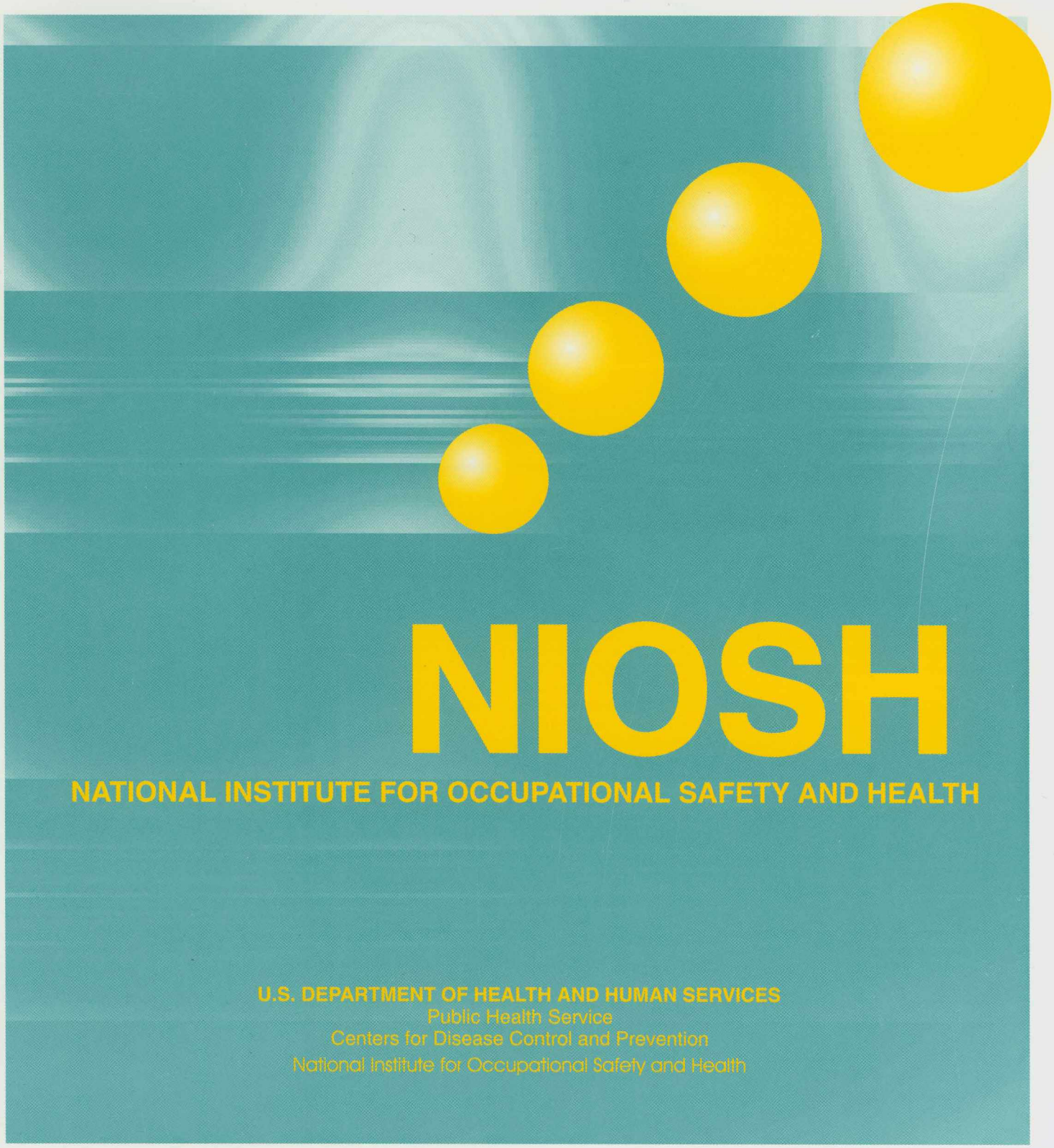
National Occupational Research Agenda



NIOSH

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

April 1996

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NIOSH

National Institute for Occupational Safety and Health

The U.S. workplace is rapidly changing. Jobs in our economy continue to shift from manufacturing to services. Longer hours, compressed workweeks, shift work, reduced job security, and part-time and temporary work are realities of the modern workplace. New chemicals, materials, processes, and equipment are developed and marketed at an ever accelerating pace. The workforce is also changing. As the U.S. workforce grows to approximately 147 million by the year 2005, it will become older and more racially diverse. By the year 2005, minorities will represent 28% of the workforce, and women will constitute approximately 48%. These changes will present new challenges to protecting worker safety and health.

