Aerosol Program Assessment Committee Report

Final Report April 7, 2003

Executive Summary

This report summarizes the findings of a cross-Institute team that was formed on January 6, 2003, at the request of NIOSH Director John Howard to assess the current status of research on aerosol issues within NIOSH and provide a report back to the NIOSH Lead Team.

Specifically, the Aerosol Team was asked to:

- catalogue/describe current activities;
- identify gaps in our research and other aerosol-related work;
- recommend priorities for future NIOSH work in this area;
- identify funding opportunities to support aerosols work; and
- make recommendations for organizational approaches that will improve program effectiveness and support useful collaborative relationships both within the Institute and with extramural partners/stakeholders.

Dr. Greg Wagner, director of the NIOSH Division of Respiratory Disease Studies provided senior NIOSH management guidance to the Aerosol Team. Aerosol Team members included: Dr. Martin Harper (HELD, co-chair), Dr. Paul Baron (DART, co-chair), Dr. Mark Hoover (DRDS), Mr. Joe Burkhart (DRDS), Dr. Vincent Castranova (HELD), Mr. Gregory Piacitelli (DSHEFS), Ms. Pamela Drake (SRL), Mr. Kenneth Williams (NPPTL), Mr. Jon Volkwein (PRL), Dr. Scott Earnest (DART), Dr. Andrew Maynard (DART), Dr. Eileen Kuempel (EID), and Dr. David Dankovic (EID).

During the period of January through March 2003, the Aerosol Team exchanged information and prepared the report by telephone, email, envision, and in a committee workshop on March 17-18, 2003, at the NIOSH facility in Morgantown, WV.

A summary of the findings of the report are presented below.

Summary of Current Activities

The body of the report summarizes a total of 94 projects in 7 divisions that either use aerosol science as a fundamental tool or develop new aerosol knowledge. These include the following areas:

- Understanding the characteristics and behavior of classes of aerosols, especially ultrafine particles, low density materials, ultra-large particles, and fibers
- Dose-response relationships, including dose and dose-rate, and alternative metrics other than mass for exposure (surface area, particle number, solubility, surface characteristics)
- Basic biology studies for initiation and progression of disease
- Control technologies to improve primary prevention
- Size-selective sampling issues to provide better correlations of measured dose and potential health consequences
- Models of infectivity
- Aerosol resuspension issues

- Combined or mixed effects between components of aerosols, and between aerosols and other chemical or physical agents.
- Procedures and consensus standards for anticipating, measuring, modeling, and mitigating the effects of aerosol dispersion and exposure.

Many of these research and programmatic initiatives apply to chemical, biological, and radiological terrorism. NIOSH research over the past 20 years has resulted in the publication of over 4000 aerosol-related documents, including journal articles, books and book chapters, health hazard evaluations, NIOSH reports and conference proceedings. Current aerosol-related activities are compiled in a set of Appendices, which cover project descriptions, project achievements, personnel, equipment and special facilities, and collaborations.

Identification of Programmatic Gaps

The significant findings of the gap analysis were that, in general:

1. major gaps in our understanding of aerosol research have been identified, and are being addressed through the current research programs, but
2. levels of staff and funding are not adequate to meet critical needs for worker protection, and
3. the current facilities need to be upgraded and expanded.

Of special critical interest is replacement of key, experienced NIOSH aerosol experts who have left or will soon leave the Institute. Formal planning, funding, recruitment, and staffing of mentorship programs should be provided to bridge this gap. A full and detailed analysis of specific gap issues will be a priority for any continuing activity of this, or related, team.

Identification of Funding Opportunities

NIOSH uses aerosol science as a basic tool in the traditional intramural research performed by NIOSH divisions and laboratories. NIOSH also funds substantial extramural research, some of which is aerosol-related.

