in mid-May and extend through the end of August. The sampling procedures will be very similar to those of the winter phase; the major difference is that the long questionnaire will not be administered during the summer phase. Study staff will be contacting you to schedule your two-week monitoring period.

DURING THE LAST TWO WEEKS of April and the first week of May, study staff will be exchanging passive radon monitors (plastic cups) in all houses (unless the monitors were changed during March). The new monitors will be picked up at the end of the summer.

AN IMPORTANT COMPONENT OF OUR indoor air quality study involves the characterization of the degree of home weatherization during the study. TVA has statistics on home weatherization status of over a million homes in the Tennessee Valley area. Information that we gain on the relationship between indoor air quality and degree of home weatherization will be valuable in interpreting information in this large TVA data base as well as for our study. One item that was not completed as planned during the winter phase was collection of signed energy audit cards. In order for TVA trained surveyors to perform a free survey of your home, we must have a signed card indicating your approval for us to give them your name and address. We do not have these cards for many of the participants. During the exchange of radon monitors (see above), the field teams will be collecting cards from those homes for which we do not have a record. Your assistance in this matter is greatly appreciated.

A SUBSET OF ABOUT 50 HOMES have been participating in a more intensive investigation of indoor air quality in homes with kerosene heaters. This study is sponsored by the Consumer Product Safety Commission. Weekly measurements of nitrogen dioxide levels in the room with the heater were made for approximately ten weeks. In addition, a usage log was maintained during this period. Four houses were monitored in detail to obtain levels of several combustion related pollutants every 6 min for about one week. Samplers and log sheets will be collected from all these homes during the radon monitor exchange period (see above). Special thanks is expressed to all homeowners who participated in this special study.

THE SMALL SILVER AND RED PELLETS used to measure the exchange rate between indoor and outdoor air are to remain in the houses until the end of the summer monitoring period. If you have had a problem with the sources staying in place, please secure the sources with tape or give us a call (or you may store them in a safe place until we return for the summer visit).

WHEN WILL WE get a final report on the study? is a question many of you have asked. Following the summer period of monitoring, we will be analyzing the data and preparing a final report to the study sponsors. Around the beginning of 1987, we will send you a summary of all the measurements made in your house. We will also provide some additional information that will be helpful to you in interpreting what various pollutant levels mean. As always, information on homeowner identity and addresses will be maintained in confidence.

STUDY STAFF: Celeste Daffron, Chuck Orebaugh, Larry Bull, Marty Cohen, Ken Monar, Kevin Ironsides, Charles Dudney, and Alan Hawthorne. Please feel free to contact us at any time (376-0089 or 576-2712).

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