Each day, an average of 137 individuals die from work-related diseases, and an additional 16 die from injuries on the job. Every 5 seconds a worker is injured; every 10 seconds a worker is temporarily or permanently disabled. In 1994, occupational injuries alone cost $121 billion in lost wages and productivity, administrative expenses, health care, and other costs.

The high toll of work injuries and illnesses is not unchangeable. In fact, significant progress has been made in improving worker protection since Congress passed the Occupational Safety and Health Act in 1970 "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources." This progress has been largely based on actions—sometimes voluntary, sometimes regulatory—directed by the science and knowledge generated from occupational safety and health research.

The National Institute for Occupational Safety and Health (NIOSH), and its partners in the public and private sectors, have developed the National Occupational Research Agenda (NORA) to provide a framework to guide occupational safety and health research in the next decade—not only for NIOSH but also for the entire occupational safety and health community. Approximately 500 organizations and individuals outside NIOSH provided input into the development of the Agenda. This attempt to guide and coordinate research nationally is responsive to a broadly perceived need to address systematically those topics that are most pressing and most likely to yield gains to the worker and the nation. Fiscal constraints on occupational safety and health research are increasing, making even more compelling the need for a coordinated and focused research agenda.

The 21 Priorities

The Agenda identifies 21 research priorities (see table). These priorities reflect a remarkable degree of concurrence among a large number of stakeholders. The NORA priority research areas are grouped into three categories: Disease and Injury, Work Environment and Workforce, and Research Tools and Approaches.

*To obtain a copy of the **National Occupational Research Agenda** (DHHS [NIOSH] Publication No. 96-115) or for information on occupational safety and health issues call the NIOSH toll free information number:*

1-800-35-NIOSH

(1-800-356-4674)
or visit the NIOSH Home Page on the World Wide Web at:
http://www.cdc.gov/niosh/homepage.html

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NORA Priority Research Areas

CATEGORY	PRIORITY RESEARCH AREAS
Disease and Injury	Allergic and Irritant Dermatitis Asthma and Chronic Obstructive Pulmonary Disease Fertility and Pregnancy Abnormalities Hearing Loss Infectious Diseases Low Back Disorders Musculoskeletal Disorders of the Upper Extremities Traumatic Injuries
Work Environment and Workforce	Emerging Technologies Indoor Environment Mixed Exposures Organization of Work Special Populations at Risk
Research Tools and Approaches	Cancer Research Methods Control Technology and Personal Protective Equipment Exposure Assessment Methods Health Services Research Intervention Effectiveness Research Risk Assessment Methods Social and Economic Consequences of Workplace Illness and Injury Surveillance Research Methods

Implementation

NORA is the first step in a collaborative effort between NIOSH and its many partners to guide occupational safety and health research over the next decade. Implementation is the necessary next phase. As the first step in the implementation phase, NIOSH is committed to bringing together its NORA partners in a public meeting for further refining the preliminary approaches they agreed to when identifying the Agenda.

Among these approaches is the commitment by NIOSH to (1) use the Agenda to guide both intramural and extramural funding decisions, (2) encourage and stimulate other government agencies to include NORA priorities in their internal and external research programs, (3) develop procedures and capacity to track the impact of NORA activities on health and safety outcomes using existing tracking models, if available, (4) update NORA, and (5) periodically review and communicate the overall role and effectiveness of NORA in occupational safety and health.

Throughout the process of implementing the Agenda, NIOSH will seek to build upon and extend its partnerships and to improve coordination throughout the occupational safety and health community, with the expectation that these activities hold great promise for improving the protection and well-being of workers.

FOREWORD

In 1970, Congress passed the Occupational Safety and Health Act to assure, "so far as possible every working man and woman in the Nation safe and healthful working conditions." The Act created the National Institute for Occupational Safety and Health (NIOSH) to identify the causes of work-related diseases and injuries, evaluate the hazards of new technologies and work practices, create ways to control hazards so that workers are protected, and make recommendations for occupational safety and health standards. The Act created the Occupational Safety and Health Administration (OSHA) to promulgate and enforce standards.