NIOSH also has strategic partnerships with other federal agencies that provide funds to support internal NIOSH work. These partnerships have included funding from EPA, DoD, DoT, FAA, OSHA, MSHA, NCI, NTP, and the Department of Mineral Resources, NSW, Australia. It was noted that much of this funding was due to expire in the near-term. Future funding opportunities included OTPER, DOD, FEMA, GSA, FBI, Postal Service, IRS, DHS for terrorism-related activities; DOT/DOD for diesel research; NTP for welding research; EPA for PM and asbestos; ASHRAE for indoor PM issues.

Recommendations

- Staffing issues were of primary concern to the Aerosol Team. While a wide range of aerosol-related problems continue to confront NIOSH researchers, the challenges have been met admirably. However, with the continuing loss of eminent researchers in this field, the situation has become critical. Addressing the staffing issues in aerosol research as noted above is essential to the continuation of NIOSH's leadership role in this crucial area.

Other areas of enhancement of the NIOSH aerosol research program were recommended:

- Enhance aerosol aspects of the NIOSH extramural grant program through the addition of an aerosol keyword or words and recommendations for a panel of peer-reviewers with specific expertise in aerosol science,
- Prepare and maintain a brochure and website devoted to areas of collaboration and recruitment,
- Hold an annual workshop to facilitate interdivisional interaction and synergy in current research issues.
- To foster increased coordination and synergy between researchers in disparate fields and locations, the Aerosol Team recommends the establishment of the NIOSH Aerosol Coordinating Committee, with membership including representation from interested Divisions, such as the current members of the Aerosol Team. The responsibilities of the NACC should include facilitation of the previous three recommendations as well as the following:
    a. Establish viable interfaces with other NIOSH focus groups (e.g., tuberculosis, fibers, beryllium, agriculture, etc.),
    b. Identify and nurture contacts with external partners to place NIOSH in the center of Federal government aerosol activities,
    c. Create a cross-cutting aerosol research agenda for NIOSH, potentially with a key-in to the NORA,
    d. Prepare a comprehensive and detailed gap analysis for use in prioritizing future research agendas,
    e. Share new project and proposal ideas,
    f. Periodically summarize and report accomplishments to management,
    g. Conduct educational outreach activities for NIOSH stakeholders,

Aerosol Program Assessment Committee Report

INTRODUCTION

An important class of hazard in the working environment is potential exposure to chemical and biological agents. Chemical agents may be present in the gas and vapor, liquid or solid states. Biological agents are normally solid, but may be dispersed in a liquid. Research on chemical hazards often is classified according to the physical state of the chemical. Liquid and solid chemical dispersed in the air are known as aerosols. Aerosols may be generated in the workplace by the condensation of combustion and gas-phase reaction products, or by the disaggregation of larger bodies, or by the escape of liquids and powders in use. Human contact with aerosols can cause disease, and the NIOSH expends a tremendous amount of resources on the issues of workplace aerosols, including their measurement, their ability to cause disease, and their control.

Definitions

An aerosol is an assembly of particles suspended in the air for a period of time sufficient to allow inhalation or measurement. Aerosol particles are typically defined as covering a size range from very large molecules (> about 1 nm) to about 100 μm. The lower end of the range is differentiated from molecules because sampling and measurement technologies for gases and vapors are different. At the upper end of the aerosol range, particles settle from the air quickly enough that few can be measured or inhaled. The size range is not sharply defined at either end and some researchers have attempted to address the issue of what should be sampled especially in the upper size range. The five order of magnitude range in particle size means that the physical mechanisms that dominate particle behavior differ depending on particle size. For instance, particle settling and impaction are likely to be the dominant mechanisms of motion for particles larger than about one micrometer diameter, while diffusion and coagulation dominate particle behavior for much smaller particles. Other mechanisms, especially electrostatic behavior of charged particles, can be highly variable and affect particles of all sizes. These mechanisms and other external factors such as air movements affect how particles are distributed in the air and how they enter and deposit in both the human airways and sampling instruments, and also have a profound effect on how exposure to aerosols can be controlled by both personal protective equipment (respirators) and engineering controls. Because particle behavior is determined largely by the suspending air, understanding air flows in the workplace, near the human body, and near samplers is essential to allow accurate measurement and control of aerosols.

