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AN SAB ADVISORY: THE NATIONAL HUMAN EXPOSURE ASSESSMENT SURVEY (NHEXA PILOT STUDIES

**PREPARED BY THE INTEGRATED HUM
EXPOSURE COMMITTEE (IHEC) OF THE
SCIENCE ADVISORY BOARD (SAB)**

February 9, 1999

EPA-SAB-IHEC-ADV-99-004

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

Subject: Advisory on the National Human Exposure Assessment Survey
(NHEXAS) Pilot Studies

Dear Ms. Browner:

The Integrated Human Exposure Committee (IHEC) of the Science Advisory Board met on September 28-29, 1998 to conduct an advisory on the National Human Exposure Assessment Survey (NHEXAS) and to be briefed on the National Health and Human Nutrition Examination Survey (NHANES) and its value to improving understanding of human exposure. The NHEXAS pilot studies are funded and managed by the Environmental Protection Agency, Office of Research and Development (ORD), National Center for Environmental Assessment (NCEA), National Exposure Research Laboratory (NERL) and the National Human and Ecosystem Effects Laboratory (NHEERL). NHANES is funded and managed primarily by the Centers for Disease Control and Prevention (CDC). Since most of the NHEXAS field studies have recently been completed, the NHEXAS results have not been fully analyzed or published. Therefore, this advisory report is based primarily on the preliminary NHEXAS data that were presented during the meeting.

At its November Strategic Planning Retreat, the Executive Committee of the Science Advisory Board concluded that new directions taken by EPA demand new directions for the SAB if the Board is going to continue to make a positive difference in the way that science is developed and used in environmental decision-making. In particular, the Executive Committee decided that the SAB needs to spend much more of its energy providing strategic, forward-looking advice. Consequently, the IHEC identified NHEXAS as the topic for its strategic activity for Fiscal Year 1998 because it was designed to provide critical information about multipathway, multimedia population exposure distributions to chemical classes. These data should be very useful in determining the most effective strategies to reduce public risk to hazardous environmental chemicals. The focus of this advisory is to provide the Agency with forward-looking advice on the analysis and future uses of NHEXAS based on the preliminary data. Due to the wide range of possibilities for analyses of the NHEXAS databases, the Committee plans to have a follow-up advisory, towards the end of 1999, on the Agency's plans for the future analyses of the NHEXAS data over the next 5 years.

In the three field studies, exposures in three study regions were measured using data on pollutant concentrations in environmental and biological media and estimates of the frequency and durations of exposure-related human activities. These studies included: a) measurements of pollutant concentrations in air, water, soil, dust, food, blood, and urine as well as on surfaces and human skin; b) measurements of direct exposure using personal exposure monitors; and c) estimations of human activity patterns using a series of questionnaires and diaries. These data are being used to estimate human exposures among the sampled populations and to test a series of hypotheses related to these exposures. The target chemicals include: volatile organic compounds (VOCs, except for the Maryland study), pesticides, metals and polyaromatic hydrocarbons (PAHs).

The Committee was charged to respond to the following Charge questions:

- a) What are the strengths and weaknesses of multimedia, multipathway measurements of exposure as represented by the NHEXAS program, insofar as they can be defined at this point?
- b) Are the ongoing and planned analyses appropriate and likely to further the goals of NHEXAS? At the level of each consortia? At the level of NHEXAS?
- c) What actions would be likely to increase the utility of the information from NHEXAS? In the near-term? In the longer term?
- d) What follow-up studies would be most useful in the near term, considering that key NHEXAS analyses will not be completed for a year? What is the appropriate balance between large population surveys and more targeted follow-up studies?
- e) What additional IHEC advice is offered for strengthening the immediate and long-term utility of NHEXAS and studies like it?

The IHEC commends the Agency for conducting the NHEXAS pilot study. The IHEC found NHEXAS to be an excellent project that will provide vital information to the EPA for addressing the many multimedia pollutant issues that the Agency is confronted with on a daily basis. When fully analyzed, the results of the NHEXAS pilot study should provide a basis for the design and implementation of an effective surveillance program for multimedia pollutants. Therefore, the NHEXAS pilot study is highly relevant to the Government Performance and Results Act (GPRA) and SAB's "Integrated Environmental Decision-making Framework" which emphasize performance evaluation as a key to effective environmental health protection. NHEXAS is also highly relevant to EPA's Cumulative Exposure Project (CEP) because it provides measurement data against which the CEP models can be evaluated.

The Committee was particularly concerned about the limited resources allocated to the analysis of the NHEXAS data and the lack of a strategic plan for follow-up studies. If NHEXAS

were to stop at this time, the considerable efforts and expenditures incurred during the last five years would be of limited utility to the Agency. Therefore, the Committee strongly encourages the EPA to pursue the completion of the study in an expeditious manner. It is important that the costs of this program be presented within a frame of future savings as a result of improved public health resulting from better targeted, more effective, and less costly regulatory efforts. In addition, the Committee highly recommends that findings that are of considerable importance to the Agency in the current risk management efforts be identified and given high priority for analysis and publication. However, the data should be presented in terms of the associated uncertainty and limitations to add to the transparency of the information.

The Committee also cites a weakness of the NHEXAS pilot studies and provides recommendations for increasing the utility of the NHEXAS data. The weakness cited by the IHEC was the criteria for the selection of the target chemicals which were measured analytes. The Committee's recommendations to the EPA for increasing the utility of the NHEXAS data include: a) the development of a strategic plan for analyzing the data; b) publicizing the NHEXAS framework (by informing the public through various media such as an EPA publication that is available in hard copy and on the Internet); c) analyzing the flexibility of NHEXAS to study special populations such as minorities and sensitive populations; d) linking the exposure data from NHEXAS with biological markers from NHANES where possible and e) improving the communication between the NHEXAS investigators and state and local health officials.

The Committee appreciates the opportunity to provide advice to the Agency on the preliminary NHEXAS data. The Committee looks forward to receiving a written response from the Assistant Administrator for Research and Development (ORD), and to conducting a follow-up advisory on the Agency's plans for the future analysis of the NHEXAS data.

Sincerely,

/signed/

Dr. Joan M. Daisey, Chair
Science Advisory Board

/signed/

Dr. Henry A. Anderson, Chair
Integrated Human Exposure Committee
Science Advisory Board

NOTICE

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ABSTRACT

On September 29-30, 1998, the EPA Science Advisory Board (SAB) Integrated Human Exposure Committee (IHEC) reviewed the preliminary data on the National Human Exposure Assessment Survey (NHEXAS) pilot studies in Durham, North Carolina. The NHEXAS pilot studies were designed to provide critical information about multipathway, multimedia population exposure distribution for selected chemical classes.