In the 25 years since the passage of the Occupational Safety and Health Act, substantial progress has been made in improving worker protection. Much of this progress has been based on actions guided by occupational safety and health research. Fatal work injuries and the rate of disabling injuries have declined substantially. Specific health hazards have been controlled, and some occupational diseases, such as byssinosis (brown lung disease) from cotton dust exposure and angiosarcoma (liver cancer) from vinyl chloride exposure, have been nearly eliminated.

However, workplace hazards continue to inflict a tremendous toll in both human and economic costs. Employers reported 6.3 million work injuries and 515,000 cases of occupational illnesses in 1994. That same year, occupational injuries alone cost $121 billion in lost wages and lost productivity, administrative expenses, health care, and other costs. This figure does not include the costs of occupational diseases.

Despite the continuing need for occupational safety and health research, both public and private sector efforts are facing increasing fiscal constraints. These financial challenges, in the face of the large burden of work-related disease, injury, and death, led NIOSH to work with the occupational safety and health community to develop a National Occupational Research Agenda (NORA). The Agenda, which identifies 21 priority research areas, is the first step in what will be an ongoing, concerted effort to target and coordinate occupational safety and health research. The Agenda should improve the use of existing resources by outlining the research priorities that can lead to improved worker safety and health.

The Agenda is truly national in scope. The occupational safety and health community was broadly represented, with active participation by employers, employees, safety and health professionals, public agencies, and industry and labor organizations. Approximately 500 organizations and individuals outside NIOSH contributed to the Agenda. I thank the participants in the public meetings; the individuals and organizations that submitted written comments; the members of the Corporate Liaison, Worker Liaison, and Outreach Committees; representatives of other Federal agencies; NIOSH staff; the NIOSH Board of Scientific Counselors; the Mine Health Research Advisory Committee; and the National Advisory Committee on Occupational Safety and Health. I look forward to our continuing collaboration in implementing the Agenda presented here.

Linda Rosenstock, M.D., M.P.H.
Director

CONTENTS

EXECUTIVE SUMMARY

The U.S. workplace is rapidly changing. Jobs in our economy continue to shift from manufacturing to services. Longer hours, compressed workweeks, shift work, reduced job security, and part-time and temporary work are realities of the modern workplace. New chemicals, materials, processes, and equipment are developed and marketed at an ever accelerating pace. The workforce is also changing. As the U.S. workforce grows to approximately 147 million by the year 2005, it will become older and more racially diverse. By the year 2005, minorities will represent 28% of the workforce, and women will constitute approximately 48%. These changes will present new challenges to protecting worker safety and health.

Each day, an average of 137 individuals die from work-related diseases, and an additional 16 die from injuries on the job. Every 5 seconds a worker is injured; every 10 seconds a worker is temporarily or permanently disabled. In 1994, occupational injuries alone cost $121 billion in lost wages and productivity, administrative expenses, health care, and other costs.

The high toll of work injuries and illnesses is not unchangeable. In fact, significant progress has been made in improving worker protection since Congress passed the Occupational Safety and Health Act in 1970 "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources." This progress has been largely based on actions—sometimes voluntary, sometimes regulatory—directed by the science and knowledge generated from occupational safety and health research.

The National Institute for Occupational Safety and Health (NIOSH), and its partners in the public and private sectors, have developed the National Occupational Research Agenda (NORA) to provide a framework to guide occupational safety and health research in the next decade—not only for NIOSH but also for the entire occupational safety and health community. Approximately 500 organizations and individuals outside NIOSH provided input into the development of the Agenda. This attempt to guide and coordinate research nationally is responsive to a broadly perceived need to address systematically those topics that are most pressing and most likely to yield gains to the worker and the nation. Fiscal constraints on occupational safety and health research are increasing, making even more compelling the need for a coordinated and focused research agenda.

The 21 Priorities

The Agenda identifies 21 research priorities. These priorities reflect a remarkable degree of concurrence among a large number of stakeholders. The NORA priority research areas are grouped into three categories: Disease and Injury, Work Environment and Workforce, and Research Tools and Approaches.

