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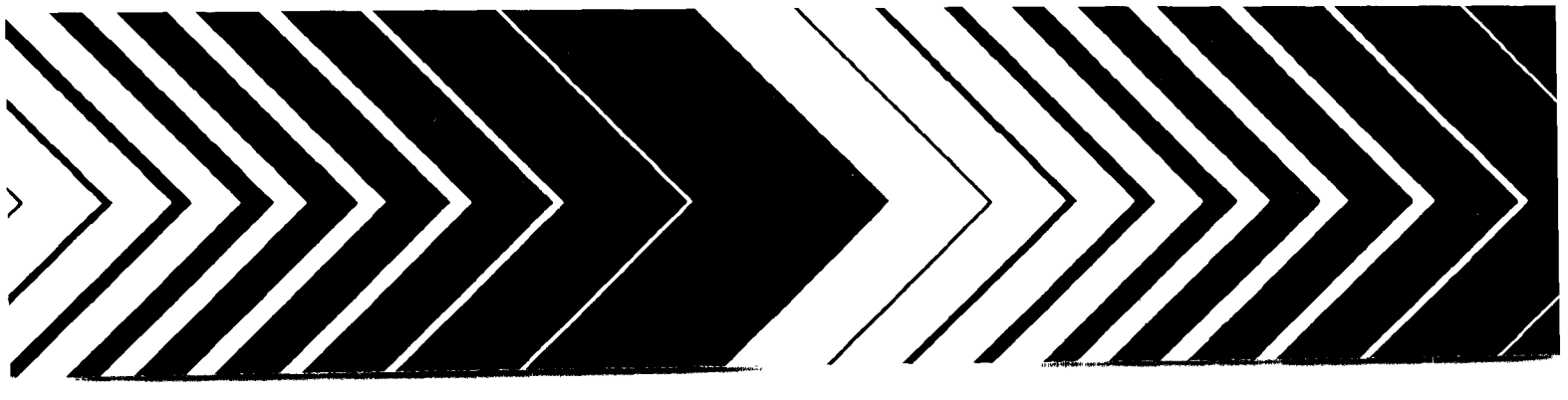
EPA

EPA Indoor Air Quality Implementation Plan:

Appendix B. FY 87 Indoor Air Research Program



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EPA Indoor Air Quality Implementation Plan

Appendix B: FY 87 Indoor Air Research Program

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Environmental Criteria and Assessment Office
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FY 87 INDOOR AIR RESEARCH PROGRAM

The following descriptions are for the research projects that comprise the FY 87 ORD indoor air research program. The program has been approved and implemented by the ORD Steering Committee for Indoor Air. Minor adjustments in the program will be made as determined by the Committee.

FY 87 INDOOR AIR RESEARCH PROGRAM

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Project 1: General Indoor Pollution Concentration Model

A. Objective:

To develop and validate a general indoor air quality model for predicting and analyzing indoor air quality in buildings. The program will be used to describe the spatial and temporal variation of pollutant concentrations due to environmental conditions including flow, thermal, and building characteristics. Ultimately, the program could be uised as a tool for evaluating the cost effectiveness of various mitigation strategies.

B. Background:

EPA and DOE have entered into an IAG with the DOC/NBS to perform detailed studies of general indoor air quality models. These research efforts have resulted in a project with three distinct phases. Funding of Phases I and II (FY 85 and FY 86) led to the development of a general framework of the model and developed general procedures for predicting indoor air quality in multizone buildings, treating each zone as well mixed with a simple HVAC system. The third phase to be funded in FY 87 will develop procedures for extending modeling capabilities to allow more complete simulation of HVAC systems and consideration of rooms that are not well mixed. Also, actual indoor environment data will be used to validate the model.

C. Approach:

Airborne contaminants introduced into a building disperse throughout the building in a complex manner that depends on the nature of air movement into (infiltration), out-of (exfiltration), and within the building. Other factors include the influence of HVAC systems, the possibility of chemical reactions of pollutants with each other, furnishings, or building materials. The approach, here, is to develop a model of this dispersal process for building systems that account for these physical processes.

D. Milestones:

Calibrate NBS models	8/87
Validate NBS models	12/87
Final Report Phase IV	4/88

E. Project Contact:

David Holland (919) 541-3126
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Project 2: Receptor Models for Assessing Indoor Levels and Sources of RSP

A. Objectives:

Perform detailed XRF analyses on 800 samples collected in the NYSERDA Study for trace elements. Extend the NYSERDA data base by including nicotine and trace metal data. Develop models of indoor microenvironmental concentrations as a function of descriptive variables. Apportion collected RSP data to various sources.

B. Background:

EPA has co-sponsored a study with DOE and NYSERDA to measure the effect of weatherization on indoor air quality. This study produced good preliminary data but needs to increase the number of homes surveyed to increase the reliability of the study. This extensive air quality data base, collected purposefully for weatherization effects, needs to be analyzed for the chemical and mass concentration differences in accord with the data base on air exchange rates measured in real time and by blower doors. Dr. Brian Leaderer, Yale University Pierce Foundation, has served as a consultant to the NYSERDA contract manager and has been intimately involved in this study and has contracted with EPA to perform the nicotine analyses of specially prepared nicotine filters.

C. Approach:

Through a 2-year CAG with Yale University, acquire from NYSERDA the computerized data base (screening questionnaire, initial questionnaire, daily source use diary, measured concentrations of RSP and infiltration, etc.) for all homes in the NYSERDA air quality study for use in the analysis. Incorporate the passively monitored nicotine values for those homes monitored into the data base. Develop an empirical/statistical model of the RSP levels using regression analysis where the dependent variable will be RSP and the independent variables will the source, source use, building characteristics and infiltration rates as they were measured in the study (questionnaires, etc.). Evaluate questions and the field study protocol used in the NYSERDA study through the statistical/empirical model. Utilize the mass balance equation to predict RSP levels in the houses monitor and then compare the predicted concentrations to the levels measured. Have elemental analysis conducted on the RSP filters collected in the NYSERDA study and incorporate the results into the data base. Compile the available elemental and RSP indoor source data from several laboratories and utilize source apportionment techniques to determine the origin of particles in the indoor residential environment.

D. Milestones:

Complete data collection	5/87
Perform XRF analyses	6/87
Report on data analyses	12/87
Final project report on analyses and modeling results	6/88

E. Project Contact:

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Project 3: Measurement of Indoor Spatial and Temporal Concentration Gradients for Indoor Environments

A. Objective:

Measure the indoor spatial and temporal gradients for indoor environments by source types, activity patterns and building classification.

B. Background:

Indoor pollutant concentrations may vary remarkably with time and measurement location. Differences in the strength of source emissions change with season, particularly those associated with heating systems. In addition, short-term variations occur from personal activities such as vacuuming, cleaning with solvents, and the application of pesticides. Thus, both the time and duration of sampling must be considered to ensure measurement of peak concentration levels. Pollutant concentrations also may vary in space. The magnitude of the variation depends on the source location and emission rate levels over time. Knowledge of the spatial and temporal concentration gradients will aid our efforts towards developing sampling protocols for representative health effect studies.

C. Approach:

EPA will conduct a number of systemmatic studies in test homes and occupied dwellings which provide measures of variation for the source/activity/building type. Recent monitoring advances in measuring volatile organics, semi-volatiles, and particles will be employed in these studies to relate the short term (less than 1-hour) concentration fluctuations to source variations and to study spatial gradients in residential and office environments.

D. Milestones:

Provide 1st progress report	9/87
Provide 2nd progress report	9/88
Final Project Report	9/89

E. Project Contact:

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Project 4: Initiate Investigation of the Composition of the Indoor Particle Size Distribution

A. Objective:

In a few residences investigate the magnitude of the differences in particle size, character and composition between indoors and outdoors for particles above and below 2.5 μm.

B. Background:

Particles of different aerodynamic diameters deposit in different locations in the respiratory system. The proposed PM_{10} regulation outdoors considers the COARSE particles from 2.5 to 10 μm as important as those below 2.5 μm. Recent work suggests that a large portion of COARSE particles indoors are re-entrained from rugs. It could be inferred that the chemistry (semi-volatiles, toxics, etc.) of the indoor COARSE particles compared to those outdoors is totally different. If 80% of ones exposure is indoors the COARSE particle fraction outdoors may not be nearly as important as is currently perceived.

C. Approach:

In test homes simulate indoor activities which may re-entrain dust while collecting size segregated particles up to ~30 μm simultaneously indoors and outdoors. Compare the particle mass and character gravimetrically and microscopically, followed by selected chemical analyses as permitted by the mass collected. Verify the test home results in occupied homes.

D. Milestones:

Procure and test size distribution samplers that are suitable indoors and outdoors	7/87
Collect samples in three residences	8/87
Analyze samples and report results	12/87

E. Project Contact:

Russell Weiner (919) 541-1910
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Project 5: Limited Scale Field Study to Test Survey Methodology and Relate Indoor Air Quality to Exposure

A. Objective:

Select the appropriate microenvironmental monitoring methodology for at least VOCs, ETS, semi-volatiles, and metals and evaluate these methods compared to exposure measurements in nine residences.

B. Background:

The SAB review of the indoor air quality program proposed that EPA better define the methodologies to conduct surveys designed to infer the contribution of indoor air quality to exposure. In a subsequent proposal to Lee Thomas, Jan Stolwijk of Yale University was more definitive in proposing steps to identify the magnitude of the indoor air problem with specific emphasis on its relationship to total air exposure. A first step in the development process would be a limited scale field study to test the methodology to relate indoor air quality to exposure levels and sources and to begin to study geographical variability for VOCs.