IHEC found NHEXAS to be an excellent project that has significant promise for improving public health in a cost-effective manner. The Committee also found NHEXAS to be outstanding in both design and implementation. When completed, NHEXAS should greatly improve understanding of human exposure to selected pollutants. This, in turn, would be helpful in determining the most effective strategies to reduce the public's risk to hazardous environmental chemicals. (The uncertainty and limitations associated with the data should be presented along with the data in order to add to the transparency of the information.) Therefore, the Committee strongly encourages the EPA to pursue the completion of the study results in an expeditious manner.

To increase the utility of NHEXAS, the Committee recommends that the EPA: a) develop a strategic plan for analyzing the data; b) publicize the NHEXAS framework by informing the public through various media such as an EPA publication that is available in hardcopy and on the Internet; c) evaluate the flexibility of NHEXAS to study special populations such as minorities and sensitive populations; d) link the exposure data from NHEXAS with biological markers from NHANES where possible; and e) improve the communication between the NHEXAS investigators and state and local health officials.

The Committee was particularly concerned about the limited resources allocated to the analysis of the NHEXAS data and the lack of a strategic plan for follow-up studies. If NHEXAS were to stop at this time, the considerable efforts and expenditures incurred during the last five years would be of limited utility to the Agency. It is important, therefore, that the costs of this program be presented within a frame of future savings as a result of improved public health resulting from better targeted, more effective, and less costly regulatory efforts. The Committee was also concerned about the selection of the chemicals that were measured in NHEXAS. Several recommendations are provided for the planned analyses of the data, actions for the increased utility of the data, and follow-up studies in both the near term and in the future.

Keywords: National Human Exposure Assessment Survey (NHEXAS); National Health and Human Nutrition Examination Survey (NHANES) strategic plan; biological markers; multimedia; multi-chemical; multi-pathway

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Science Advisory Board
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1. EXECUTIVE SUMMARY

On September 28-29, 1998, the Integrated Human Exposure Committee (IHEC) met in Durham, North Carolina to conduct an advisory on the National Human Exposure Assessment Survey (NHEXAS). At this meeting, the IHEC was also briefed on the National Health and Human Nutrition Examination Survey (NHANES) and its value to improving understanding of human exposure by a representative of the Centers for Disease Control and Prevention. Given the early stage of the NHEXAS data analysis, the purpose of the first advisory was to provide advice to the Agency on the strengths and weaknesses of the NHEXAS pilot study data and on the ongoing and future analyses and uses of the data.

The Committee selected NHEXAS as the topic for its strategic activity for Fiscal Year 1998 following the SAB Executive Committee's decision to spend much more of its energy providing strategic, forward-looking advice to the EPA. NHEXAS was chosen because it was designed to provide critical information about multipathway, multimedia population exposure distributions for chemical classes and will be very useful in determining the most effective strategies to reduce the public's risk to hazardous environmental chemicals.

The NHEXAS data has not been fully analyzed, and therefore, has not yet been published. Therefore, the background material did not consist of published studies on the NHEXAS data analysis. Instead, the Committee was provided with articles that described the history of NHEXAS; the strategies, goals, objectives, and the hypotheses to be tested; and the study design, including the study area, population and sampling methods, and data evaluation and analytical methods. During the meeting, the NHEXAS Principal Investigators gave presentations on the preliminary data. The Committee's advice is based primarily on those data.

The IHEC found NHEXAS to be an excellent project that has significant promise for improving public health in a cost-effective manner. When completed, NHEXAS should provide a greatly improved understanding of human exposure to selected pollutants. This, in turn, will be helpful in determining the most effective strategies to reduce the public's risk to hazardous environmental chemicals. The Committee also found NHEXAS to be outstanding in both design and implementation. Therefore, the Committee strongly encourages the EPA to pursue the completion of the study in an expeditious manner.

The Committee was particularly concerned about the limited resources allocated to the analysis of the NHEXAS data and the lack of a strategic plan for follow-up studies. If NHEXAS were to stop at this time, the considerable efforts and expenditures incurred during the last five years would be of limited utility to the Agency. It is important, therefore, that the costs of this program be presented within a frame of future savings as a result of improved public health resulting from better targeted, more effective, and less costly regulatory efforts.

To increase the utility of NHEXAS, the IHEC recommends that the EPA: a) develop a strategic plan for analyzing the data; b) publicize the NHEXAS framework by informing the public through various media such as an EPA publication that is available in hardcopy and on the Internet; c) evaluate the flexibility of NHEXAS to study special populations such as minorities and sensitive populations; d) link the exposure data from NHEXAS with biological markers from NHANES, where possible; and e) improve the communication between the NHEXAS researchers and the state and local health officials.

The Committee also recommended several additional actions for the Agency to increase the utility of the NHEXAS data. Those actions include:

- a) analyzing the questionnaire data (including analysis of the responses on the questionnaires and analysis of the questionnaire itself to determine what worked and what did not work),
- b) analyzing the exposure data,
- c) identifying the most cost effective approaches to exposure assessment based on the NHEXAS data,
- d) conducting a prototypical analysis of exposure and assessments of intervention strategies,
- e) archiving the information in a manner such that the data can be retrieved years from now for further analysis,
- f) integrating the databases from the three pilot studies, where possible, and
- g) developing a feasibility study for a national human exposure survey.

For longer term activities, the Committee recommends that the Agency: a) place emphasis on developing physically-based quantitative models that can be used to evaluate various possible risk management options; b) consider using advanced measurement technologies such as advanced sensors and sampling technologies, and robotics for multiple analyses, and advanced software for analysis of chromatographic outputs; and c) applying the NHEXAS pilot data, after the analyses have been completed, to on-going programs within the Agency such as validation of multimedia transport models.

The Committee looks forward to the Agency's response and to the follow-up advisory on the Agency's plans for future analyses of the data.