The primary route of exposure to aerosols is the human respiratory tract because of the sensitivity and reaction of the body to this route of entry. Particles may also deposit on the skin or eyes in sufficient quantity to produce toxic effects. Individual particles can have a wide range of physical, chemical, radiological, and biological properties that affect their toxicity. Further, the type of generation process and source of the aerosol play an important role in determining the size and type of particle likely to exist in the workplace. The transport of particles from source to the respiratory system is affected by the air movement surrounding the worker. Once these particles have deposited in the respiratory tract, many of these properties come into play in the etiology of disease. Therefore, measurement of the appropriate properties to most efficiently predict toxicity has not only been a long term goal, but also has been part of the evolution of measurement techniques. Quite often, measurement techniques use surrogate particle properties in order to control exposure without full understanding of which measurement parameters might be most appropriate. In spite of this lack of understanding, control of exposures can be effectively accomplished using these surrogate properties. Research into disease etiology is important not only to improve the measurement techniques, but more importantly to provide techniques for treating exposures to aerosols. Finally, transferring available knowledge and technology to the workplace is essential in effective reduction of disease.

The present document provides an overview of aerosol-related activities being carried out at NIOSH. This is the first occasion that such an overview has been attempted. The committee has collected information on all projects that, at least in part, involve measurement, evaluation, or reduction of the effects of aerosols on workers. Sometimes the decision to include or not include a specific project, or under which category to include it was difficult. The Committee generally respected Project Officer wishes in these respects. Placement of the aerosol-related research at NIOSH into specific categories is a somewhat arbitrary process, but provides a framework for discussion of individual projects. The categories selected include Measurement, Control, Exposure Characterization, and Health Effects, and within these major categories, projects have been further categorized by specific toxicant or application. Many projects cut across more than one category or subcategory. 94 projects from 7 Divisions that either use aerosol science as a fundamental tool or apply new aerosol knowledge were included. Research within those projects covers the following areas:

- Understanding the characteristics and behavior of classes of aerosols, especially ultra-fine particles, low density materials, ultra-large particles, and fibers;
- Size-selective sampling issues to provide better correlations of measured dose and potential health consequences;
- Dose-response relationships, including dose and dose-rate, and alternative metrics other than mass for exposure (surface area, particle number, solubility, surface characteristics);
- Basic biology studies for initiation and progression of disease;
- Control technologies to improve primary prevention;
- Studies on microbiological aerosols, including measurement techniques, identification of organisms, models of infectivity, and aerosol resuspension issues;
- Combined or mixed effects of complex aerosols, and synergistic effects between aerosols with other agents;
- Developing procedures and consensus standards for anticipating, measuring, modeling, and mitigating the effects of aerosol dispersion and exposure.

Many of these research and programmatic initiatives apply to chemical, biological, and radiological terrorism.

Measurement

These projects cover all aspects of particle generation and monitoring in the workplace. Techniques for real-time measurement, sampling, laboratory and field analysis play an essential role in reducing worker exposure. Sampling projects include investigations of airflow in the workplace that affect aerosol transport, and design and evaluation of collection devices to target size ranges that affect specific parts of the respiratory system. Analysis of the collected samples requires a wide range of analytical techniques including: optical and other types of microscopy to determine particle shape, chemistry or crystallinity; various types of chromatography and spectroscopy for chemical analysis; and biological analysis. Direct-reading instruments also are under development and evaluation. Such instruments are an important tool in understanding particle generation mechanisms in the workplace and allow efficient development of control techniques. Biological samples from exposed workers have been used to assess the extent of exposure and etiology of disease. As part of any of the above measurement processes, involvement in quality assurance research and programs is important in providing believable, accurate, and legally supportable results. Dissemination of information gained in the measurement research program is essential to providing nationwide capability in measuring aerosols likely to cause disease.