C. Approach:

Assemble the hardware and protocols necessary to monitor VOCs, ETS (nicotine), semi-volatiles (gas and particle phase), and metals (RSP fraction) both on a microenvironment and exposure basis. Test the methodologies as they may be used in a large scale study in conjunction with questionnaires to select the participants and identify potential sources. The first level evaluation of the monitors would be in a controlled test home environment. This would be followed by an evaluation in up to nine homes in a previous TEAM location (ideally Baltimore). Analysis of questionnaire data and samples would be designed to test protocols, help identify sources, and study residences previously identified by the TEAM study as having unusually high or low VOC concentrations. A report would be prepared on the capabilities of the monitoring and survey (questionnaire) instruments for performing studies of indoor air quality to provide exposure information.

D. Milestones:

Assemble hardware and protocols	6/87
Test home evaluation	7/87
Field sampling in RTP area	9/87
Analyses of samples and data	12/87

E. Project Contact:

Ross Highsmith (919) 541-7828
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Project 6: Indoor Source Emissions Data Base

A. Objective:

(1) Develop and maintain a computerized file of data from research studies of emissions from sources of indoor air pollutants.

(2) Make this data base available to U.S. and foreign researchers, public officials, product manufacturers, builders, and the interested general public.

(3) Encourage consistency, completeness, and accuracy in reporting of research data from source characterization studies.

B. Background:

Indoor concentrations of contaminants can vary significantly depending upon the prevalence and diversity of indoor sources. Consequently, source characterization studies that measure the emissions from agents and/or activities are an essential part to understanding the indoor air problem. A survey compiled in 1985 of source emissions data from the period 1979-1984 demonstrated the potential variety of source-related research. It also demonstrated the clear need for better organization of current and future data. The organization and standardization would make the resulting data readily available to the user communities of both the public and private sectors. AEERL began an in-house effort in 1985 with the objective of developing a user-friendly, PC-based indoor air emission source data base that would meet this need. The prototype version, developed with dBASE III software, was distributed to 12 reviewers in July 1986.

C. Approach:

Development of the Indoor Air Source Emissions (IASE) data base will be continued through a cooperative agreement with the University of North Carolina at Chapel Hill. UNC will work to optimize the existing dBASE III prototype for performance, compile it for speed enhancement, and develop a more user-friendly interface. In addition, UNC will be responsible for developing a standardized nomenclature suited to the breadth of the user community. UNC will also be responsible for implementing quality control, providing literature review, data entry, and the general maintenance of a database which will be made available to the international user community.

D. Outputs and Milestones:

Survey of source emissions data (1979-84) completed	4/85
Papers by Crum presented at APCA meetings	4/86, 6/86
Peer review of prototype database	7/86
Distribution of initial version to public	7/87
Presentation of database (Berlin conference)	8/87

E. Project Contact:

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Project 7: Evaluation of Field Methods to Estimate Environmental Tobacco Smoke (ETS) Exposure in Epidemiological Studies

A. Objective:

Conduct preliminary field research to determine optimal methods for quantifying ETS exposure to facilitate more quantitative exposure assessment in future epidemiologic studies of indoor air.

B. Background:

Due to the prohibitive expense of monitoring indoor environments in large epidemiologic studies, methods are being developed and validated to derive exposure estimates from questionnaire responses.

C. Approach:

Ongoing studies at the University of New Mexico and Harvard University were modified to accomplish the following:

(1) To assess biologic markers of exposure to cigarette smoke in children with passive exposure in cigarette smoking households.

(2) To correlate these measures with direct monitoring of indoor environmental exposure.

(3) To determine the frequency of observations necessary to characterize relative levels of exposure in a population setting.

(4) To test the reliability of a questionnaire about passive smoking in adults.

(5) To determine validity in adult subjects reporting and not reporting passive smoking by questionnaire by determining the cotinine content of urine or blood.

D. Milestones:

"Reliability and Validity of Questionnaire Assessment of Involuntary Tobacco Smoke Exposure" submitted to 4th International Conference on Indoor Air Quality and Climate (Berlin) 03/87

E. Project Contact:

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Project 8: Personal Activity Related Exposure to Environmental Tobacco Smoke (ETS) in Airliner Cabins and Other Transportation Related Environments

A. Objective:

(1) Determine personal activity exposure profiles for nonsmokers exposed to ETS in airliner cabins using chemical and biological markers.

(2) Determine personal activity exposure profiles for nonsmokers exposed to ETS in automobiles and related transportation sources.

B. Background:

As a result of Congressional hearings in 1983 and 1984, the National Academy of Sciences conducted a study to determine whether air quality and standards aboard commercial aircraft were adequate to protect human health. This study resulted in a committee report entitled "The Airliner Cabin Environment" in 1986 which "... will be controversial. It is unanimously and forcefully proposing that smoking be banned on all commercial flights ...." Although the NAS report (1986) provides documentation of ETS related pollutants in airliner cabins, these have been principally limited to RSP, CO, and NO_2. Very little data on ETS specific components (e.g., nicotine) have been reported and no studies have been conducted on human exposures using biological markers. The Surgeon General has requested that NCI conduct such a study and EPA has been requested to jointly participate in this study. DOT is also considering collaboration with EPA and NCI for a larger study.

C. Approach:

The initial phase of this project will involve a collaborative NCI-EPA pilot study of human exposure to ETS on commercial aircraft. Air pollutants to be measured will include respirable particulates (RSP), mutagenicity of the RSP, nicotine and CO. Efforts will be undertaken to measure or estimate the air exchange rate and other semi-volatile and volatile organics (e.g., aldehydes) if possible. Nonsmoking human volunteers will be located in various sections of the aircraft, wearing and/or carrying personal monitoring equipment. Body fluid samples (e.g., urine, blood and saliva) will be taken before, during and after the flights. Body fluids will be analyzed for nicotine and cotinine (nicotine metabolite).

The pilot study will be conducted on a limited number of flights. Based on the results from this pilot study, a larger study or series of studies in a variety of transportation "cabins" including aircraft, automobiles and other transportation sources.

D. Milestones:

Report on pilot study of personal exposures to ETS in airline cabins	06/87
Study design and protocol for larger scale studies of airline cabins	09/87

Report on pilot study of personal exposures to ETS in automobiles 03/88

E. Project Contact:

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Project 9: Develop and Test Revised Screening and Source Use Questionnaires for Indoor Air Quality Studies

A. Objective:

Develop optimal design of questionnaires, diaries, source use and activity logs for use in surveys of indoor air quality.

B. Background:

Many organizations including EPA have used different questionnaires to perform indoor surveys. The questionnaires served different purposes and it is not clear whether or not they can be condensed into a single standard questionnaire or even whether it is desirable. Special questionnaires need to be developed to meet specific survey purposes and background research is necessary to accomplish this.

C. Approach:

EPA will continue to work with other researchers to develop the basic structures and to standardize components where possible. For each different survey type (targets, purposes, intensity of monitoring) EPA will conduct Focus groups, evaluate proposed questionnaires in field tests and prepare the necessary documentation to support ICR's to OMB.

D. Milestones:

Review past questionnaires in cooperation with ongoing joint project	3/87
Hold Focus Group sessions of various groups (high-low SES, urban-rural, rental apartment-single family owner occupied, etc.)	7/87
Provide questionnaires for studies of indoor air quality based on results of pilot studies	10/87

E. Project Contact:

David Holland (919) 541-3126
(FTS) 629-3126

Project 10: Field Evaluation of Sampling and Analysis for Organic Pollutants in Indoor Air

A. Objective:

To develop, construct, and evaluate a sampler for semivolatile organic compounds (SVOC) in indoor air that is quiet, convenient, reliable and that collects sufficient sample for both bioassay and chemical analysis.

B. Background:

A prototype indoor air sampler for SVOC has been designed and built. Evaluation of this prototype indicates that it meets the requirements of low noise, reliability, transportability, and sufficient sample size for chemical analysis and microbioassay. Several aspects of the sampler performance remain to be investigated: evaluation of the possible contribution to the total SVOC levels in the indoor environment from the sampler itself, and evaluation of the sampler performance in real indoor environments.

C. Approach:

Two modified samplers will be built and tested in the laboratory, to ensure that they meet the performance criteria set for the prototype. Experiments will be performed in an indoor microenvironment, with samplers vented first outside and then inside. Chemical analyses and screening microbioassay, if necessary, will be done on the collected room air samples to detect any sampler contribution to the SVOC levels. Field evaluation of the samplers will be done in a few residences, which will be selected to represent homes both with and without cigarette smoking and wood combustion.

D. Milestones:

Construct and test two modified indoor air samplers	2/87
Evaluate sampler contribution to the indoor environment	6/87
Evaluate sampler performance in nine homes	12/87

E. Project Contact:

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(FTS) 629-4723

Project 11: Evaluation of Sampling and Analytical Methods for Nicotine and PAHs

A. Objective:

To evaluate sampling and analysis methodology that allows simultaneous collection of nicotine and PAHs from indoor air with subsequent analysis for these species in one analytical procedure.

B. Background:

Measurement of the contribution of tobacco smoke to total indoor air contaminant levels is necessary for determination of the impacts of various sources to overall indoor air pollution. Nicotine has been used as a specific tobacco marker in several indoor air studies. Current methodology for nicotine is cumbersome and expensive, requiring separate collection of nicotine on bisulfate-treated filters and also separate analysis from the collection and analysis of PAHs.