2. INTRODUCTION

2.1 Introduction

In order to assess the risks posed by chemical pollutants in the environment, the EPA must be able to estimate the number of people exposed to these chemicals as well as the intensity of exposure. In the past, most studies have focused on exposures to one chemical at a time by one route of exposure. While such studies are important, they do not reflect actual patterns (distributions) of human exposure to chemicals in the environment because people are exposed to multiple chemicals from various routes and media. The ultimate goal of the National Human Exposure Assessment Survey (NHEXAS) is to document status and trends of national distributions of human exposure to potentially high risk chemicals to improve the accuracy of exposure (and risk) assessments, and to evaluate whether exposure (risk) is decreasing or increasing over time with the application of risk management steps by taking into account exposure to multiple chemicals from various routes and media. In doing so, NHEXAS will help to identify those pathways and routes that are responsible for the greatest exposure and will therefore provide direction for decisions on the most effective strategies to reduce risks.

The five major objectives for NHEXAS are:

- a) to evaluate the feasibility of NHEXAS concepts, methods, and approaches for the conduct of future population-based studies;
- b) to evaluate the utility of the NHEXAS data for improved risk assessment and management decisions;
- c) to test the hypothesis that the distribution of exposure given by modeling and extant data does not differ from the measurement-based distribution of exposure;
- d) to define the distribution of total human exposures for a relatively large geographic area by:
 - (1) identifying the upper 10th percentile of distribution,
 - (2) providing baseline data for later comparisons,
 - (3) evaluating pathways,
 - (4) identifying predictors, and
 - (5) comparing exposure data with biomarkers of exposure; and
- e) to stimulate exposure research and forge strong working relationships between government and non-government scientists.

Phase I of NHEXAS consists of pilot studies designed to evaluate the feasibility of evaluating total human exposure to multiple chemicals on a community and regional scale. The pilot studies focus on the exposure of people to environmental pollutants during their daily lives. Hundreds of volunteer participants were randomly selected from several areas of the country to obtain a population-based probability sample. The levels of target chemicals to which participants were exposed were measured in the air they breathe, in the food and beverages they consume, in the water they drink, and in the soil and dust around their homes. In addition, chemicals or their

metabolites were measured in biological samples (including blood and urine) provided by the participants. Finally, participants completed questionnaires which will be used to help identify possible sources of exposure to chemicals and to characterize major activity patterns and conditions of the home environment.

The EPA Office of Research and Development entered into three Cooperative Agreements with three different Consortia to conduct these field studies. The Consortia include: 1) a consortium from the University of Arizona, Battelle Memorial Institute, and the Illinois Institute of Technology; 2) a consortium from the Research Triangle Institute (RTI) and the Environmental and Occupational Health Sciences Institute (EOHSI); and 3) a consortium from Harvard University, Johns Hopkins University, Emory University, Southwest Research Institute, and Westat. In addition, the EPA Office of Research and Development has entered into Inter-agency Agreements with: 1) the Centers for Disease Control and Prevention (CDC) to analyze blood and urine samples; 2) the Food and Drug Administration (FDA) to analyze food and beverage samples; 3) the National Institute for Standards and Technology (NIST) to provide quality assurance support; and 4) the General Services Administration (GSA) to provide data management support.

Sample collection began in mid-1995 and was completed for all of the projects in late 1997. Almost all of the planned sample analyses were completed late in 1998. Statistical analyses of the data were ongoing in 1997 and 1998 and funded for additional analyses in 1999. Initial publications by the Principal Investigators are expected beginning in early 1999. Analyses of the combined databases from the three consortia can provide considerable additional information, but will require a strategic plan for this data analysis due to the wide range of possibilities for analyses. The Integrated Human Exposure Committee plans to conduct a follow-up advisory, late in 1999, on the Agency's plans for a strategy for the data analysis. In 2000, the actual NHEXAS databases for the pilot studies should become available to the public in hardcopy and on the Internet.

2.2 Charge to the Committee

On September 29-30, the IHEC met in Durham, North Carolina to conduct an advisory on the National Human Exposure Assessment Survey and to be briefed on the National Health and Human Nutrition Examination Survey. The IHEC was charged to respond to the following five questions:

- a) What are the strengths and weaknesses of multimedia, multipathway measurements of exposure as represented by the NHEXAS program, insofar as they can be defined at this point?
- b) Are the ongoing and planned analyses appropriate and likely to further the goals of NHEXAS? At the level of each consortia? At the level of NHEXAS?

- c) What actions would be likely to increase the utility of the information from NHEXAS? In the near-term? In the longer term?
- d) What follow-up studies would be most useful in the near term, considering that key NHEXAS analyses will not be completed for a year? What is the appropriate balance between large population surveys and more targeted follow-up studies?
- e) What additional IHEC advice is offered for strengthening the immediate and long-term utility of NHEXAS and studies like it?

3. RESPONSE TO THE CHARGE

3.1 Charge Question 1: Strengths and Weaknesses

What are the strengths and weaknesses of multimedia, multipathway measurements of exposure as represented by the NHEXAS program, insofar as they can be defined at this point?

Overall, the Committee found that the NHEXAS pilot program is strong scientifically and addresses many of the issues of concern to the Agency. Another strength of NHEXAS is that it can be used to identify serious human health risks. The criteria for the selection of the target chemicals that were measured was identified as a weakness of the NHEXAS pilot program.

3.1.1 Strengths

Scientifically, NHEXAS is outstanding in both study design and implementation and provides an excellent model for future EPA studies. Key scientific strengths include: a) a hypothesis-driven design; b) the integration of models with measurements to test and refine models and to understand causality; c) some advances in measurement methods; and d) a strong quality assurance plan. These are essential features of the "scientific method" and provide great power for addressing environmental health problems. The framework of NHEXAS makes it possible to track many of the exposure pathways back to sources of exposure and provides a sound scientific basis for exposure and risk reduction. In addition, the NHEXAS pilot study has also generated a rich database.

Another important strength of the emerging NHEXAS data is the ability to quantify multiple pathways of exposure from different source media to a single or to multiple exposure media. No other data set includes temporally and spatially concurrent measurements that makes it possible to simultaneously trace chemicals from air and soil to house dust or from air and soil to indoor air. NHEXAS data can help to identify serious human health risks, to decide what interventions would be helpful in reducing these risks, and to document the effectiveness of interventions in actually reducing exposures.

3.1.2 Weaknesses

If EPA decides to proceed with further phases of the NHEXAS program, better criteria for the selection of target analytes (chemicals of concern that are measured in food, air, water, etc.) need to be developed. In future phases, there should be more two-way interaction between risk assessment experts and NHEXAS program participants so that the list of target chemicals to be measured evolves dynamically as our understanding of human exposures and health risks advances.