NORA Priority Research Areas

CATEGORY	PRIORITY RESEARCH AREAS
Disease and Injury	Allergic and Irritant Dermatitis Asthma and Chronic Obstructive Pulmonary Disease Fertility and Pregnancy Abnormalities Hearing Loss Infectious Diseases Low Back Disorders Musculoskeletal Disorders of the Upper Extremities Traumatic Injuries
Work Environment and Workforce	Emerging Technologies Indoor Environment Mixed Exposures Organization of Work Special Populations at Risk
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Implementation

NORA is the first step in a collaborative effort between NIOSH and its many partners to guide occupational safety and health research over the next decade. Implementation is the necessary next phase. As the first step in the implementation phase, NIOSH is committed to bringing together its NORA partners in a public meeting for further refining the preliminary approaches they agreed to when identifying the Agenda.

Among these approaches is the commitment by NIOSH to (1) use the Agenda to guide both intramural and extramural funding decisions, (2) encourage and stimulate other government agencies to include NORA priorities in their internal and external research programs, (3) develop procedures and capacity to track the impact of NORA activities on health and safety outcomes using existing tracking models, if available, (4) update NORA, and (5) periodically review and communicate the overall role and effectiveness of NORA in occupational safety and health.

Throughout the process of implementing the Agenda, NIOSH will seek to build upon and extend its partnerships and to improve coordination throughout the occupational safety and health community, with the expectation that these activities hold great promise for improving the protection and well-being of workers.

INTRODUCTION

Work—when fulfilling, compensated fairly, healthy, and safe—can help build long and contented lives and strengthen families and communities. Such work can reduce health care costs and improve organizational effectiveness and profits. Although some workers may never face more than minor adverse health effects from exposures at work, (such as occasional eye strain resulting from poor office lighting), there is not a single industry that does not grapple with serious hazards.

There are about 125 million workers in the United States—almost one of every two Americans. Each day, an average of 137 individuals die from work-related diseases, and an additional 16 die from injuries on the job. Every 5 seconds a worker is injured; every 10 seconds a worker is temporarily or permanently disabled. In 1994, occupational injuries alone cost $121 billion in lost wages and productivity, administrative expenses, health care, and other costs. This figure does not include the cost of occupational illnesses. Clearly, work injury and disease create substantial human suffering and place a heavy burden on the U.S. economy.

The high toll of work injuries and illnesses can be drastically reduced. In fact, significant progress has been made in improving worker protection since Congress passed the Occupational Safety and Health Act in 1970 "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources." This progress has been largely based on actions—sometimes voluntary, sometimes regulatory—directed by the science and knowledge generated from occupational safety and health research. For example, vinyl chloride-induced liver cancers and brown lung disease (byssinosis) from cotton dust exposure have been almost eliminated. Reproductive disorders associated with certain glycol ethers have been recognized and controlled. Fatal work injuries have declined substantially through the years. Notably, since 1970, fatal injury rates in coal miners have been reduced by more than 75%, and there has been a general downward trend in the prevalence of coal miners' pneumoconiosis. Other occupational hazards have proved more intractable. For example, two age-old problems, silicosis and lead poisoning, continue to afflict workers. Their causes are well understood, but prevention is plagued by a myriad of complex factors.