C. Approach:

Methodology based on the use of quartz filters and back-up XAD-4 resin traps will be employed to collect both PAH and nicotine in indoor air sampling.

The filter and adsorbent extracts will be pooled, and several analytical methods will be used to determine whether both nicotine and PAH can be measured in a single analytical procedure.

D. Milestones:

Determine optimum extraction procedure for nicotine and PAH from XAD-4 resin	2/87
Conduct indoor air sampling with smoking and nonsmoking conditions	4/87
Evaluate analytical procedures	8/87

E. Project Contact:

Nancy Wilson (919) 541-4723
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Project 12: Field Evaluation and Final Modification of Prototype Dual Channel Particulate Sampler

A. Objective:

Test the research prototype particulate sampler (developed in FY 86) under field conditions and modify as needed to be field ready.

B. Background:

A research prototype dual channel ($PM_{2.5}$ and PM_{10}) microenvironment particulate sampler was developed in FY 86. This microenvironment sampler was designed to be unobtrusive, operate at 10ℓ/min (as compared to 4ℓ/min for the Harvard Sampler) to collect more sample, and collect the semi-volatile gas phase fraction if necessary. The sampler would be multi-functional for versatile use in either focus research studies on larger scale characterization studies. The current prototype needs field testing to identify problems that may be encountered.

C. Approach:

The existing research prototype would be field tested either in an occupied residence or a dedicated test house. Testing criteria would be similar to that already established for the Harvard sampler, e.g., noise level, flow control, filter overloading, etc. Additionally modification to provide accurate and reliable sampling under outdoor conditions would be addressed to permit determination of indoor/outdoor relationships.

D. Milestones:

Upgrading of research prototype for field tests	5/87
Field testing complete	8/87
Final modifications completed and field prototypes delivered	11/87

E. Project Contact:

Russell Weiner (919) 541-1910
(FTS) 629-1910

Project 13: Assess the Effectiveness of Currently Available Screening Techniques for Indoor Pollutants

A. Objective:

Review the currently available screening techniques for indoor pollutants and assess their technical and cost effectiveness.

B. Background:

Screening techniques for indoor pollutants can be used to identify microenvironments deserving more extensive study or to determine how extensively to analyze samples already collected. Passive devices such as the Palmes tube for NO_2 and active devices such as portable GC for gross VOC quantification both qualify as screening techniques. Screening techniques can provide inappropriate information if there are substantial spatial and temporal gradients (See earlier project related to gradients and measurement averaging time) or if the integration interval is inconsistent with the study objectives.

C. Approach:

Review the available screening techniques for indoor pollutants and prepare a comprehensive report on advantages and disadvantages. For selected pollutants test the screening techniques in test homes and assess both their precision and accuracy and their cost effectiveness. Prepare a guideline document recommending screening techniques for specific application.

D. Milestones:

Survey report on available methods	7/87
Field test of selected methods	11/87
Guideline document	2/88

E. Project Contact:

Charles Rodes (919) 541-3079
(FTS) 629-3079

Project 14: Initiate Methods Development for Polar Organic Compounds

A. Objective:

To develop sampling and analysis methodology for polar volatile and semivolatile organic compounds (VOCs and SVOCs) in indoor air.

B. Background:

In several indoor air studies, it has been shown that the nonpolar portion of the collected organic material, which includes the polynuclear aromatic compounds as well as some smaller more volatile species, produces less than half of the mutagenic activity detected in bioassay. To account for the remaining biological activity, it is necessary to identify and quantify the polar portion of the air sample. However, reliable sampling and analytical methodology for the polar compounds is not well-developed. Three needs can be easily identified: sample collection methodology for the polar organics that preserves the integrity of the sample and is free of artifacts; separation methodology that divides the polar sample extracts into identifiable fractions that are amenable to further chemical characterization and bioassay screening; and analysis methodology that allows identification and quantification of specific polar components, to facilitate further speciation of those compounds responsible for biological activity and linkage with particular pollution sources.

C. Approach:

Polynuclear aromatic hydrocarbons (PAH) and their polar degradation products collected during air sampling and formed during sample storage will be identified and quantified. The results will be used to establish a list of target PAH, degradation products and polar compounds that should be monitored in a future indoor air study. Analytical methodology for both volatile polar organic compounds, such as ethylene oxide and acrolein, and semivolatile polar organic compounds, such as nicotine and nitroaromatics, will be developed. Methods for detailed chemical characterization of polar air sample fractions will be pursued.

D. Milestones:

Chemical characterization of polar SVOCs in air and related sampling artifacts	6/87
Method development for nicotine and other polar SVOCs	9/87
Method development for ethylene oxide and other polar VOCs	12/87

E. Project Contact:

Nancy Wilson (919) 541-4723
(FTS) 629-4723

Project 15: Development of Electrochemical Realtime Detector for NO_2

A. Objective:

Develop a realtime NO_2 detector appropriate for personal exposure monitoring with ± 25 ppb sensitivity, less than 1 minute response, and compact enough to be comfortably worn by the subject.

B. Background:

There are serious questions about the adequacy of point monitors for determining human exposure to pollutants. This project will provide measurement systems of sufficient sensitivity and compactness to allow monitoring of individuals as they move through their normal exposure cycles. The data can then be compared to results from point monitors to assess the need for personal monitors vs. point monitors.

The first phase of this effort has produced an electrochemical sensor of adequate sensitivity to monitor low level (non-acute) exposures to NO_2.

C. Approach:

The sensor developed under phase one will be packaged in a more compact sampling system and will be tested for a number of possible interferences. The interference tests will be interpreted in terms of probability of verified interference being present and the degree of interference will be quantified. For example, while SO_2 is expected to cause some interference, the concentration of SO_2 indoors is likely to be low relative to NO_2.

D. Milestones:

EPA interim project report on development of miniaturized electrochemical sensor for NO_2	10/87

E. Project Contact:

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Project 16: Methods Development/Intercomparison for VOCs

A. Objective:

To develop and evaluate canister-based sampler methodologies and analytical procedures for quantitation of VOCs.

B. Background:

Development initiatives taken by EMSL in FY 85 and FY 86 have resulted in practical, field-tested canister-based methods for sampling and storage of VOCs in whole air. Comparison with sorbent-based methods on indoor and outdoor samples have identified specific advantages and disadvantages of each approach. Specially designed sampling units for the indoor air have been developed to satisfy a variety of needs. Canister-based units to sample without the need for power, others to sample over periods of up to one week, and still others to take and store a sequence of individual samples for studies of VOC concentration variability -- all have been demonstrated.

The parallel development and evaluation of analytical procedures for automated analysis of canister-based samples has resulted in the demonstration of analytical capabilities for a set of forty-one non-polar organics. Automation of the analytical sequence has significantly reduced the time and cost per sample analyses.

C. Approach:

Initiatives in FY 86, such as the development and testing of a canister-based indoor air sampler for up to one week monitoring periods and development of screening procedures for canister samples, require further work to complete. Resources will be used for completion and testing of these two products. Sampling and analytical methods development for polar VOCs will be emphasized in FY 87.

D. Milestones:

Battelle Columbus report on portable GCs and canister-based indoor air samplers	5/87
Issue article for proceedings of 4th International Conference on Indoor Air Quality and Climate	10/87
Journal article on development of Tek-Mar® sample introduction system for passive sampling devices and canisters	10/87

E. Project Contact:

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Project 17: Development of a Versatile Unobtrusive Indoor Air Quality Sampling Package

A. Objective:

Develop a total indoor air quality sampling package for VOCs and particles including SVOCs.

B. Background:

Recent focus group exercises conducted by RTI showed that the packaging of the sampling hardware was crucial to public participation in IAQ measurement studies. Rather than packaging the samplers individually it is highly desirable to assemble a basic sampling system to meet a variety of needs and package the system in one unobtrusive unit.

C. Approach:

Select the sampling techniques to be incorporated and the unobtrusiveness levels (size, noise, etc.) to be accepted. Design and construct a prototype package system and test its unobtrusiveness in focus group settings.

D. Milestones:

Select sampling methods to package	7/87
Develop sampling packages and test	10/87

E. Project Contact:

Russell Weiner (919) 541-1910
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Project 18: Determine Population Exposure to Indoor Pollutants

A. Objective:

Review published literature to determine concentrations and activity patterns to estimate the population exposure to various indoor air pollutants.

B. Background:

There is a need to determine the extent of health risk to the population caused by the various indoor air pollutants. This information will be used to establish priorities for research to most effectively mitigate exposure.

C. Approach:

Search the relevant literature and compile information about each air pollutant discussed in the Indoor Air Pollutant Information Assessment, and estimate risk of disease/death from each; also determine additive or synergistic effects. An exposure assessment document will be produced and reviewed at a peer review workshop of experts on air pollution exposure.

D. Milestones:

Scope of work for contractor	6/87
Exposure assessment completed	10/87
Peer Review Workshop	10/87
Final Version-Exposure Assessment	12/87

E. Project Contact:

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Project 19: Biological Markers for Environmental Tobacco Smoke (ETS) Human Exposure Assessment

A. Objective:

(1) Evaluate mutagenicity as a biological marker for human exposure to ETS.

(2) Characterize ETS emissions using bioassay methods.

(3) To identify the chemical/biological markers specific to the indoor organic emission sources.