3.2 Charge Question 2: Ongoing and Planned Analyses

Are the ongoing and planned analyses appropriate and likely to further the goals of NHEXAS? At the level of each consortia? At the level of NHEXAS?

The ongoing and planned analyses were outlined well at the meeting with the exception of setting limitations on the degree of extrapolation of the data. One strength of the data analyses is that all food/beverages, water, and biologicals were analyzed by FDA, EPA contract laboratories, and CDC, respectively, with the exception of some food samples that were analyzed by RTI. However, there are some significant differences in the methods for collection for some of the samples and in the protocols for the use of those samples. Therefore, the integration and meta-analysis of the food/beverages, water and biologicals data from all three Consortia should be done where possible. In addition, each consortium had certain samples analyzed in its own laboratories. There were inter-laboratory analyses of performance evaluation samples (coordinated by NIST) and of split samples (or extracts). Since there are some differences in sample collection and analysis, the IHEC realizes that there are some limitations on the extent of data integration and "meta-analyses" that can be done.

The NHEXAS pilot surveys that have been conducted to date have emphasized data collection. During the meeting, a representative of the Agency mentioned that a minimal amount of resources have been allocated for further analysis of the NHEXAS data. The EPA should ensure that sufficient resources are available to fully analyze the data from this large study.

The ability to analyze the data at the level of NHEXAS (combined three studies) is contingent upon the development of a strategic plan to assure that the data from the consortia are comparable to allow for meta-analysis. IHEC recommends that the Agency complete the quality assurance of the data before entering the data into a master database. The Committee strongly recommends that the data be analyzed using the original protocol and that the hypotheses be tested first using the constraints of the protocol, e.g. there were only sufficient samples to calculate the upper 90th percentile. Criteria should be established before the analyses are conducted for each of the parameters, including such things as: a) the number of observations required to calculate the mean, 50th percentile, 75th percentile and 90th percentile; b) the treatment of censored and missing data; c) non-response calculations; and d) application of weighting factors.

The Committee highly recommends that findings that are of considerable importance to the Agency in current risk management efforts be identified and given high priority for analysis and publication. The Committee also provides recommendations for analyzing the questionnaire data, analyzing the exposure data, conducting hypothesis testing, developing models to integrate exposure from different media and estimating long-term exposures from short-term measurements.

3.2.1 Analyses at the Level of Each Consortia

With limited resources, all three consortia explored their data to different depths and varying dimensions, some even beyond the original goal of the Phase I field work to plan, design, test, and demonstrate critical components of NHEXAS.

The Committee was concerned about the difference in participation rates amongst the three consortia and the potential for a difference in representativeness of the population sampled in the different consortia. To assess the feasibility of the population-based probability sampling design, all three consortia presented some data on representativeness, response rates, and dropout rates. The representativeness of the probability samples of Region V and the State of Arizona does not appear to be problematic since the demographics of samples from these two regions are not very different from census data. A simple observed-against-expected chi-square test can be used to test whether or not deviations from proportions of census data reach a statistically significant level.

The response and completion rates are comparable to other large surveys, but are still lower than the expected 75%. Therefore, demographics of nonparticipants and dropouts should be compared with those who participated and remained in the study to see if there is any bias throughout the various stages of the project. If detailed analysis can be carried out to identify factors related to non-response and dropout, investigators may gain some insight on how to increase the response rate for the national survey. NHANES, a national sample of over 30,000 people had a response rate of approximately 80%. The NHEXAS pilot studies should be able to achieve response rates close to those of NHANES.

Unlike the other two consortia, higher-than-expected completion rates (>95%) and high retention rates (>95%) have been observed in the Maryland study. The level of incentive was based on the extent of participation, with higher incentives offered for more difficult procedures. The IHEC recommends that the Agency explore the use of incentives for a national survey. In doing so, the Agency should conduct an analysis of the cost-effectiveness of incentives.

3.2.2 Analysis at the Level of NHEXAS

- a) Master database and strategic plan for data analysis - The IHEC strongly recommends that the Agency develop a strategic plan to analyze the data from the three consortia in a systematic way so that the core information can be delivered to the Agency in a timely manner. This strategic plan would ensure that all datasets have been checked and found to meet quality control/quality assurance standards before they are entered into a master database. The master database should be user-friendly and easily installed on a personal computer. Data from the three consortia should be comparable in format, so that cross-checking and meta-analysis can be easily carried out. The database should be designed so that it can easily incorporate other relevant datasets, such as time-activity studies and

NHANES data, for an integrated data analysis. The master database should provide a user-friendly environment for future data management, statistical analysis and modeling work of all datasets stored in the database. The Committee is concerned about the Agency's ability to retrieve electronically stored data in a few years from now given the rapid pace at which computer technology is advancing and changing. Therefore, the IHEC strongly recommends that, in addition to any electronic versions of the NHEXAS data, the EPA maintain a complete paper copy of all data, including measurement results and questionnaires.

Key elements of the strategic plan for data analysis should include:

- (1) completion of quality assurance of the data,
- (2) statistical analyses to develop some feel for the data, e.g., means, shapes of data distributions, ranges, etc.,
- (3) testing of study design hypotheses plus any related hypotheses,
- (4) model validation and refinement,
- (5) evaluation and comparison of tools, e.g., questionnaires and measurements,
- (6) critical evaluation of the potential value of meta-analysis across the three sub-components of NHEXAS and development of a plan for any meta-analysis, and finally
- (7) the identification of findings of considerable importance and help to the Agency in some current risk management efforts (the early analysis of the NHEXAS data suggest that there may be findings of this nature).

- b) Evaluation of survey instruments and Quality Assurance/Quality Control data - In order to assess total exposures, questionnaires on baseline information and time-activity were administered, diet-diaries were obtained, direct observations by field personnel were noted, and environmental samples from air, soil, dust, water, food, beverage, urine, and blood were taken. Classes of chemicals analyzed include metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and pesticides. Some of the monitoring and measurement techniques are well established, some require validation (e.g., using market basket surveys and food diaries to estimate dietary exposures), and others still need further development (e.g., skin wipes for dermal exposure to pesticides). Due to the diversity (questionnaires, diaries, environmental measurements and biological samples) of the survey tools, one of the most important objectives of the Phase I field work is to evaluate the survey instruments. None of the three consortia presented data on the evaluation of the survey tools. However, this was not expected at this stage of the research. In the follow-up advisory, the Committee is interested in the analysis of the questionnaire responses. The Committee is also interested in the analysis of the questionnaire itself to determine what worked and what did not work. Additional advice on the questionnaire is provided under the next subheading, *Questionnaire data*.