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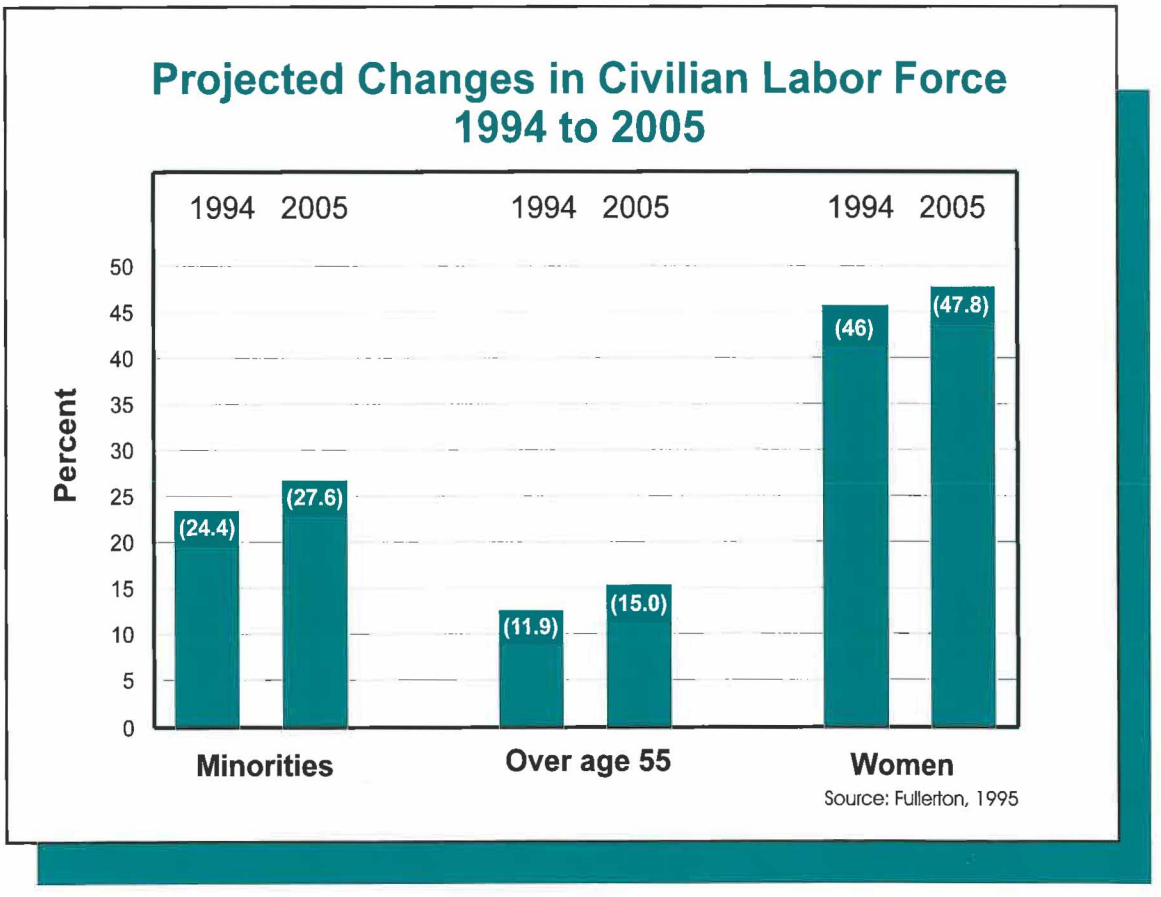
In addition to these persistent, historical occupational safety and health problems, there are many current and emerging challenges. The U.S. workplace is rapidly changing and becoming more diverse. Jobs in our economy continue to shift from manufacturing to services, with the service sector now employing 70% of all workers. Major changes are also occurring in the way work is organized. Longer hours, compressed workweeks, shift work, reduced job security, and part-time and temporary work are realities of the modern workplace. New chemicals, materials, processes, and equipment (such as latex gloves in health care, or fermentation processes in biotechnology) are developed and marketed at an ever-accelerating pace. The workforce is also changing. As the U.S. workforce grows to approximately 147 million by the year 2005, it will become older and more racially diverse. By the year 2005, minorities will represent about 28% and women about 48% of the workforce. These changes are accompanied by new issues.

The National Institute for Occupational Safety and Health (NIOSH) and its partners in the public and private sectors have developed the National Occupational Research Agenda (NORA) to provide a framework to guide occupational safety and health research in the next decade—not only for NIOSH but for the entire occupational safety and health community. This attempt to guide and coordinate research nationally is responsive to a broadly perceived need to address systematically those topics that are most pressing and most likely to yield gains to the worker and the nation. Fiscal constraints on occupational safety and health research are increasing, making even more compelling the need for a coordinated and focused research agenda. For example, NIOSH resources (when adjusted for inflation) have shrunk by more than 25% since 1980. Resources in the private sector are similarly decreasing. A recent survey of safety, industrial hygiene, and environmental professionals found that almost 25% of the professionals said that "holding on to their jobs" will be a concern in 1996. This is consistent with the observed cutbacks in corporate safety and health programs that have accompanied the current trend of corporate downsizing. The decreased investment in occupational safety and health research in both the public and private sectors makes more compelling the need for a coordinated and focused research agenda.