(4) To develop and evaluate the biological markers which can be used effectively in assessing the exposure and dosimetry of the indoor combustion emissions.

B. Background:

In order to provide definitive data on the relationship between human exposure, dose and effects of indoor organic pollutants, it is necessary to develop markers for exposure and dosimetry. Personal exposure and dosimetry of ETS is dependent upon so many factors that optimal assessment should be measured directly through the use of biological markers of exposure, uptake into blood, distribution and metabolism, binding to macromolecules (e.g., protein and DNA), and excretion into urine. One approach is to identify unique tracer compounds present in ETS and their metabolites. Nicotine, for example, is virtually unique to tobacco sources and both nicotine and its metabolite cotinine can be measured in human tissue or fluids. This approach will provide the basis for relating health effects to specific exposure concentrations and dose.

The highly exposed to ETS or in a potentially more sensitive population such as preschool children. Cotinine, a metabolite of nicotine from ETS, has shown that it can be a candidate as a biochemical marker for ETS exposure. This study will evaluate if cotinine can serve as a marker compound for ETS exposure.

C. Approach:

A stepwise approach to these studies will include evaluation of biological and chemical markers of ETS in laboratory chambers, model homes, and in pilot field studies in collaboration with AEERL, ASRL, and EMSL. Initial studies are being performed in controlled chambers. This phase of the project is focused on air characterization in chambers, chemically and biologically, and on the factors that will effect the mutagenicity and organic emission rates including (a) number of cigarettes; (b) smoldering versus sidestream versus exhaled mainstream; (c) effect of tar and nicotine content; and (d) comparison of organics associated with the various phases of ETS including particles, semi-volatiles, and volatiles. The initial phases of this project have produced promising results suggesting that the mutagenic emission rate may be constant across all cigarette types and that the RSP, nicotine and mutagenicity of emissions is predictable and that it may be possible to model exposure.

Targeted pilot field studies are being undertaken collaboratively by EPA and UNC investigators at the Frank Porter Graham (FPG) Child Development Center [initially (86/87)] in conjunction with a CPSC/EPA project on NO_2 and gas stoves. There are forty children enrolled in the Center from an age of 3 months to 5 years. Approximately half of the childrens' parents smoke cigarettes. The homes of selected children enrolled in the (FPG) Center for Child Development operated by UNC as a research day care center are monitored for NO_2, carbon monoxide, nicotine concentrations, and particulate mutagenicity. Body fluids of these preschool children both exposed and nonexposed to ETS will be used in biological marker studies. Urine mutagenicity will be determined together with exposure to the particulate organics (mutagenicity), volatile nicotine and urinary and serum cotinine (a metabolite of nicotine). These parameters will be evaluated as dosimeters of exposure to ETS and potential risk. Potential dietary confounding factors will be monitored and controlled where possible. Other collaborators on this project include scientists from CDC (R. Etzel), American Health Foundation (N. Haley), U. of Mass. (K. Hammond), and Yale U. (B. Leaderer).

D. Milestones:

Journal article on monitoring ETS exposure using a micromutagenesis assay	04/87
Paper and presentation (International Indoor Air Conference) on mutagenic emission factors for ETS	08/87
Paper and presentation (International Indoor Air Conference) on serum and urine cotinine as quantitative measures of exposure to ETS	08/87
Journal article on characterization of the mutagenicity and concentration of selected organic tracers in ETS chamber studies	01/88
Journal article(s) on using nicotine, mutagenicity, and cotinine to assess preschool childrens' exposure to ETS	06/88

E. Project Contact:

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Project 20: Development of Biological Markers for Molecular Dosimetry Resulting from Exposure to Environmental Tobacco Smoke (ETS)

A. Objective:

(1) Evaluate the DNA adduct postlabeling method for application to ETS exposed cells, tissues and body fluids.

(2) Optimize DNA adduct postlabeling methods for detection of ETS specific DNA adducts.

(3) Validate and apply the DNA adduct postlabeling method to human tissues from ETS exposed populations.

(4) Evaluate new hemoglobin adduct methods that may provide ETS specific markers of exposure and dose.

B. Background:

Highly sensitive methods are now becoming available for determining protein or DNA-adducts of environmental carcinogens and toxic agents in circulating blood and tissues. Several constituents that occur in ETS, e.g., benzo(a)pyrene and 4-aminobiphenyl, have been reported as hemoglobin or DNA adducts, however these chemicals are not specific or unique to ETS. Everson et al. have recently reported detection of DNA adducts in the placentas of smoking women using these new techniques. The development and validation of methods to detect ETS specific adducts would provide an ideal marker of human exposure and in some cases (e.g., DNA-adducts) dose to ETS. The National Academy of Sciences (1986) in its recent report on ETS concludes that validation and quantitative determination of the uptake of tobacco smoke carcinogens is urgently needed. Studies are needed to develop and apply highly sensitive methods (e.g., immunoassays or postlabeling) for measuring DNA and protein adducts of tobacco-specific chemicals.

C. Approach:

The highly sensitive ^{32}P-postlabeling techniques developed by Randerath et al. using a P_1 nuclease enhancement and the butanol extraction method developed by Gupta et al. will be evaluated with human placental tissue, buccal cell tissue and lymphocytes from highly exposed individuals. With optimization this procedure can detect 1 adduct per 10^{10} nucleotides and has been successfully applied to the detection of adducts in smokers' tissue and in animals exposed to mainstream smoke. Tracheal cells from the respiratory tract of both humans and rodents exposed to ETS will be used as a model system to optimize detection of adducts and characterization of the adducts. Evaluation of the rate of formation and persistance of the adducts will be necessary to interpret human studies. Subsequent studies to determine adduct levels in humans exposed to varying levels of ETS will be conducted to evaluate exposure-DNA dosimetry relationships. New highly sensitive analytical (mass spectrometry) and radioimmune assay methods for protein adducts (e.g., hemoglobin) have recently been reported. Hemoglobin adducts are usually detectable in circulating blood in higher concentrations than DNA adducts in the blood lymphocytes. Concurrent

studies to evaluate the potential utility of measuring hemoglobin adducts of ETS specific chemicals will be investigated.

D. Milestones:

Comparison and evaluation of two postlabeling methods for detection of ETS induced DNA adducts	06/88
Optimization and validation of a postlabeling method for ETS induced DNA adducts	12/88
Evaluation of ETS DNA adduct persistence in tracheal cells	05/89
Evaluation of hemoglobin adduct methods in blood from ETS exposed individuals	11/89
Human pilot study of an ETS exposed population	09/90

E. Project Contact:

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Project 21: Evaluation and Improvement of Cotinine as a Biomarker of Environmental Tobacco Smoke (ETS) Exposure in Children and Adults

A. Objective:

(1) Determine if urine cotinine levels in infants and young children are a good indicator of exposure to ETS.

(2) Determine if the elimination half-life of urine cotinine changes with age, sex or other parameters effecting metabolism in children.

(3) Improve cotinine detection limits and quantitation.

(4) Determine the relationship between nicotine exposure in ETS, nicotine dose and cotinine levels.

(5) Establish relationships between personal air exposure to RSP, mutagens and nicotine to measured nicotine intake and nicotine metabolites in body fluids for different exposure conditions and population groups.

B. Background:

Increased concern has been expressed about the potential health risks associated with the exposure to ETS. Recent studies implicate exposure to ETS as a particular health risk in infants and young children. Research into the health effects of exposure to ETS in children would be greatly aided if a chemical marker could be used to predict the level of exposure to ETS. Several substances, isolated from tobacco smoke, or their metabolic products, have been measured in biological fluids to estimate this exposure to ETS. These substances include carboxyhemoglobin, thiocyanate, nicotine and cotinine. Cotinine, a metabolite of nicotine, and derived only from tobacco smoke, has been shown to be a good indicator of the exposure to ETS. Studies in adults have shown that there is a dose-response relationship between the number of cigarettes smoked and the level of cotinine in the urine. The elimination half-life of cotinine in the urine and in the blood has also been reported in adults. Although cotinine is the best biological marker of human exposure to ETS, it is currently limited by both the sensitivity of the polyclonal RIA assays available and the lack of the necessary data needed to interpret cotinine values in light of potentially varying clearance rates.

The use of cotinine as an indicator of ETS exposure in children has been studied at the University of North Carolina (UNC). They found a high correlation between the exposure of children at home to ETS and their levels of urinary cotinine. These results suggested that uninary cotinine may be a useful indicator of ETS exposure in infants and young children. Additional studies at UNC provided data on the elimination half-life of cotinine in the urine of newborn infants exposed to ETS in utero. The level of exposure for both these studies, however, came from the self-reported smoking behavior of the mother. Objective information on the uptake of nicotine and the elimination of its metabolite, cotinine in young children, age 1 to 3 years of age, exposed to ETS is unavailable.

In order to improve the interpretation of cotinine measurements in body fluids, research is urgently needed to understand the absorbtion, metabolism and excretion of nicotine and its metabolites, including cotinine in nonsmokers of various ages. Specific studies to be conducted under controlled human clinical conditions include: (1) determination of the dose of nicotine absorbed from ETS by simultaneous chamber exposure to ETS and infusion of dueterated-nicotine in adults, and (2) continuation of studies of adults, and children of various ages, including infants, from homes where ETS is present to determine cotinine clearance rates and to compare exposure, uptake and dosimetry using nicotine and its metabolites.