Although IHEC cited a strong quality assurance plan as one of the key scientific strengths of the NHEXAS design, the Committee was particularly concerned that Quality Assurance/Quality Control (QA/QC) data were not presented at the meeting, and was further concerned that limited resources have been allocated for data analysis. The completeness, accuracy, and validity of questionnaires should be evaluated. Issues on accuracy, precision, sensitivity, specificity, portability, and affordability of environmental measurements should be addressed. After the evaluation, questions with too many missing or incorrect responses should be deleted from further analysis and invalid chemical measurements should be deleted from further processing.

- c) Questionnaire data - So far, data analysis has been focused on descriptive and summary statistics, tables, and figures of chemicals measured in various media. The analysis of questionnaire data has been delayed. At the preliminary stage of data analysis, efforts should be spent on entering, checking, correcting and cleaning all measured variables. All questionnaire and environmental data are needed for the estimation of integrated long-term exposure. Without the questionnaire data, such as time-activity and diet diary, it is not possible to integrate exposures across different media and from various microenvironments. It is important that the data format and reports of descriptive and summary statistics from the three consortia are uniform so that preliminary results from different research groups can be easily compared. Given that this was a pilot study which will provide information on how to improve future studies, the Committee strongly recommends that the Agency analyze the questionnaire itself to determine what worked and what did not work.
- d) Exposure data - Once descriptive and summary statistics have been completed, concentration data should be transformed into exposure data. All three consortia generated some exposure distributions from measured chemicals. The Committee emphasizes the importance of presenting the data in terms of the associated uncertainty and limitations to add to the transparency of the information.

When examining the shapes of exposure distributions that were presented at the meeting, it became clear that not all exposure distributions are log-normal. The data presented at the meeting indicated that some compound-specific distributions are close to exponential while others are log-normal, with a second mode towards the tail. Further work needs to be done to integrate total exposures from all media and to estimate long-term exposures from short-term measurements. To predict more long-term exposures, it is important to know intra-individual/household, inter-individual/household, day of week, and seasonal variations. The optimal timing and frequency of sampling are determined by the relative size of different variations.

- e) Hypothesis testing - Long lists of hypotheses were formulated by the Arizona and Region V consortia (Pellizari, et al., 1995). However, the results of the hypotheses testing were not presented at the meeting. Some hypotheses may not be testable due to the lack of data or insufficient sample size (e.g. for sensitive populations and/or minority groups). However, the Committee recommends that the Agency attempt to test hypotheses that can be addressed with the collected data.

- g) Modeling - The data collected from the Phase I field work provide many possibilities for modeling work. The interrelationship of measured variables can be explored. Models can be developed to integrate exposures from different media and to estimate long-term exposures from short-term measurements. Relative contribution of various sources to total exposures and body burdens can be assessed. Factors related to the high-end of exposures can be identified. Among all possible modeling efforts, the most important one is the exposure assessment modeling work. Examples of modeling projects where the NHEXAS data can be applied include the Cumulative Exposure Project and the Total Risk Integrated Methodology (TRIM). The Office of Policy, Planning, and Evaluation developed the Cumulative Exposure Project to provide a national distribution of cumulative exposures to environmental pollutants, providing comparisons of exposure across communities, exposure pathways, and demographic groups. The Total Risk Integrated Methodology is a multimedia, time-series simulation modeling system developed by the EPA Office of Air Quality Planning and Standards for the assessment of human and ecological risks resulting from hazardous and criteria air pollutants.

Rigorous and thoughtful data analysis is an essential component of any research and requires adequate time and funding. It is not sufficient to simply make environmental measurements and stop. The analysis phase of research is essential to fully understanding and utilizing the results of expensive field measurements.

3.3 Charge Question 3: Increasing the Utility of NHEXAS

What actions would be likely to increase the utility of the information from NHEXAS? In the near-term? In the longer term?

The IHEC found NHEXAS to be an excellent project that has significant promise for improving public health in a cost-effective manner. When completed it should provide a greatly improved understanding of human exposure to selected pollutants. This, in turn, will be helpful in determining the most effective strategies to reduce the public's risk. Therefore, the Committee strongly encourages the EPA to pursue the completion of the study in an expeditious manner.

3.3.1 In the Near Term

The EPA should review the goals of this research and develop a strategic plan for the analyses of the Phase I data. Included should be a clear statement of the limitations of the Phase I studies (with attention to distributions, tails, 95th percentiles, etc.). Detailed recommendations for the analysis of the data are provided in the IHEC response to Charge question 2.

The EPA should provide funding to complete the primary data analyses. The NHEXAS information will be of only limited utility if such analyses are not completed. Furthermore, EPA should facilitate cooperation among the three consortia during the data analysis phase in order to achieve optimal coordination of the resulting information. Detailed recommendations for analyzing the data in a systematic way are presented in the Committee's response to Charge question 2.

While the experience is fresh in the minds of the various members of the consortia, the EPA should encourage the investigators to: a) evaluate the different field study designs; b) identify the most cost-effective approaches (to exposure assessment) that were used during the study; and c) identify less expensive ways to accomplish exposure assessment.

The EPA should conduct a cost-benefit analysis of the various components of the study. Such an analysis could prove quite useful in discussions regarding the value of the program and would also be of utility in seeking future funding. It is important that the costs of this program be presented within a frame of future savings as a result of improved public health resulting from better targeted, more effective, and less costly regulatory efforts.

- a) Prototypical analysis of exposure and assessments of intervention strategies - In the near-term, prototypical analyses of exposure and assessments of intervention strategies should be made for a variety of chemicals measured in the NHEXAS pilot program. It is recognized that NHEXAS data collected to date are for demonstration purposes, so any assessments based on the data would be limited and preliminary. Nevertheless, a diverse set of analyses such as those listed below could be performed using NHEXAS data. Examples of chemicals or products for inclusion in NHEXAS that should provide significant information to the Agency include the following:
 - (1) trace metals - For example, the mercury concentrations measured in the NHEXAS pilot studies in various environmental media and the contributions of each to overall human exposure should be reported to other EPA programs that are responsible for regulating mercury in the environment. Although late, input on this issue could still be helpful to EPA's risk assessment and risk management for mercury.