Creating NORA

The process of forming NORA began with a list of 48 potential research topics developed by an initial planning work group of senior scientists inside and outside NIOSH. This planning work group incorporated into their decisions consideration of a broad range of data and information, such as the Public Health Service *Healthy People 2000* goals for the Nation, the



recently completed OSHA Priority Planning Process (which was aimed at identifying the top–priority workplace safety and health hazards in need of either regulatory or nonregulatory action), and the occupational health research planning strategies of several other countries. The potential topic list was expanded and modified to include approximately 60 items (Appendix A)—with input from four additional working groups (occupational safety and health researchers from outside NIOSH, NIOSH scientists, occupational safety and health professionals, and other professionals in the field) and oral and written comments from individuals and representatives of other institutions and organizations. Town meetings were held in Seattle, Boston, and Chicago to receive direct input from workers, employers, individual researchers, and policy makers. Written comments were accepted throughout the process until early March. Other Federal agencies are playing a critical role in the successful development and implementation of NORA: About 30 Federal agencies or programs with missions involving the safety and health of U.S. citizens (including workers) identified individuals to serve as agency representatives to contribute to the development of the Agenda (Appendix B). Liaison committees (corporate, worker, and outreach) were formed to obtain the broadest possible input into the Agenda. A final public meeting was held in Washington, D.C., to review the draft NORA document. Many members of the liaison and advisory committees, agency representatives, working group members, and the public participated. Appendix C summarizes the processes used to develop the Agenda and lists the members of the participating committees.

Selection Criteria

Final research priorities were determined based on consideration of the input from the five working groups, written comments, oral comments made at the public and town meetings, and comments made during deliberations throughout the process. The criteria used to guide evaluation of potential topics included some or all of the following, as appropriate:

- Seriousness of the hazard based on death, injury, disease, disability, and economic impact
- Number of workers exposed or magnitude of risk
- Potential for risk reduction
- Expected trend in importance of the research area
- Sufficiency of existing research
- Probability that research will make a difference

The Agenda relied substantially on the expression of expert scientific and stakeholder opinion because sufficient quantitative data do not exist to address many of these criteria, and because different subsets of the criteria are relevant for different research topics.

The 21 Priorities

The Agenda identifies 21 research priorities (***Table 1***). These priorities reflect a remarkable degree of concurrence among a large number of stakeholders. Sixteen of the 21 research areas were identified as top priorities by three or more of the five working groups. These areas were also endorsed by many individuals through written and oral comments. Of the remaining five topics on the Agenda, four received support from one or two work groups and were heavily endorsed by individuals through written and oral comments and in discussions at the final public meeting in March (Cancer Research Methods, Infectious Diseases, Allergic and Irritant Dermatitis, and

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Table 1. NORA Priority Research Areas

CATEGORY	PRIORITY RESEARCH AREAS
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Risk Assessment Methods). In the final public meeting in March, participants deemed one topic (Control Technology and Personal Protective Equipment) sufficiently distinct and important to warrant its separation from another topic (Intervention Effectiveness Research).

The priorities are not ranked and reflect an attempt to consider both current and emerging needs. Numerous items not included on the Agenda are still important and merit research effort. Moreover, research priorities may evolve with time.

The NORA priority areas are grouped into three categories: Disease and Injury, Work Environment and Workforce, and Research Tools and Approaches. Priority areas may not be mutually exclusive. For example, there is overlap between some aspects of Health Services Research and the Social and Economic Consequences of Workplace Illness and Injury. In addition, it is anticipated that researchers will draw from multiple categories to focus research needs. For example, researchers may use intervention effectiveness research to evaluate the barriers to preventing hearing loss; or a health services research project may compare the success of treatment protocols for occupational asthma.

During the development of the Agenda, the importance of sector–specific research was consistently raised. It was finally decided that the most effective way to integrate consideration of research efforts within specific sectors (such as construction, mining and

agriculture) was to apply a matrix approach of coordinated research in some or all of the 21 priority areas, as appropriate for each sector. This approach is illustrated in ***Table 2***. There was agreement that sector-focused research has had much success and continues to hold great promise for gathering and translating knowledge and information into prevention.

The following section (NORA Priority Research Areas) presents an overview of the 21 priorities, organized by the three categories. Each topic summary emphasizes the reasons for its importance and examples of the kind of research that could be undertaken in connection with each priority. It should be emphasized that the research opportunities presented are illustrative only and do not constitute a comprehensive research strategy.