C. Approach:

Adults and infants from homes where tobacco smoke is present will be exposed to known concentrations of ETS in an environmentally controlled chamber. Blood samples will be taken prior to and following a controlled exposure. Serum cotinine levels and blood carboxyhemoglobin will be measured. Urines will be collected from subjects, prior to exposure, out to several days post exposure. Urine cotinine excretion rates will be determined and correlated to air nicotine exposure. The dose of nicotine will be varied by changing the number of cigarettes smoked during the exposure in order to give a dose response. The excretion of cotinine will be correlated with the dose of nicotine as well as age, sex and race in the infant/child population. This information is considered critical because it will allow one to estimate prior exposure, with a high degree of certainty, rather than rely on questionnaire data. This study was undertaken to determine the exposure dose of nicotine, the peak level of urinary cotinine, the time to peak levels of cotinine, and the elimination half-life of urinary cotinine when children are exposed to a controlled amount of ETS.

D. Milestones:

Conduct an interagency cotinine workshop	11/86
Relationship between the ambient air nicotine concentration and the time to peak urinary cotinine levels and elimination half-life values for urinary cotinine in a population of young children. Presented at 4th International Indoor Air Conference	08/87
Report and recommendations from cotinine workshop	09/87
Evaluation of improved monoclonal radioimmune assay for cotinine	10/88
Determine dose of nicotine absorbed from ETS in controlled chamber studies using dueterated-nicotine in adults	12/88
Establish relationship between personal exposure to nicotine and other pollutants (e.g., mutagens, RSP) and cotinine in saliva, blood and urine	03/89

Elimination half-life of urine cotinine in young children exposed to different dose levels of ETS	08/89
Study of parameters (e.g., age and sex) that effect in children and adults elimination half-life of urine cotinine	06/91

E. Project Contact:

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Project 22: Indoor Air Studies of the Mutagenic and Carcinogenic Emissions from Unvented Combustion Sources

A. Objectives:

(1) To develop and evaluate methods for determining the mutagenicity and potential carcinogenicity of indoor organic pollutants from unvented combustion appliances.

(2) To evaluate the comparative mutagenicity, toxicity and carcinogenicity of complex organic emissions from unvented combustion appliances for risk characterization.

(3) To identify the mutagens and carcinogens emitted from unvented combustion appliances.

(4) To support engineering studies (AEERL) to develop emission factors and emission models including evaluation of mitigation parameters using bioassay methods.

(5) To support unvented combustion source exposure assessment studies (EMSL) via bioassay monitoring in test home and field studies.

(6) For future mitigation, to determine the contribution of these sources to the mutagenicity of indoor air.

B. Background:

Indoor combustion emissions are known to be a significant source of human exposure to particles, POMs and other organics including both semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs). Since the soot from incomplete combustion is generally recognized as a human carcinogen (IARC) and the POMs from these sources are also mutagenic, it is important to evaluate the relative contribution that various combustion sources, particularly unvented sources, could make to the human exposure and risk from these carcinogens. These studies will initially evaluate kerosene heater emissions due to the widespread use of these appliances (over 10 million sold).

The conventional bioassay methods require large quantities of sample for testing and usually only small quantities of indoor air emission samples are available. There is a need, therefore, to develop microassays for indoor air studies. Little effort has been applied toward the bioassay of SVOCs and VOCs in the indoor environment. It is important to develop bioassay methods for POMs, SVOCs and VOCs from unvented combustion sources indoors since exposure to these chemicals may be relatively high.

C. Approach:

Initial studies developed and evaluated micro-mutagenesis methods to apply to both indoor air laboratory (e.g., chamber) and field studies where only a few milligrams of organic matter can be collected. Studies are also being conducted in the initial phase of this project to evaluate sampling

and extraction methodologies for the bioassay of combustion appliance indoor air samples of all phases of the organics (particles, SVOCs, VOCs). The stepwise approach being taken in these studies includes evaluation of the mutagenicity of these sources in chambers in the laboratory, model homes, and in pilot field studies in collaboration with AEERL and EMSL. The initial studies will be performed on unvented kerosene heaters and gas stoves. Chamber samples of both the particles (POMs) and SVOCs collected on XAD-2 will be bioassayed in S. typhimurium micro-assay (Kado assay). Nitroreductase proficient and deficient strains will be employed to detect the presence of mono-nitro-PAHs and dinitro-PAHs. Initially, the effect of heater types, maintainance, and operating conditions on the mutagenic activity will be determined. A sample set will be selected for more in-depth bioassay and chemical characterization to determine the class of organic compounds which are mutagenic. If sufficient samples are available, other bioassays will be performed at the J.B. Pierce Foundation (including operating conditions, heater type and age, fuel parameters, etc.) to provide confirmatory dose-response data on the mutagenicity and carcinogenicity of these emissions.

In order to evaluate the VOC emissions from unvented appliances, the research will focus on the application of recently developed inexpensive bioassay systems for in situ monitoring of VOCs using direct gas-phase bioassay methods in chambers. The in situ system will be compared to other methods including sorbant (e.g., XAD) collection and extraction followed by bioassay. Efforts will be made to make the test chambers inexpensive, light-weight, portable, and inert. Initially, the bioassay testing will be conducted using bacterial tester strains; however, in the future, other organisms and bioassay methods which detect nonmutagenic VOCs which may induce cancer via other mechanisms will be used. In the initial phases, the system will be evaluated using known volatile mutagens. After evaluation, the system will be applied to either chamber studies and/or test home studies in collaboration with AEERL. Where possible indoor atmospheric transformation processes will be explored, particularly nitration of organics which is known to increase mutagenicity.

D. Milestones:

Development of microbioassay methods	03/86
Kerosene exploratory studies completed and APCA paper presented	06/86
Report and presentation of initial study on the comparative evaluation of the influence of combustion emissions on indoor air mutagenicity (International Indoor Air Conference)	08/87
Journal article(s) on exploratory studies of mutagenic emission rates from kerosene heaters and the role of NO_2-PAHs	12/87
Journal article on evaluation of the mutagenicity of kerosene heater emissions from chamber and test home studies	06/88

Journal article on the identification of mutagens and carcinogens in emissions from kerosene heaters	11/88
Report on gas space heaters	10/89

E. Project Contact:

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Project 23: Effect of Peak Exposure to NO_2 on Respiratory Symptoms and Pulmonary Function

A. Objective:

To study the effects of short-term exposure to high levels (ranging from 400 $\mu g/m^3$ to over 2500 $\mu g/m^3$) of nitrogen dioxide on pulmonary function and respiratory symptoms in asthmatic and non-asthmatic subjects.

B. Background:

Several studies have suggested that exposures to high levels of NO_2 even for brief periods can affect lung symptoms and functions. Recent indoor air monitoring studies conducted by Columbia University and sponsored by the Electric Power Research Institute (EPRI) indicated that such exposures are common to women using unvented gas cooking stoves in high rise apartments where air exchange rates have been minimized in the interest of energy conservation. Previous studies by Columbia University had also shown high asthma prevalence rates among residents of such apartments. For these reasons it was believed that the EPRI studies should be extended to include a health effects component.

C. Approach:

Both the person cooking the evening meal and any other household members present in the kitchen are given lung function tests and questioned about respiratory symptoms before cooking begins, while cooking is underway, immediately after, and 1 to 2 hours after cooking is completed. Continuous monitoring of NO_2 at the breathing level of the cook is conducted throughout this period. Simultaneous passive monitoring is done throughout the apartment. Each of the 20 to 25 families is studied on 5 occasions.

D. Milestones:

"Acute Exposure to Nitrogen Dioxide and Pulmonary Function" submitted to 4th International Conference on Indoor Air Quality and Climate (Berlin)	03/87

E. Project Contact:

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Project 24: Respiratory Effects of Indoor Formaldehyde Exposure

A. Objective:

(1) To assess respiratory effects of indoor formaldehyde exposure in especially sensitive and normal adults and children.

(2) To improve indoor exposure characterization for a large prospective air pollution study.

B. Background:

Through the base program in air pollution epidemiology a prospective study of approximately 500 families of municipal employees in Pima County, Arizona, was initiated in 1985. Acute and chronic respiratory effects in adults and acute effects in children are being assessed in relationship to indoor and outdoor pollution. The 500 families are a sample from over 3000 families stratified in the basis of questionnaire responses relating to family composition and household characteristics which indicate probable indoor exposures. Daily diaries and peak flows are used to assess short-term changes in respiratory status in children and adults. Yearly spirometry is used to evaluate longer-term effects. Weekly spirometry is conducted in subsamples of adults with and without bronchial reactivity. As this study as originally planned has a substantial indoor component, it presented an opportunity for expansion through the indoor air quality research program.

C. Approach:

Through supplemental funding from the indoor air program, the study was expanded in two ways. First, frequency and duration of indoor monitoring in the 500 homes was increased. Second, a substudy of formaldehyde effects was added. In this substudy, families who change residences during the study will be followed, and formaldehyde exposures in the residences will be measured. Those moving into new conventional or mobile homes with presumably high formaldehyde exposure will be compared with those relocating into older homes.

D. Milestones:

All submitted to 4th International Conference on Indoor Air Quality and Climate (Berlin)

"Formaldehyde Exposure and Acute Health Effects Study"	3/87
"Indoor-Outdoor Relationships for Particulate Matter and Verification of Exposure Classifications"	3/87
"Epidemiological Study of Respiratory Responses to Indoor/Outdoor Air Quality	3/87

E. Project Contact:

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Project 25: Neurobehavioral and Sensory Irritant Effects of Complex VOC Mixture in Humans

A. Objective:

(1) Replicate and extend Danish studies of controlled human exposures to complex VOC mixtures.