- (2) disinfection byproducts - Many water systems are switching from chlorine to chloramines to provide drinking water treatment and residual disinfection in the water distribution system. This is motivated, in part, because there are concerns about the formation of disinfection byproducts (notably trihalomethanes such as chloroform) when chlorine is used as the disinfectant, and also because there are concerns about hazardous materials present during accidental atmospheric releases of chlorine gas. It may be possible, using NHEXAS data, to distinguish between water systems in the same area using chloramines instead of chlorine to disinfect drinking water. This would be a good prototypical example of assessing the effects of a source intervention on human exposure to chloroform. However, the Agency must keep in mind that the data from these NHEXAS pilot studies are not necessarily nationally representative.
- (3) volatile organic compounds - Reformulated gasoline (RFG) was required beginning in 1995 in Chicago, Phoenix and other cities nationwide. In addition to requiring the use of oxygenated compounds such as methyl tert-butyl ether (MTBE) or ethanol in gasoline, a separate mandate of the Clean Air Act limited benzene in gasoline to 1% by volume or less. It may be possible to document changes in benzene inhalation exposures by comparing areas in all three of the pilot study regions where RFG was used to other cities where RFG was not required, and/or by comparing with historical benzene exposures measured in the Total Exposure Assessment Methodology (TEAM) study (EPA, 1987).
- (4) pesticides - Similar analyses to those presented for mercury could be conducted to demonstrate how NHEXAS data could help assess the importance of various environmental media in contributing to exposure of one or more pesticides of concern. The pesticide measurements may also be of value to the Office of Prevention, Pesticides and Toxic Substances in its effort to implement the Food Quality Protection Act.

The EPA should archive the information from NHEXAS in a manner that the data can be readily searched several years from now. This is especially true for the analytical data. As an example, the Agency should consider the total ion chromatograms collected as part of the program. Although specific sets of VOCs were chosen as target chemicals to be measured, there is the potential of searching these chromatograms for other analytes. This would require that all the associated information be stored in a cross-referenced fashion that is readily retrievable.

- b) Database integration - The IHEC recommends the following to improve the quality and utility of the databases from the three pilot studies:

- (1) the databases from Arizona and Region 5 should be integrated in some fashion,
- (2) the NHEXAS researchers should assess the implications of the Maryland study for the Arizona and Region 5 study,
- (3) the NHEXAS results should be integrated with information on *criteria pollutants* from fixed site monitoring stations, and
- (4) the databases from NHEXAS and NHANES should be cross referenced in a fashion that fully takes advantage of the "complementarity" of the data.

As recommended in the response to Charge question 2, the Committee recommends that the EPA initiate the development of a strategic plan and feasibility study for a national survey.

During the meeting, the Committee was informed of the interagency involvement including local departments of health. However, the Committee noted gaps in the interagency communication. For example, there were cases in which high levels of lead were measured in homes but this information was not provided to the local health department due to reasons of confidentiality. The Committee recommends improvement in the communication between the NHEXAS investigators and state and local public health officials to maximize the reduction of health risks from exposure to environmental chemicals that can be achieved through the NHEXAS program. For example, the confidentiality agreement might be modified to permit notification of health officials and subjects when high exposures have been measured.

The EPA should also develop a public education strategy. The extent to which the community leaders were aware of the NHEXAS studies is unclear. When the data are released to the public, information should also be communicated on the findings and their implications. The data that are released should include specific recommendations for reducing exposures to potentially harmful agents, if appropriate.

3.3.2 In the Longer Term

The EPA should consider studies designed to bridge NHEXAS and NHANES. Such studies have the potential to significantly enhance the utility of information derived from both programs.

Implementing a national survey could significantly improve public health. However, it should be designed in the most cost-effective manner. The EPA should use the experiences of the Phase I consortia to evaluate the feasibility of a national survey. The EPA should focus on those areas that most contribute to risk reduction. It may be desirable to coordinate such a survey with NHANES. The Committee recommends that if the EPA finds a national survey to be feasible

upon evaluation of the NHEXAS data and conducts such a survey, the Agency should also consider sub-populations such as, children, minorities, and inner city residents.

In light of a potential national survey, the EPA should reassess the target chemicals to be measured. This includes specific volatile organic compounds as well as selected biologicals that are emerging as substantial risks to susceptible populations such as , children, minorities and inner city residents.

3.4 Charge Question 4: Follow-up Studies

What follow-up studies would be most useful in the near term, considering that key NHEXAS analyses will not be completed for a year? What is the appropriate balance between large population surveys and more targeted follow-up studies?

3.4.1 Follow-up Studies in the Near Term (over the next 12 months)

It is difficult to propose near-term studies with the limited analysis of the data obtained to date. In addition, the time line for completion of the NHEXAS pilot data analyses (i.e., one year) is probably optimistic, and it is highly unlikely that any new studies could be proposed, reviewed, and performed during such short time frame. At this time, EPA will be best served by directing resources to the analysis of the data already collected, and to a thorough evaluation of the methodologies used during the pilot studies. In this context, it is important to carefully examine the different approaches taken by the three consortia in order to determine what methods did or did not work, and give careful thought to alternative methods that could be more cost effective. Another important issue to address is the amount and nature of the new knowledge derived from the pilot studies as it relates to the methodologies implemented. New studies should be considered only after the pilot data are analyzed. The Committee recommends that the Agency present the results of the data analysis and methodology evaluation at the follow-up IHEC advisory so that the Committee may provide advice and assistance in the development of future studies.

3.4.2 Balance between Large Population Surveys and More Targeted Follow-up Studies

The Committee recognizes the Agency's struggle to identify the appropriate balance between large population surveys and more targeted follow-up studies. Given the goals of risk management, to lower the central tendency of an exposure distribution and to reduce the percentage of the population above the health-related benchmark, both large population surveys and more targeted follow-up studies provide valuable information. Population probability-based studies are the only means for collecting baseline information that can be used for current risk assessment as well as trend analysis. On the other hand, more targeted special studies tend to assess high end exposures more precisely and identify sources and factors associated with such exposures. For populations at or above such benchmarks, identification of major sources, media and pathways are essential in order to reduce unacceptably high risk through mitigation strategies.

If the majority of the national population is exposed to pollutants at levels under health-related benchmarks, source identification for such exposures is not a priority from a health standpoint.