Control Technology

Prevention or reduction of exposure to workplace aerosols requires the conduct of laboratory research, field studies and on-site demonstrations to develop or evaluate engineering control technology for biological and chemical hazards. Some control techniques involve development of new or modified industrial processes to replace those producing significant aerosol exposures. Other approaches involve reduction of exposure by local exhaust ventilation system, reduction of airborne concentration by area ventilation, or enveloping the workers in clean air. When these approaches are not feasible, personal protective equipment can be used to reduce worker exposure. Transfer of research findings and technology to the relevant industries and workers was included in this category.

Exposure Characterization

Characterization of worker exposure is carried out at several levels. Measurement of worker exposure is performed through several approaches, including health hazard evaluations, industry wide field studies, and collection of data from other governmental or private agencies. These characterization studies can include measurements of workplace aerosol concentrations as well as monitoring of biological markers of exposure in worker bodily fluids. Analysis of the available exposure data from national and international sources allows surveillance of the workplace to determine the incidence and prevalence of acute and chronic effects from workplace aerosols.

Health Effects

NIOSH studies of the adverse health effects of aerosol exposures include toxicological studies, epidemiological studies, and risk assessment. Toxicological studies involve hazard identification, elucidation of toxic mechanisms, and characterization of time course and dose response relationships. Test systems include acellular, sub-cellular and cell in vitro models, as well as in vivo models employing intratracheal or inhalation exposure in rodents. In addition, toxicological studies have been conducted in support of field investigations to identify the etiologic agent(s) in mixed exposure situations found in many workplaces. Toxicological studies are also underway to identify and evaluate susceptibility factors influencing pathological responses to aerosol exposure, identify biomarkers of exposure and response, and develop possible therapeutic strategies. Epidemiological studies include the identification of aerosol hazards in the workplace and determination of the adverse health effects associated with those exposures (e.g., bioaerosols, pesticides, etc.). Risk assessment provides quantitative estimates of the excess risk of disease, and a scientific basis for developing recommended exposure limits. Current risk assessments of aerosols include silica, titanium dioxide, chromium, cadmium and chrysotile. Biologically-based mathematical models have also been developed using toxicological and pathological data to better understand the mechanisms of particle and fiber retention in the lungs and the initiation and progression of disease.

CURRENT STATUS OF AEROSOL RESEARCH

Measurement

Aerosol related projects in DART, and in the Exposure Assessment Branch of HELD have primarily focused on sampling, analysis, and control of aerosols. The measurement projects include evaluation and improvement of personal sampling devices (inhalable, thoracic and respirable samplers) and direct reading instrumentation (Aerodynamic Particle Sizer [APS] and Aerosizer). The accuracy of the APS for liquid droplets was investigated. A fiber length classifier developed within DART continues to be used for producing samples for toxicity studies. The properties of ultrafine particles have been investigated from several viewpoints: understanding the appropriate metric (e.g., surface area) for measurement, evaluation of instrumentation for measurement of particle surface area, and investigation of particle characteristics produced in commercial processes such as welding and grinding. HELD/EAB has several projects relating to particle surface properties. Hard metal dusts and silica are examples of specific agents that have come under scrutiny.

Analytical methods for specific toxic aerosols continue to be developed and improved. These include metals, carbon (diesel fume), isocyanates, asphalt fumes, metal working fluids, silica, pesticides, and bacteria. Researchers working on these materials use a wide range of techniques and often have to deal with complex mixtures of analytes, and for each of these analytes, the toxicity may be unknown. Direct reading instruments and field analytical instruments have been evaluated for metals, including lead and chromium. The polymerase chain reaction (PCR) technique has been applied to bacterial

(TB and histoplasma capsulatum) sampling and quantitative analysis (patented). OSHA has requested assistance on evaluating the accuracy and improving the sensitivity for crystalline silica analysis. Many of these improved methods have been incorporated into the latest update to the NIOSH Manual of Analytical Methods, now in press.