(2) Study the neurobehavioral and sensory irritant effects of controlled exposure to a complex VOC mixture in a normal, healthy adult population.

(3) Identify sensitive measures for use in subsequent field studies related to the Sick Building Syndrome (SBS).

(4) Evaluate the utility of a computerized behavioral test battery in a controlled human exposure study.

B. Background:

A prime example of health effects associated with exposure to outgassing chemicals in newly constructed buildings is the "Sick Building Syndrome" (SBS). Symptoms associated with SBS are eye, nose, and throat irritation, memory impairment, and attentional deficit. SBS symptoms are neurobehavioral in nature, although pulmonary, immunological and other system effects may also be present. Volatile organic compounds constitute an important part of the complex mixture of chemicals present in "sick" buildings, but little information is currently available about the health effects of exposure to ambient levels of VOC mixtures found in new buildings.

Molhave et al., acutely exposed humans known to have "sick building syndrome" to a complex mixture of 20 VOCs commonly found in Danish homes. The subjects experienced memory impairment and sensory irritation. Giving the existing data base, Molhave has hypothesized that VOCs have additive or synergestic effects and that they are causally involved in sick building syndrome. Some other VOCs found to be present in homes also cause neurotoxic effects.

C. Approach:

The first formal study will be designed to replicate and extend results of studies conducted by Molhave and his colleagues in Denmark. Molhave will serve as consultant in planning the study. Normal healthy adults will be exposed to a complex mixture of volatile organic compounds selected on the basis of the frequency and intensity of occurrence in buildings -- i.e., the 20 VOCs found most frequently and at highest levels. The initial mixture tested will be as similar as possible to the Molhave mixture, substituting only for chemicals now known to be carcinogenic. Behavioral, sensory irritant and subjective rating measures will be obtained from subjects using a repeated measures design in which each subject will complete control and exposure sessions at one week intervals. Sensorimotor and memory function will be evaluated using a computerized test battery. Measures of eye and nose irritation will also

be obtained. To ensure that all procedures are functional and that personnel are trained adequately, the first formal study will be preceded by a small pilot study, using the same protocol. Later studies will explore effects of a second (perhaps "Americanized") VOC mixture, of VOC exposure in SBS responder or other susceptible populations, and the role of olfactory and trigeminal sensitivity and climate variables such as temperature and humidity in VOC response.

D. Milestones:

Complete planning of Molhave replicate VOC mixture protocol	6/87
Commence pilot study for Molhave replication	9/87
Commence Molhave replicate study	1/88
Complete data collection of Molhave replicate study	3/88
Begin controlled exposure study of second VOC mixture	6/88
Presentation on Molhave replication study	9/88
Report on Molhave replicaltion study	12/88
Presentation on second VOC mixture study	3/89
Report on second VOC exposure study	6/89

E. Project Contact:

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Project 26: Trigeminal Sensitivity of "Sick Building" Responders

A. Objective:

To measure the sensitivity of the nasal endings of the trigeminal sense to stimulation by a volatile organic comppound (VOC) in a group of subjects who are sensitive to emissions in so-called "sick buildings". Signal detection theory will be used to assess the sensitivity of the subject separately from the subject's bias to respond.

B. Background:

The difference in "sick building" responders and nonresponders may be in the indivudual sensitivity to stimulation of the trigeminal sense (sting or burn) to a mixture of VOC. Alternatively, such subjects may simply have a different propensity (bias) to respond. Sensitivity and bias may be separately evaluated in the so-called signal detection model of sensory systems. This study would help determine the nature of the "sick building syndrome" as far as the complaints of sensory irritation are concerned. This project is to evaluate the sensitivity bias of sensitive subjects using a representative VOC, to be followed up with additional VOCs, depending upon results.

C. Approach:

Trigeminal nerve endings will be stimulated by injecting vapor-phase VOC into the naris of a subject. To avoid stimulation of the olfactory sense, which is more sensitive than the trigeminal, a stream of purified, humidified air will be injected into one naris while the subject closes the velopharyngeal port. This will produce an effluent air stream from the contralateral naris. The VOC stream will be directed against the nasal mucosa of the contralateral side where the VOC mixture will be washed away from the olfactory receptors by the stream of effluent air. Thus, only the trigeminal receptors in the immediate area of the VOC injector will be stimulated. After completion of modifications to an existing instrument, the procedure will be standardized on a group of normal subjects (subjects who have not been selected for sensitivity to "sick building" emissions). Following the standardization experiment, a group of sensitive subjects will be recruited and evaluated by the same method. The first chemical evaluated will be toluene.

D. Milestones:

Procurement and construction of test equipment	1/88
Protocol for representative VOC Study	4/88
Completion of representatives VOC Study using normal subjects	12/88
Completion of representative VOC Study using "sensitive" subjects	12/89

Submission of peer-reviewed paper describing studies using representative VOC	5/90

E. Project Contact:

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Project 27: Genetic Bioassay Studies of Volatile Organic Chemicals Emitted from Building Materials

A. Objective:

(1) To determine the mutagenicity and potential carcinogenicity of mixtures of indoor volatile organic chemicals (VOCs) as they are emitted from indoor building materials.

(2) To characterize and identify the volatile organic mutagens and carcinogens emitted from indoor building materials.

(3) To determine the relative contribution of VOCs to the overall mutagenicity of indoor air and to determine how mitigation methods affect the levels of mutagenic VOCs. This will include the testing of individual VOCs.

B. Background:

It is well known that building materials emit complex mixtures of organic gaseous pollutants. Some of the VOC emissions (e.g., formaldehyde) are known to be mutagenic and carcinogenic. It also is known that most individuals spend up to 80 percent of the time indoors and that due to the removal and introduction of building materials (e.g., for repairs) into indoor air spaces that individuals are continually exposed to building material pollutants; however, these exposures are very dynamic in nature. It is important to determine the mutagenicity of emissions from various indoor combustion sources, thereby; identifying potential carcinogenicity, setting priorities for further investigation, and providing procedures to monitoring possible efforts for mitigation.

C. Approach:

Emissions from indoor combustion sources will be tested using short-term genetic bioassays, especially the Salmonella typhimurium plate incorporation test (Ames test) for mutagenicity. This research will be done in collaboration with AEERL who will be responsible for the associated chemistry and the generation of the VOC emissions. Initial studies will begin with representative sources (e.g., paints). Emissions from these sources will be passed through a Tedlar inert chamber in order to expose the bacterial mutagencity test system. When possible, activity will be correlated with chemistry and attempts will be made to identify and bioassay individual VOCs that are likely to be responsible for the bioassay activity. The testing of individual VOCs will confirm this activity. Since many chlorinated compounds cannot be efficiently detected in bacterial bioassays, research will be conducted to identify, develop, and apply other appropriate short-term test systems to these emissions. After identification of VOCs that are mutagenic, these will be suggested to the National Toxicology Program (NTP) as high priority compounds for testing in whole animal bioassays for carcinogenesis.

D. Milestones:

Salmonella test procedures developed for coupling to AEERL chamber studies VOC mixtures	01/88
Exploratory tests with initial materials completed in collaboration with AEERL	03/88
Selection and exploratory efforts with second bioassay (for chlorinated hydrocarbons) completed	06/88
Initial report on Salmonella bioassay of building material VOCs	11/88
Initial report on chlorinated hydrocarbon VOCs	06/89
Report on integrated chemistry/bioassay of building material VOCs	11/89

E. Project Contact:

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Project 28: Indoor Air Quality Evaluation of Three Office Buildings

A. Objective:

To study the Indoor Air Quality of three office buildings of similar design where one has a reported sick building syndrome (SBS) problem, one does not, and one was constructed specifically to use materials and ventilation rates to optimize indoor air quality.

B. Background:

C. Approach:

Through a joint effort between the Georgia Tech Research Institute and ASHRAE, study the indoor air quality in three office buildings of similar design. One of the buildings has been the source of complaints by occupants but for reasons not yet identified. The second building is of similar design and age but has not had any similar complaints. The third building was designed with materials and ventilation rates to optimize indoor air quality. A questionnaire of SBS office building studies developed by Georgia Tech will be administered and samples collected for formaldehyde, VOCs, nicotine, TSP, metals, NOx, CO, CO2, and selected bio-aerosols.

D. Milestones:

Initiate study	Spring/87
Complete sampling	Fall/87

E. Project Contact:

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Project 29: Develop Low Cost Easy to Use Procedures for Determining Air Exchange Rate

A. Objective:

Evaluate current methods for determining air exchange rate (AER) and develop more accurate, lower cost and easier to use methods.

B. Background:

Recent work has shown that current AER procedures may not adequately deal with varying averaging times. Also the current techniques are relatively expensive and hard to use. The accuracy and precision of current methods should be evaluated and low cost easy to use procedures should be developed to replace existing methods.

C. Approach:

Evaluate selected AER procedures in lab and test house situation. Investigate and evaluate possible replacement techniques in lab and test home situations. Determine limits of usefulness of the various techniques. Publish the results in a technical report which describes techniques and provides guidance on appropriate applications of various techniques.

D. Milestones:

Initiate research and monitoring techniques	7/87
Complete evaluation	5/88
Report	8/88

E. Project Contact:

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Project 30: Support for the Canadian Multi-pollutant Indoor Air Quality Study

A. Objective:

To support the measurement of VOCs in a Canadian study of situations leading to sick building syndrome (SBS) problems in residences and public access buildings.