Due to the cost of a national survey, population sample size and the number of analytes must be minimized. A well designed population study can be accomplished with a population-based sample of less than one thousand individuals. To minimize the cost and maximize the utility of the data that are collected in population surveys designed to establish baseline exposure data, the IHEC recommends that the Agency: a) focus on obtaining important parameters of the population survey, such as, the central tendency (mean, median, and mode), the variation (standard variation, 25th percentile, and 75th percentile), and the shape of the distribution; and b) evaluate the six pages of hypotheses (Pellizari, et al., 1995) to decide which worked and which did not work and apply this information to future studies.

Determining the upper tail of the exposure distribution requires a much larger sample size than establishing baseline exposure. A stratified sampling scheme would be more efficient for this purpose, but the survey design must stratify the population based on exposure-related characteristics and over-sample those sub-populations at the high end of the distribution. A national survey of this kind would require measurements of many environmental contaminants. This type of survey would be more difficult than a population study because the exposure-related characteristics of different chemicals can be quite variable and the characteristics of the sub-populations at the extremes of the distributions can also be quite variable. This type of information can only be acquired through more targeted studies.

The IHEC provides the following recommendations to reduce the cost and maximize the utility of more targeted follow-up studies. The EPA should use the experience, lessons learned, and wisdom gained from the pilot studies to guide the Agency and external investigators on how to optimize the measurement and analytical approaches. The Committee also recommends that the Agency design surveys that can address multiple goals. For example, if the exposure-related determinants are similar for the chemicals/subpopulations, they could be combined into one survey. Examples of multiple theories that can be tested are: a) Are exposures to pesticides high in agricultural areas; and are Hispanics who live in those areas more likely to be exposed?; and b) Are exposures to indoor air pollutants in urban areas of health concern; and are African Americans more likely to be exposed to the indoor air pollutants and more likely to have high asthma rates?

In summary, it was difficult to answer the question because the NHEXAS data have not yet been fully analyzed. The Committee found utility in both population surveys and more targeted follow-up studies and provides recommendations for increasing the cost-effectiveness and utility of both types of studies.

3.5 Charge Question 5: Additional Advice

What additional IHEC advice is offered for strengthening the immediate and long-term utility of NHEXAS and studies like it?

3.5.1 Advice for Strengthening the Utility of NHEXAS in the Near Term

- a) **Model Development** - There is a tendency in the exposure analysis community to adopt the epidemiological/statistical analysis methods utilizing “factors” such as presence or absence of a pollutant source, human activity, etc., rather than models based on mechanisms and physical causality. Models based on the underlying physical causes are much more powerful because they are more explanatory and more quantitative, and because they have predictive power as well as the ability to integrate existing measurement data. For example, indoor air models have often been based in the past on the presence or absence of a source rather than a mass balance model with quantitative source emission rates. With the measurements made in the NHEXAS pilot study, emphasis should be on developing physically-based quantitative models that can be used to evaluate various possible risk management options.
- b) **Other EPA programs** - It is important that NERL disseminate the NHEXAS data to other divisions within the Agency, and that NERL personnel be aware of which projects in other divisions could use such data.
- c) **Assessing source-to-dose trends** - The EPA should use the NHEXAS data, where possible, to assess source-to-dose trends for chemicals such as lead, benzene and PAHs. This would provide the Agency with information on how environmental measurements compare with known changes in sources and emissions.

3.5.2 Advice for Strengthening the Utility of NHEXAS in the Long-Term

- a) **Instrumentation** - More streamlined and less costly methods will be needed for a national survey, e.g., advanced sensors and sampling technologies, robotics for multiple analyses, and advanced software for analysis of chromatographic outputs. NERL should explore using some of the advanced measurement technologies that are being developed by EPA and agencies such as the Department of Defense (DOD) and the Department of Energy (DOE), that might be adapted for use in a national survey.
- b) **Other EPA programs** - The data already collected during the pilot phase of NHEXAS can be useful for on-going programs within the Agency. Several of these include:

- (1) Outdoor, indoor and personal air concentrations of multiple contaminants that can be utilized for validation of concentration and exposure estimates derived from models (for example, the Office of Planning, Policy, and Evaluation Cumulative Exposure Project);
 - (2) Concentrations of contaminants in other media that can also be used for validation of multimedia transport models;
 - (3) Information on biological analytes that can be used for the purpose of comparison with exposure benchmarks (Even though the NHEXAS pilot data do not provide exposure distributions for a representative sample of the US population);
 - (4) The concentration, external exposure, and biological analyte data which can be used for the development/optimization of exposure factors;
 - (5) Information on minority populations, especially Hispanics, that is seriously lacking including activity patterns, food preferences, and exposures (These data should be used with care, however, given its limited statistical power.); and
 - (6) Both in the short term and long term, the data can be useful in the prioritization of programmatic and regulatory efforts. (For example, the NHEXAS pilot data suggest that exposure pathways involving water intake may not be significant for several commonly used pesticides. This finding could be used for re-targeting regulatory efforts in this area to other contaminants for which water intake represents a significant pathway or limiting those efforts to sources of drinking water that may indeed result in significant pesticide intake, e.g., shallow water wells in rural areas).
- c) Data simulation - The EPA should work with statisticians and modelers to better understand the capabilities and limitations of the NHEXAS data for making multimedia source-to-dose assessments.
- d) Iterative analysis - The EPA should consider using the NHEXAS data to develop preliminary concentration distributions for exposure concentrations of a chemical in multiple media. These distributions can be used to develop premises regarding exposures prior to the collection of additional site-specific or local data. In the context of Bayesian statistics, the preliminary distributions are referred to as "prior" distributions. The collection of additional data can be used to develop a likelihood function that expresses the likelihood, given the prior distributions, of observing the value ranges and distribution of collected data. When the prior distributions; a smaller, more site-specific data set; and the likelihood functions are

combined, the resulting "posterior" distribution includes both the broad range of data in the prior distribution and the calibration of that data using a small, but better-targeted sample set. The resulting posterior distribution is statistically more robust and better tailored to the likely distribution of local exposures than either the NHEXAS data (the prior) or the small site-specific sample set used alone.