Aerosol Measurement in Mining

PRL has been most active in the area of mining-related aerosols. The continuing occurrence of coal workers' pneumoconiosis has increased the level of effort to better measure miners' exposure to coal dust. The emphasis has been to provide miners with more timely knowledge of their exposures to enable corrective measures to occur before an overexposure results. Unlike industrial workplaces, the mine environment is continually moving as mining advances and the need for frequent and timely knowledge of dust exposures is important to preventing pneumoconiosis.

Measurement of aerosols in the mining workplace involves the development of improved instruments for real-time, or short term determination of worker exposure. Special issues for mining include the overall functionality of the instruments, instrument accuracy, elements of ergonomics, cost, frequency of sampling, precision and intrinsic safety. Aerosol science plays a key role in the optimization of many of these elements.

Aerosols in mining currently being examined include coal mine dust, diesel particulate matter, silica dust and smoke particulate. These aerosols cover a size spectrum from about 10 nanometers up to 10 micrometers in aerodynamic diameter and mechanisms governing their motions and behavior in mine environments change radically in this size regime. For example, combustion aerosols from diesel engines or mine fires must be characterized for source identification to understand what parameters might be used for development of new instrumentation that can distinguish these aerosols from mineral dusts. Furthermore, instrumentation or methods need to be developed to determine the effectiveness of a control technology in the field as a part of a routine maintenance procedure.

The size-selective aerosol sampling method developed at the former Bureau of Mines in combination with the NIOSH Method 5040 has provided mines and MSHA with an accurate personal sampler for diesel particulate sampling. This combination of technologies has the advantage of removing interfering ores from the analysis. Work is in progress to monitor the efficacy of Method 5040 elemental carbon measurements, and the effect that new control technologies may have on the EC measurements.

Control

There are numerous aerosol-related projects occurring in the Engineering and Physical Hazards Branch (EPHB) of DART. In fact more than fifty percent of the airborne contaminant research projects involve aerosols. The aerosol-related research in EPHB generally has had a single unifying theme. That theme is the reduction and control of workplace exposures to airborne contaminants. Current EPHB aerosol-related projects include the development of guidelines and solutions to protect workers from the effects of a terrorist release of chemical, biological, or radiological (CBR) agents in large buildings or in mail handling facilities, control of airborne disease transmission on commercial aircraft, control worker exposure to beryllium aerosols, use of computational fluid dynamics (CFD) modeling to control worker exposures to tuberculosis (TB) in healthcare settings or to other agents in the workplace, control of exposures to silica and common aerosols in construction, and control of asphalt fumes from roofing kettles. Each of the projects mentioned above requires a fundamental understanding of aerosol science in addition to the basic principles of engineering control and industrial hygiene. These research projects also frequently require an understanding of basic principles of ventilation. Therefore, although each project is aerosol-related, the project officer must have expertise in various related areas in order to successfully complete the project.

Exposure Evaluation

DSHEFS has projects evaluating workers exposure to bioaerosols, including to TB (*Mycobacterium tuberculosum*) and anthrax (*Bacillus anthracis*), and in characterizing airflow patterns in aircraft cabins (with HELD). This group also evaluates exposure of farm workers and their families to pesticides. EID has projects involving the assessment of risks of exposures to silica and fibers. DRDS has an evaluation of exposures leading to beryllium disease.