B. Background:

The Environmental Health Directorate of Canada is sponsoring a large-scale study of a variety of pollutants found indoors in buildings in Canada. The focus is on SBS situations where human comfort is of primary concern. The measurements include formaldehyde (passively) in 4000 homes, radon in 2300 homes, "fungal propagules" in 52 homes, and VOCs in 6 office buildings, 3 hospitals, and 4 homes. The first year will be an exploratory effort including the testing of SBS investigation protocols. The second year is planned to be a national multi-pollutant survey of residences.

C. Approach:

Participate by funding the portion of the study dealing with VOC measurements in the first year. To reduce costs we would provide canister sampling hardware, if available. By supporting the VOC portion we would participate in the study design, selection of bulildings, the number of samples to be collected, and the analysis of results.

D. Milestones:

Complete study protocols	Midsummer/87
Complete VOC sampling	Fall/87

E. Project Contact:

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Project 31: Test House Studies of Indoor Sources

A. Objective:

(1) Develop emission testing procedures for organic compounds from unvented combustion sources, material sources, and activity sources in a representative residential setting.

(2) Generate organic compound emission factors and emission models for combustion, material and activity sources in a representative residential setting.

(3) Compare and correlate emission factors and models determined in the test house with emission factors and models developed from chamber study measurements (for combustion and material sources).

(4) Conduct joint studies with HERL (genotoxicity of emissions from sources, biochemical marker studies related to sources) and with EMSL (evaluations of instrumentation to be used in field studies).

B. Background:

Air contaminant levels in the indoor environment are the result of a complex interaction of several related variables including the nature and number of indoor sources, the characteristics of the building, the removal of contaminants by surfaces and chemical reactions, the outdoor concentrations of potential contaminants, and meteorological conditions. Indoor source characterization has to consider the full range of factors. Consequently, the concept of a test house is becoming an essential tool to evaluate the potential impacts of a suspect indoor air emission source. Test houses are currently in use by both TVA and ORNL and have provided data on indoor concentrations of formaldehyde and classical combustion products in the indoor air. Such a facility is being established by AEERL to validate indoor air emission models that are based on small-chamber studies of material sources and large-chamber studies of combustion sources.

C. Approach:

Research on indoor air source emissions will be conducted under actual indoor conditions in a leased residential dwelling. The test house will be located convenient to RTP; it is a single-floor, ranch style house of standard construction with approximately 1400 ft^2 of living space. It is seven years old and has been fully weatherized during construction. The house will be characterized with respect to baseline organic pollutant concentrations and air exchange rate. It will be equipped to measure indoor air contaminants as well as measurements of significant ambient environmental parameters including temperature, RH, and ambient concentration of selected chemical species. The initial indoor air experiments will focus on kerosene heaters and will be in coordination with the project on large-chamber studies of kerosene heaters. The objective will be to measure emissions from their sources both temporarally and spatially, to verify emission source model predictions based on the chamber

studies. Future research will include the evaluation of indoor sources, e.g., consumer products and building materials such as carpeting; indoor activities (cooking and cleaning), and IAQ control technologies. The research will be coordinated with the project on small-chamber studies of materials, and provide validation of emission factors in a residential situation.

D. Outputs and Milestones:

Rental of IA test house	8/86
Characterization of test house	10/86
Begin testing of kerosene heaters	11/86
Presentation on kerosene heater emissions (Berlin conference)	8/87
Report on kerosene heaters	9/87

E. Project Contact:

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Project 32: Engineering Evaluations of Air Cleaners for Indoor Particles

A. Objective:

(1) Determine the stage of technical development of commercially available devices for removing particles from indoor air.

(2) Evaluate the collection efficiency, for the particle size ranges found indoors, of available devices.

(3) Develop and performance-test improved designs.

(4) Work with equipment manufacturers to help bring improved designs into the market.

(5) Prepare guidelines on the use of air cleaners for control of indoor particles.

B. Background:

Indoor particles arise from a number of sources and activities, including smoking, cooking, outdoor soil, wood stoves/fireplaces, and building materials. Many indoor particles are respirable and potentially hazardous, including those with adsorbed radon progeny. Most commercial and residential building HVAC systems include particle filters in the recirculating air ducts; a few also have high efficiency (HEPA) filters and/or electrostatic precipitators. Free-standing air cleaners are also commercially available. Unfortunately, the efficiency of these and other devices for removing specific, respirable particles from the indoor environment is not well documented. IITRI recently completed a preliminary study of 47 different air cleaners and developed removal efficiency data for tobacco smoke, household dust, and pollen. Further research is needed to develop efficiency data for other types of particles, additional devices (including "in-duct" units), and a wider range of operating and environmental conditions.

C. Approach:

AEERL's expertise in dealing with industrial particulate control will be applied to the control of indoor particles. Initial work will focus on commercially available equipment; evaluations will be conducted to determine their effectiveness in removing the types and sizes of particles found in the indoor environment. The manufacturers of the devices will be contacted to obtain available test data and explore cooperative testing programs. Alternative designs to increase removal efficiency of respirable particles will be explored, developed, and tested. Options to be investigated include: new/improved filter materials, pretreatment particle conditioning, and advanced ESP and fabric filter designs. (AEERL scientists have applied all of these concepts to industrial gas cleaning systems.)

D. Outputs and Milestones:

Complete evaluations of commercial indoor air particle removal equipment and publish report	1/87
Develop new/improved design concepts	1/88
Prepare and publish interim guidance on the selection and use of indoor particle control systems	6/88
Complete testing of selected new/improved particle control device prototypes and publish report	6/89

E. Project Contact:

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Project 33: Engineering Evaluations of Air Cleaners for Indoor Organic Vapors

A. Objective:

(1) Determine the stage of technical development of commercially available devices for removing organic vapors from indoor air.

(2) Evaluate the removal efficiency and capacity, for representative organic compounds, of available devices.

(3) Develop and performance-test improved techniques.

(4) Work with equipment manufacturers to help bring improved devices into the market.

(5) Prepare guidelines on the use of air cleaners for control of indoor organic vapors.

B. Background:

Organic vapors are emitted from a wide variety of building materials, consumer products, and occupant activities. Control of indoor organic vapors generally involves removing the source and/or increasing the ventilation rate. The ubiquitous nature of sources of organic vapors in many cases makes source removal impractical. Increased ventilation causes increased energy usage with its resultant economic penalties. Therefore, practical methods for removing organic vapors from indoor air are needed. Small commercial units employing carbon adsorbents or low temperature catalysts are available, but data on their performance is extremely limited and show poor removal efficiency for organic vapors. Further research is needed to evaluate the application of vapor control techniques to the control of indoor organic vapors. Candidate technologies include adsorption, absorption (scrubbing), and catalytic oxidation.

C. Approach:

Existing techniques for controlling organic vapors will be evaluated to determine their applicability to the indoor environment. Initial focus will be placed on adsorption. The removal effectiveness of activated carbon, as well as other adsorbents, will be evaluated for a variety of indoor organic pollutants. The effect of variations in temperature, humidity, and vapor concentration will be investigated. Commercially available units will be tested first, in cooperation with the manufacturers, if possible. Later, new/improved designs (including a variety of adsorbents) will be developed and tested. The research on adsorption will be followed by similar evaluations of catalytic oxidation and absorption.

D. Outputs and Milestones:

Complete initial evaluation of adsorption for control of indoor organic vapors and publish report (FY 86 RTI study)	1/87
Complete tests of commercially available adsorption units and publish report	1/88
Complete theoretical evaluations of catalytic oxidation and absorption	1/88
Prepare and publish interim guidance on techniques for controlling indoor organic vapors	6/88
Develop new/improved design concepts	6/89
Complete testing of selected prototypes of new/improved indoor vapor control devices	6/91

E. Project Contact:

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Project 34: Support of the Library of Congress Sick Building Syndrome Study

A. Objective:

Support the Library of Congress SBS Study by providing support through Yale University to include VOC measurements.

B. Background:

The Library of Congress complex in Washington, DC, was built in the late 1970s and has been the subject of numerous SBS complaints, especially in the largest building which houses 3300 employees. Preliminary walk-thru investigations by NIOSH has not identified the causes of the complaints. A more definitive diagnostic effort is being coordinated by NIOSH with DOE taking a lead role in ventilation-related measurements. DOE has funded NBS for much of the ventilation work. Yale Unviersity has also been funded to study the comfort levels, health concerns, and relationships to pollutant levels.

C. Approach:

A screening study is planned in the summer of 1987 to identify concentration ranges and areas of concern. Questionnaires will be administered to all employees and selected measurements made after the questionnaire results have been analyzed. The area to be supported is the addition of 30-40 VOC measurements using canister technology at selected locations in an attempt to characterize the magnitude of the VOC contribution to the problem.

D. Milestones:

Initiate screening study	7/87
Complete VOC measurements	8/87
Final report	12/87

E. Project Contact:

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Project 35: Chamber Studies of Organic Emissions from Unvented Combustion Sources

A. Objective:

(1) Develop emission testing procedures for particle-bound and vapor-phase organics from unvented combustion sources.

(2) Generate emission factors for organic pollutants from unvented combustion sources (kerosene heaters, gas-fired space heaters, and cigarettes), taking into account source conditions that may influence such emissions.

(3) Develop emission models for unvented combustion sources that account for the influence of major factors that affect emissions.