- e) National survey - The Committee recommends that the EPA use the data from the NHEXAS pilot studies to build the premises for a national exposure survey. Planning for Phase 2, a national surveillance plan, should require a plan that uses the experience of the pilot study so that the most appropriate multimedia measurements (including questionnaires) are used in Phase 2. Given the very limited information on actual multimedia exposures which now exists, the emphasis should be placed on determining median exposures rather than measuring highly exposed populations.
- f) Community-based environmental programs - The Committee recommends that the Agency continue to communicate and disseminate the NHEXAS data in the communities. The Committee also recommends that the Agency determine how the NHEXAS data can be used to address community-based questions regarding public health and environmental trends.
- g) Quantification of sources and emissions - In the NHEXAS pilot studies, there are qualitative measures of sources, i.e. presence of smokers, cooking patterns, proximity to traffic and industrial emissions, etc. However, the Agency should attempt to match sources to some of the environmental measurements. Data on sources were collected using the questionnaires. However, during the presentations, minimal information was presented on the content of these questionnaires. Therefore, it is unclear at this point, until further analysis is completed and published, whether the information collected was adequate to make important links between sources of contaminants and their concentrations in environmental media to allow the Agency to determine which sources should be controlled to reduce exposure. As recommended in Section 3.3 of this report, the Committee recommends that the Agency analyze the responses on the questionnaires and that the Agency also analyze the questionnaire itself to determine what worked and what did not work.

4. CONCLUSIONS

4.1 Strengths and Weaknesses

Overall, the IHEC found the NHEXAS pilot program to be strong scientifically. Given that NHEXAS provides vital information to the EPA for addressing the many multimedia pollutant issues that the EPA is confronted with on a daily basis, the Committee also found NHEXAS to be highly significant research which will be useful in identifying serious human health risks. Key scientific strengths include: a) a hypothesis-driven design; b) the integration of models with measurements to test and refine models and to understand causality; c) some advances in measurement methods; and d) a strong quality assurance plan. Another strength of the emerging NHEXAS data is the ability to quantify multiple pathways of exposure from different source media to a single or to multiple exposure media. The criteria for the selection of the target chemicals that were measured was identified as a weakness of the NHEXAS pilot program.

4.2 Ongoing and Planned Analysis

The ongoing and planned analyses were outlined well at the meeting with the exception of setting limitations on the degree of extrapolation of the data. Although the quality assurance plan was identified as a scientific strength of the NHEXAS pilot program, the Committee was particularly concerned about the minimal analysis of the quality assurance data to date. Therefore, it was difficult to determine the quality of the data. However, this may be attributable to the timeframe of the first NHEXAS advisory. The Committee was also concerned about the difference in participation rates amongst the three consortia and the potential for a difference in representativeness of the population sampled in the different consortia.

Analysis of the data at the level of NHEXAS is contingent upon the development of a strategic plan to assure that the data from the consortia are comparable to allow for meta-analysis. IHEC recommends the completion of quality assurance of the data prior to entering the data into a master database. The Committee highly recommends that findings that are of considerable importance to the Agency in the current risk management efforts be identified and given high priority for analysis and publication. The Committee also provides recommendations for analyzing the questionnaire data, analyzing the exposure data, conducting hypothesis testing, developing models to integrate exposure from different media, and estimating long-term exposures from short-term measurements. The Committee emphasizes the importance of analyzing the questionnaire, itself, to determine what worked and what did not work since the NHEXAS Phase I studies are pilot studies.

4.3 Increasing the Utility of NHEXAS

In the near term, the IHEC recommends that the Agency focus on developing and implementing guidelines and a strategic plan for completing the data analysis. The Committee also recommends that the EPA: a) identify the most cost effective approaches to exposure assessment based on the NHEXAS pilot study data; b) conduct a prototypical analysis of exposure assessment of intervention strategies; c) archive the information in a manner such that the data can be retrieved years from now; d) integrate the databases from the three pilot studies, where possible; and e) develop a strategic plan and feasibility study for a national human exposure survey.

In the longer term, the Committee recommends that the Agency develop a public education strategy, consider studies designed to bridge NHEXAS and NHANES, evaluate the feasibility of a national survey, and reassess the target chemicals to be measured.

4.4 Follow-up Studies

The Committee found it difficult to propose near-term studies given that the analysis of the data obtained to date is limited. Therefore, the Committee recommends, as previously stated, that the Agency direct its resources to the analysis of the data that has already been collected and to an evaluation of the methodologies used during the pilot studies. Also, the six pages of hypotheses (Pellizari, et al., 1995) need to be reviewed and analyzed to determine which worked and which did not work.

4.5 Balance between Large Population Surveys and more Targeted Follow-up Studies

In summary, it was difficult to answer the question because the analysis of the NHEXAS has not been completed. However, the Committee found utility in both population surveys and more targeted follow-up studies and provides recommendations for increasing the cost-effectiveness and utility of both types of studies. In addition, The Committee recommends defining the high end of exposure in the more targeted studies based on a health-related benchmark.

4.6 Additional Advice

The IHEC recommends that the EPA:

- a) place emphasis on developing physically-based quantitative models that can be used to evaluate various possible risk management options;
- b) consider using advanced measurement technologies such as advanced sensors and sampling technologies, and robotics for multiple analyses; and advanced software for analysis of chromatographic outputs; and

- c) disseminate the NHEXAS pilot data, after the analyses has been completed, to on-going programs within the Agency, such as programs that are trying to validate multimedia transport models.

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APPENDIX A - ACRONYMS AND ABBREVIATIONS

CDC	-	Centers for Disease Control and Prevention
CEP	-	Cumulative Exposure Project
DOD	-	Department of Defense
DOE	-	Department of Energy
EOHSI	-	Environmental and Occupational Health Sciences Institute (EOHSI)
FDA	-	Food and Drug Administration
GPRA	-	Government Performance and Results Act
GSA	-	General Service Administration
IHEC	-	Integrated Human Exposure Committee
MTBE	-	methyl-tert-butyl ether
NAAQS	-	National Ambient Air Quality Standards
NCEA	-	National Center for Environmental Assessment
NERL	-	National Exposure Research Laboratory
NHANES	-	National Health and Human Nutrition Examination Survey
NHEERL	-	National Human and Ecosystem Effects Laboratory
NHEXAS	-	National Human Exposure Assessment Survey
NIST	-	National Institutes of Standards and Technology
ORD	-	Office of Research and Development
PAHs	-	Polyaromatic Hydrocarbons
QA/QC	-	Quality Assurance/Quality Control
RFG	-	reformulated gasoline
RTI	-	Research Triangle Institute
SAB	-	Science Advisory Board
TEAM	-	Total Exposure Assessment Methodology
TRIM	-	Total Risk Integrated Methodology
VOCs	-	Volatile Organic Compounds

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