Implementation of NORA

NORA is the first step in a collaborative effort between NIOSH and its many partners to guide occupational safety and health research over the next decade. The success of NORA will be measured by its utility in directing occupational safety and health research and ultimately by improvements in worker safety and health. NIOSH will take a leadership role in disseminating the Agenda and tracking its implementation. However, no single organization has the resources necessary to accomplish the entire Agenda. Its success will be commensurate with the degree to which the entire occupational safety and health community engages in collaboration and coordination.

The following identifies some specific approaches to implementation. These approaches were generally endorsed in discussions among contributors to the Agenda, recognizing that the effort to date has focused on defining the Agenda, not designing its implementation strategy. Implementation is the necessary next phase of NORA. As the first step in the implementation phase, NIOSH is committed to bringing together its NORA partners in a public meeting to further refine the preliminary ideas presented in the following.

NIOSH is committed to facilitating the formation of partnership teams that will assist in the development, pursuit, review, and dissemination of research under each NORA topic. It is expected that although Partnership Teams will include a broad representation of researchers from the occupational safety and

Table 2. Matrix illustrating application of selected priority research areas by selected sectors

Sector	Allergic and Irritant Dermatitis	Asthma and Chronic Obstructive Pulmonary Disease	Fertility and Pregnancy Abnormalities	Hearing Loss
Agriculture	X*	X	X	X
Construction	X		X	X
Service	X	X	X	
Mining	X	X		X
Manufacturing	X	X	X	X

* = priority research area within a sector

health community, they may differ by membership and structure. For example, some corporations represented on the Corporate Liaison Committee have offered to foster public-private partnerships to increase resources and efforts in selected research areas (e.g., as the "champion" of low back disorders).

Sector–specific interests in topics should also be reflected in team and other NORA-related activities. Teams can identify sectors associated with topics and obtain representation from the sectors and from leading researchers with experience in the sectors. Consensus on research needs for each topic should be sought through some or all of the following: (1) commissioning and reviewing an issue paper on the topic, (2) convening workshops, and (3) using other methods to ensure the complete and critical review of the available information and identification of specific research needs and strategies.

NIOSH is also committed to:

- Using the Agenda to guide both intramural and extramural funding decisions
- Encouraging and stimulating other government agencies to include NORA priorities in their internal and extramural research programs
- Developing procedures and capacity to track the impact of NORA activities on safety and health outcomes using existing tracking models, if available (e.g., *Healthy People 2000*)
- Updating NORA
- Periodically reviewing and communicating the progress and successes of partnership teams, NIOSH intramural and extramural activities, and the overall role and effectiveness of NORA in occupational safety and health.

Working with its partners, NIOSH will take a leadership role in disseminating and promoting the results of NORA activities. All partners will be encouraged to pursue publication of peer-reviewed articles, issue papers, proceedings from public workshops, articles for trade and professional journals, employer/worker educational publications, and to use innovative electronic and other communication strategies to reach those who can protect worker safety and health. Implementation efforts will include the development of evaluation projects to assess the effectiveness of communication activities. NIOSH will also work with the partnership teams and others to publish periodic reports regarding NORA implementation and changes in NORA priorities.

Throughout the process of implementing the Agenda, NIOSH will seek to build upon and extend its partnerships and work to improve coordination throughout the occupational safety and health community. Our expectation is that these activities hold great promise for improving the protection and well-being of workers.

NORA PRIORITY RESEARCH AREAS

Disease and Injury

- Allergic and Irritant Dermatitis
- Asthma and Chronic Obstructive Pulmonary Disease
- Fertility and Pregnancy Abnormalities
- Hearing Loss
- Infectious Diseases
- Low Back Disorders
- Musculoskeletal Disorders of the Upper Extremities
- Traumatic Injuries

Eight of the 21 priority research areas are grouped in the category of adverse health effects—namely, disease and injury. An earlier effort by NIOSH in the 1980s identified the "top ten" leading workplace diseases and injuries. In the development of NORA, participants recognized the need to include a list of diseases and injuries (albeit updated and more focused than the "top ten") and to include research areas grouped into two other broad categories: work environment and workforce, and research tools and approaches.

Early in the process, many disease and injury topics were offered for potential inclusion in NORA. Obviously, a list of significant workplace diseases and injuries could easily be many times the size of the list presented in the Agenda. Working groups performed the difficult task of refining and prioritizing to achieve this list of eight topics—topics for which concerted research efforts have the potential to improve the well-being of large numbers of workers and their families. Indeed, significant advances in the prevention of diseases or injuries encompassed by these eight areas would improve the health of millions of U.S. workers and save billions of dollars in costs related to medical treatment and lost productivity.