(4) Rank the health significance of unvented combustion sources, by estimating indoor concentrations from the source models and pollutant dispersion (decay models, and considering pollutant toxicities).

(5) Generate emissions data to support product standards, if necessary (e.g., by CPSC or manufacturers).

(6) Gain insight into the controllability of the emissions by source modifications.

B. Background:

Efforts to reduce residential energy consumption over the past several years have fostered a number of energy saving strategies including weatherization and the use of supplemental space heaters. Concurrent with the implementation of these strategies has been the increased potential for high exposure to a large number of air contaminants particularly from unvented combustion sources. The most popular of these unvented sources may be kerosene space heaters; over 10 million have been sold in the United States in the past 10 years. Kerosene space heaters have been evaluated in a number of chamber studies and test houses for the classical combustion products (NO, NO_2, CO, CO_2, and SO_2). These studies indicate that unvented kerosene heaters used in a residential setting can result in exposure to concentrations of pollutants greater than the national ambient air quality standards. Laboratory studies show that kerosene combustion may be a source of PAH including the highly mutagenic nitrated PAHs. In 1986 AEERL and HERL completed an exploratory, large-chamber study at LBL to measure organic pollutants including PAHs from unvented kerosene space heaters. The AEERL study confirmed that the kerosene combustion process emits several categories of organics including aliphalic hydrocarbons, alcohols, ketones, phthalates, alkylbenzenes and PAH. Furthermore, specific mutagenic activity was detected by HERL in particulate samples indicative of the presence of nitrated PAH. The study, however, was semi-quantitative and did not provide the level of detail required to evaluate the impacts of kerosene heaters. Additional work is needed to quantify kerosene emissions as well as to incorporate other residential combustion sources such as environmental tobacco smoke (ETS) and unvented gas heaters.

C. Approach:

Due to the need for large scale and a controlled environment, further research on unvented combustion sources will be conducted in cooperation with HERL at the J. B. Pierce Foundation. The facility has a 34 m^3 aluminum test chamber in which emissions and emission rates can be measured in a tightly controlled environment. The research effort will investigate the potential for the emissions of trace elements, acid aerosols, organics and biologically active organics; determine the emission rates for important species; identify the conditions which produce the highest and lowest emissions, and predict exposure potentials. Emphasis will be placed on measuring organic emissions and evaluating their mutagenic potential under a range of heater operating conditions, e.g., heater type, heater age, fuel consumption rate, etc., typically found in the home. The data from this study will also be used to drive kerosene heater studies to be done in the EPA test house. Plans also include the extension of this type of study to address environmental tobacco smoke (ETS) and unvented gas space heaters.

D. Outputs and Milestones:

Test procedures developed	9/85
Exploratory tests completed for kerosene heaters	3/86
Paper presented by Traynor et al at APCA	6/86
Report on exploratory kerosene heater study	9/86
Begin kerosene heater chamber study	11/86
Begin ETS chamber study	6/87
Presentation on kerosene emissions (Berlin conference)	8/87
Begin gas space heater chamber study	2/88
Report on ETS chamber study	2/89
Report on gas space heater study	10/89

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Project 36: Chamber Studies of Organic Emissions from Material Sources

A. Objective:

(1) Develop emission testing procedures for use by EPA and other organizations for measuring evaporative and sublimative emissions from indoor material sources.

(2) Generate emission factors for organic pollutants for a variety of building materials, furnishings, and consumer products that are suspected to be major sources of indoor organics, based on field studies.

(3) Develop emission models for indoor material sources.

(4) Rank the health significance of material sources, by estimating indoor concentrations from the source models and dispersion models, and considering toxicities.

(5) Generate emissions data to support product standards, if necessary (e.g., by EPA/OPTS, CPSC, HUD, or manufacturers).

(6) Incorporate sink effects (adsorption) into objectives (1) through (5).

(7) Gain insight on control of emissions by source modification and ventilation practices.

B. Background:

Several European and United States field studies of indoor air quality in homes and office buildings have shown the presence of many organics at or above concentrations at which criteria pollutants are currently regulated (e.g., 50-120 $\mu g/m^3$). Many of these organic compounds are constituents of building materials or other contents of buildings, and many times "sick building" complaints arise shortly after a new building is put into operation or an existing building is renovated, or new materials are brought in. Clinical specialists are also noting a rise in reports of hypersensitivity to indoor chemicals in homes as well as office buildings. Although some studies of organic emission rates from building materials have been conducted, most notably in Denmark, there was no ongoing and sustained effort to characterize emissions under realistic indoor conditions when EPA started its research program in 1984. The most relevant work was on formaldehyde emissions from pressed-wood products. In designing the research plan for this project, EPA drew heavily on the testing experience of Europeans and Oak Ridge National Laboratory, where most of the formaldehyde emissions testing had been done.

C. Approach:

Research on organic emissions from indoor materials is conducted primarily in-house, in the AEERL small-chamber test facility. The facility has two small chambers (each 166 liters) where emission rates of volatile organic compounds can be measured as a function of temperature, relative humidity, air exchange rate, and time. An additional 6-8 chambers for testing under standard conditions are being installed and will be operational by the summer of 1987. Material testing procedures have been developed based on testing experience with various adhesives, caulking compounds, and flooring materials. An interlaboratory testing project was completed with Oak Ridge National Laboratory in the spring of 1986; results from testing emissions of formaldehyde from a standard pressed-wood product compared favorably between the two laboratories. Plans are to expand interlaboratory comparisons in FY 87 to include several laboratories in the United States and Europe, and cover a wide range of organic compounds. Emission factors obtained from the small-chamber test facility will be checked for selected materials under actual indoor conditions in the AEERL test house, which is described in a separate project description.

D. Outputs and Milestones:

Project plan evaluated by review panel	3/84
RTP testing facility in operation	4/85
Papers by Dunn, Sanchez et al., and Merrill et al. submitted for publication	8/85
Paper by Nelms et al. presented at ASHRAE's IAQ'86	4/86
Papers by Tichenor et al. presented at APCA meetings	4/86, 6/86
Report on first interlaboratory comparisons	9/86
Report on testing procedures (for consideration by ASTM)	6/87
Preliminary health risk ranking of 5-10 material types	10/87
Presentation on emissions from materials (Berlin Conference)	8/87
Preliminary health risk ranking of up to 50 indoor materials (if expanded program)	12/87

E. Project Contact:

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Project 37: Annual Review of Existing Indoor Air Quality Data to Determine Direction of Future Programs

A. Objective:

In a manner similar to ECAO review of existing IAQ information conduct an annual review of new information and prepare an annual report.

B. Background:

The SAB review of the IAQ program was critical of EPA's awareness and understanding of existing information.

C. Approach:

Following the format developed during the ECAO review of existing data relevant to the IAQ program, continue the review annually.

D. Milestones:

Annual report, 1987	2/88
Annual report, 1988	2/89

E. Project Contact:

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Project 38: Review Symposium of Indoor Air Quality Information Assessment Document

A. Objective:

Bring together experts to peer review the indoor air quality information assessment document prepared by EPA's Environmental Criteria Assessment Office (ECAO).

B. Background:

In response to the SAB review of EPA's indoor air program a information assessment document is being prepared by ECAO. This document will be used to help plan the future direction of the indoor air program. After a review draft is prepared an external peer review is needed to determine if the review is accurate and comprehensive.

C. Approach:

Utilize the expertise at the Harvard School of Public Health to assemble indoor air quality experts, coordinate the review, and prepare a review document summarizing changes needed.

D. Milestones:

Finalize agreement with HSPH	10/86
Complete research needs document	1/87
Hold review symposium	1/87
Final report	2/87
Hold follow-up symposium	8/87

E. Project Contact:

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Project 39: Support to Committee on Indoor Air Quality

A. Objective:

Provide funding to support Committee on Indoor Air Quality (CIAQ).

B. Background:

The CIAQ was established to coordinate Federal government efforts relating to indoor air quality with EPA as the lead agency.

C. Approach:

Utilize extramural contractor to support the coordination of CIAQ meetings and activities.

D. Milestones:

E. Project Contact:

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Project 40: Update and Revision of Indoor Air Pollution Information Assessment

A. Objective:

To respond to comments from reviewers; summarize information known about pollutants discussed in the assessment; incorporate recent data into the existing document.

B. Background:

If a clear understanding of the hazards posed by exposure to indoor pollutants is to be achieved, information contained in it must be current. The information assessment is a long document that continues to be revised as new data, new analyses, or new interpretations come to light.

C. Approach:

Literature searches of current journals are continuing to be made, and as reviewers submit comments and critiques, the document is revised and updated by the project officer. Research and development for technical assistance will be provided as needed.

D. Project Contact:

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Project 41: Establish and Update EPA's Indoor Air Reference Data Base

A. Objective:

To compile and maintain a complete and up-to-date bibliography of reference materials on indoor air pollution.

B. Background:

Prior to this project there was no comprehensive bibliography of reference materials on indoor air pollution. The Environmental Criteria and Assessment Office (ECAO) conducted a thorough search of the literature and combined several existing reference databases to establish the Indoor Air Reference Data Base. This source consists of a single data base of references for use by personnel within EPA, other Federal agencies, State agencies, and private individuals upon request.

C. Approach:

ECAO will maintain and update periodically the Reference Data Base, which currently contains over 2,200 references.

D. Milestones

Final version of the Indoor Air Reference Data Base completed	9/87
Indoor Air Reference Data Base update completed	12/87
Indoor Air Reference Data Base update completed	3/88

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