Health Effects

NIOSH studies of the adverse health effects of aerosol exposures include toxicological studies, epidemiological studies, and risk assessments. These mainly take place within the various Branches of HELD. Toxicological studies involve investigation and elucidation of toxic mechanisms, and characterization of the time course and dose-response relationships. Test systems include acellular, sub-cellular and cell *in vitro* models, as well as in vivo models employing intratracheal or inhalation exposure in rodents. In addition, toxicological studies have been conducted in support of field investigations to identify the etiologic agent(s) in mixed exposure situations found in many workplaces. Toxicological studies are also underway to identify and evaluate susceptibility factors influencing pathological responses to aerosol exposure, identify biomarkers of exposure and response, and develop possible therapeutic strategies. Epidemiological studies include the identification of aerosol hazards in the workplace and the adverse health effects associated with those exposures (e.g., bioaerosols, pesticides). Risk assessment provides quantitative estimates of the excess risk of disease, and a scientific basis for developing recommended exposures limits. Current risk assessments of aerosols include silica, titanium dioxide, chromium, cadmium, and chrysotile. Biologically-based mathematical models have also been developed using toxicological and pathological data to better understand the mechanisms of particle and fiber retention in the lungs and the initiation and progression of disease.

Historical Successes

A search was made of the NIOSHTIC-2 database (http://www2.cdc.gov/nioshtic-2/nioshtic2.htm). Over the past 20 years NIOSH has published over 4000 aerosol-related documents, including journal articles, books and book chapters, health hazard evaluations, NIOSH reports and conference proceedings. Between 1998 and 2002, there were 582 aerosol-related publications, including 229 journal articles, 69 books or book chapters and 109 health hazard evaluations. Because of the search limitations, these numbers may somewhat underestimate actual publications.

Listed below are some of the more recent successes, considered as most noteworthy by the Aerosol Team. This is by no means an exhaustive listing of activities that have led to successful end-points, but they will serve to give an indication of the ability of the aerosol community within NIOSH to respond to pressing workplace issues:

1. Pulmonary toxicity of an artificial butter flavoring –
   A Health Hazard Evaluation documented a high prevalence of fixed airway obstruction in workers at a popcorn manufacturing plant, where a range of aerosols and vapors were present. Environmental evaluation indicated sporadic, high airborne levels of artificial butter flavorings containing diacetyl, acetoin, 2-nonanone, and methyl ethyl ketone. Inhalation exposure of rats to atmospheres from heated artificial butter flavoring or diacetyl (the major component of this flavoring) resulted in severe damage and denudation of the airway epithelium and airway hyperreactivity. Biopsies of the airways of workers have shown similar necrotizing bronchitis. Identification of the causative agent has resulted in implementation of effective control measures.

2. Pulmonary disease in nylon flocking –
   A Health Hazard Evaluation documented a high prevalence of bronchiolitis obliterans in workers at a nylon flocking plant. Extensive environmental evaluation identified the generation of shreds during the cutting of long-thick nylon fibers into short-thick flock fibers. These nylon shreds were found to be respirable and highly inflammatory in an animal model. Identification of the causative agent has resulted in implementation of effective control measures.

3. Criteria document for respirable coal mine dust –
   In 1995, NIOSH scientists published a criteria document indicating that pulmonary disease was still occurring at the current coal dust standard of 2 mg/m^3 and recommending that control to 1 mg/m^3 would be necessary to avoid coal workers' pneumoconiosis. This criteria document was the result of the joint efforts of industrial hygiene evaluation of coal mine dust levels, epidemiologic evaluation of pulmonary disease prevalence, pathological evaluation of lung

tissue from the National Coal Workers Autopsy Study, and mechanistic studies of the pulmonary response to coal dust.

4. Criteria document for metalworking fluids –
In 1998, NIOSH published a criteria document to assist in the prevention of disease resulting from exposure to metalworking fluids, lubricating oils used in many machine shops. Drawing on broad interdivisional expertise, this document included a recommended limit value based on sampling in accordance with the thoracic size-selective convention, the world's first such limit value. In addition, the limit value also reflected the general industry transition to longer shifts (10 hours), again becoming a world pioneer.

5. Surface reactivity of particles –
NIOSH scientists have made a substantial contribution to the current theory that surface reactivity of particles plays an important role in their pulmonary toxicity. Electron spin resonance spectroscopy has been employed to identify the generation of radicals on the surface of freshly-fractured crystalline silica or coal dust. In addition, the presence of trace levels of transition metals on particles, such as asbestos or silica, has been shown to generate hydroxyl radicals and lead to oxidant-induced toxicity. Scanning electron microscopy and energy dispersive x-ray analysis of particles has been employed to show that surface coating of particles can greatly diminish their pulmonary toxicity. This mechanistic information has been useful in risk assessment.

6. Silicosis –
NIOSH scientists have made a substantial contribution to the identification of workers at risk of silicosis and the elucidation of mechanisms for disease initiation and progression. Industrial hygiene evaluations have documented that high exposure levels still exist in rock drilling and sand blasting operations. Such exposures result in a high incidence of acute silicosis in these workers. Mechanistic studies have shown that operations, such as rock drilling and sand blasting, generate freshly-fractured dust. The generation of radicals on the fracture planes results in enhancement of the toxicity of this dust. Studies have evaluated the dust generation from abrasive blasting substitutes for sand and the pulmonary toxicity of these substitutes. Short-term studies suggest that iron oxide or steel grit may be economically feasible, less toxic substitutes for silica sand. NIOSH has also conducted a long-term inhalation study with silica in rats. Results of this study have been used to model pulmonary response vs. lung burden in rats. This relationship in rats has been found to be predictive of human response. Lastly, NIOSH scientists have published a book entitled "Silica and Silica-induced Lung Diseases" which has become a major reference text for occupational health scientists in this field.

7. Mining –
Through a series of workshops with industry, NIOSH has raised the level of awareness of the capabilities of new diesel particulate control technology to the

point where mines are voluntarily installing controls. In response to a mandate by the Secretary of Labor, NIOSH developed a mass based instrument to continuously monitor miners' exposures to coal mine dust. This new technology has been incorporated into recent MSHA rules to protect miners' health. NIOSH aerosol research developed a size-selective diesel impactor that separates carbon containing mineral dusts from diesel particulate to enable assessment of DPM levels in mines. This new sampler is now commercially available. NIOSH was lauded by industry at a recent silica conference for the development of several engineering controls used in minerals processing plants to reduce worker exposure to silica. These included overhead air supplied islands, bag machine dust controls, and controls for bag stackers.

Program Gap Analysis

Despite, in some cases, nearly a century of investigation, many diseases associated with aerosols continue to be diagnosed in workers, underlining the complex and difficult nature of aerosol problems. While there have been considerable successes in reducing the prevalence of workplace disease, it has not been eliminated entirely. A good example is exposure to silica containing dusts; cases of silicosis are still newly diagnosed year after year. After careful consideration of the current areas of research, as noted above, the Aerosol Team came to the conclusion that these continued to be the most important issues requiring further research. This includes both the general research activities as well as the specific etiologic agents (e.g. silica, diesel exhaust, secondary organic aerosol, ultrafine particles, bioaerosols, fibers, etc.) where there are still many unanswered questions. In the short time available to this committee, it was not possible to prepare a thoroughly researched comprehensive and detailed gap analysis. In general, it was felt that the major gaps in our understanding of aerosol research have been identified, and are being addressed through the current research programs, although this research could benefit from better funding and resources.

It was suggested that aerosol research could be supported better if there could be explicit recognition of aerosol issues in the NORA priority research areas. It was suggested that a NORA cross-cut aerosol research area would provide greater visibility for aerosol activities. Additional resources for aerosol research would certainly bring us closer to a more complete understanding of the role of aerosols in disease, and an ability to control exposures more effectively.

Of considerable concern to the Aerosol Team was the continuing departure through retirement of many of the most talented and experienced researchers, who had put into place highly successful research programs in the past. It is a recommendation of this Team that some effort be made to retain these senior scientists, at least in an advisory role, if not as active researchers, in order to avoid a gap of knowledge and experience during recruitment and training of new researchers. A formal plan to identify, recruit and mentor new researchers should also be considered.

It was noted that interaction between the grants program and NIOSH experts appeared to be minimal and that feedback from these experts in the review process could result in funding of more relevant and productive projects. The flexibility of aerosol research programs to acquire necessary expertise for the future, as well as specialized equipment to solve unique problems could be enhanced by closer coordination between the in-house research programs and extramural grant or contract programs. It is a recommendation of this Team that a portion of current grant funding expenditures be at the discretion of the in-house research program. Closer co-ordination of intramural and extramural activities would also be enhanced by the use of a specific searchable keyword or words in the database of extramurally-funded projects.

It was further noted that current outreach educational activities to NIOSH stakeholders such as workers, unions, regulatory agencies and industrial hygienists were minimal in several areas, although with pockets of excellence, such as found in the Program for On-site Metals Analysis, which could be used as a model for future activities.

NIOSH also has strategic partnerships with other federal agencies that provide funds to support internal NIOSH work. These partnerships have included funding from EPA for cadmium and arsenic exposure for exposure reconstruction and risk assessment; from the National Cancer Institute for pesticide sampling and evaluations, from DoD/EPA for aerosol threat sampling/analytical methods; from the Department of Mineral Resources, NSW, Australia for diesel instrumentation; from the DoD and DOT for diesel research; from OSHA for research into silica, beryllium, and other metals; from MSHA for sampling instrumentation; from NTP for asphalt and welding fumes; from the FAA for airplane cabin air quality; and from HUD for bioaerosols and lead. It was noted that many of these sources of funding were in a waning phase. Funding sources that were identified for the future: OTPER for terrorism research, as well as DOD, FEMA, GSA, FBI, Postal Service, IRS, and the DHS; DOT/DOD for diesel; NTP for welding fume; EPA for PM and asbestos; ASHRAE for indoor PM issues.

Recommendations of NIOSH Aerosol Priorities

The Aerosol Team considered recommendations for actions that could be implemented within the NIOSH organization to expand and enhance our ability to address initiatives in aerosol research.

- Staffing issues were of primary concern to the Aerosol Team. While a wide range of aerosol-related problems continue to confront NIOSH researchers, the challenges have been met admirably. However, with the continuing loss of eminent researchers in this field, the situation has become critical. Addressing the staffing issues in aerosol research as noted above is essential to the continuation of NIOSH's leadership role in this crucial area.

Other areas of enhancement of the NIOSH aerosol research program were recommended:

- Enhance aerosol aspects of the NIOSH extramural grant program through the addition of an aerosol keyword or words and recommendations for a panel of peer-reviewers with specific expertise in aerosol science,
- Prepare and maintain a brochure and website devoted to areas of collaboration and recruitment,
- Hold an annual workshop to facilitate interdivisional interaction and synergy in current research issues.
- To foster increased coordination and synergy between researchers in disparate fields and locations, the Aerosol Team recommends the establishment of the NIOSH Aerosol Coordinating Committee, with membership including representation from interested Divisions, such as the current members of the Aerosol Team. The responsibilities of the NACC should include facilitation of the previous three recommendations as well as the following:
  a. Establish viable interfaces with other NIOSH focus groups (e.g., tuberculosis, fibers, beryllium, agriculture, etc.),
  b. Identify and nurture contacts with external partners to place NIOSH in the center of Federal government aerosol activities,
  c. Create a cross-cutting aerosol research agenda for NIOSH, potentially with a key-in to the NORA,
  d. Prepare a comprehensive and detailed gap analysis for use in prioritizing future research agendas,
  e. Share new project and proposal ideas,
  f. Periodically summarize and report accomplishments to management,
  g. Conduct educational outreach activities for NIOSH stakeholders,

The NACC would not usurp the traditional NIOSH approach to investigator-initiated research and external project peer-review, but would provide an important mechanism for oversight and feedback leading to more probable successful outcomes by providing a forum for aerosol researchers to collaborate with, and be advised by, their peers. It was felt that the NACC should be co-Chaired by representatives from more than one Division, to ensure no one Division is able to monopolize the committee agenda.