Allergic and Irritant Dermatitis

Allergic and irritant dermatitis (contact dermatitis) is overwhelmingly the most important cause of occupational skin diseases, which account for 15% to 20% of all reported occupational diseases. There is virtually no occupation or industry without potential exposure to the many diverse agents that cause allergic and irritant dermatitis. Research is needed to better identify the prevalence, causes, exposure assessment methods, and early biologic markers of this ubiquitous condition.

Importance

In the workplace, the skin is an important route of exposure to chemicals and other contaminants. According to the U.S. Bureau of Labor Statistics, occupational skin diseases—mostly in the form of allergic and irritant (contact) dermatitis—are the second most common type of occupational disease. From 1983 to 1994, the rate of occupational skin diseases increased from 64 to 81 cases per 100,000 workers. In 1994, there were approximately 66,000 reported cases of occupational skin diseases, accounting for about 13% of all occupational diseases. Moreover, occupational skin diseases are believed to be severely underreported, such that the true rate of new cases may be many fold higher than documented. These data stress that the national objective for reducing the rate of new cases of occupational skin diseases to 55 per 100,000 workers (as set by *Healthy People 2000*) is far from being met. Estimated total annual costs (including lost workdays and loss of productivity associated with occupational skin diseases) may reach $1 billion annually. Workers' compensation claims rates for occupational skin diseases vary by State and range from 12 to 108 per 100,000 workers per year. Self-reported occupational dermatitis prevalence in the 1988 National Health Interview Survey was nearly 2% (1,700 cases per 100,000 workers).

Irritant contact dermatitis is the most common occupational skin disease, usually resulting from toxic reactions to chemical irritants such as solvents and cutting fluids. Allergic dermatitis is estimated to constitute about 20% to 25% of all contact dermatitis; it is caused by a wide variety of substances such as latex and some pesticides that trigger an allergic (delayed hypersensitivity) reaction. Contact urticaria (hives occurring soon after an allergen or irritant contacts the skin) is considered here also because it may evolve into contact dermatitis. A number of substances may cause both irritant and allergic dermatitis as well as contact urticaria. For example, latex (which has been reported to cause skin disorders in up to 10% of exposed health care workers), most commonly causes irritant dermatitis but it also results in allergic contact dermatitis and, least commonly, contact urticaria.

Because the prognosis of occupational irritant and allergic dermatitis is poor, prevention is imperative. This fact is emphasized by one

study showing that 75% of patients with occupational contact dermatitis developed chronic skin disease. With thousands of potentially harmful chemicals being introduced into the workplace each year, and with the threat of rapidly emerging skin diseases such as latex allergy, further research of irritant and allergic contact dermatitis is greatly needed.

Research Opportunities

Just as the plight of news reporters with carpal tunnel syndrome captured public attention, disability occurring among nurses and other health care workers allergic to latex is now capturing the attention of health scientists. There has been relatively little occupational research to evaluate causes of occupational dermatitis, identify high risk occupations, develop interventions to protect workers, or assist workers who have developed skin diseases that commonly afflict them for the rest of their lives. Despite a high rate of dermatitis among agricultural workers and high numbers of cases in manufacturing, there is little research to identify and target the most important causes. Also needed are new laboratory *in vitro* skin models, improved statistical models for pharmacokinetic testing in animals, and improved field methods to measure permeation of skin by individual substances and mixtures. The lack of adequate tools prevents the next step in research which aims to eliminate contact with irritants and allergens by substituting safe materials for hazardous ones or by redesigning processes or materials to prevent hazardous exposures. When elimination of causative agents is economically or technically infeasible, work safety and health programs must consider the use of protective clothing and "barrier creams." However, there is insufficient substance-specific research evaluating the effectiveness of different glove and other clothing materials—particularly research involving actual work conditions and the related issues of fit, comfort, durability, multiple chemicals, and other environmental conditions. The effectiveness and utility of barrier creams are largely unexamined. Moreover, there is almost no research to identify major causes for improper use of protective clothing and to target specific populations requiring improved education about appropriate use. Research also needs to provide protection and treatment for workers who have special susceptibility or who have already developed a chronic occupational skin disease.

Asthma and Chronic Obstructive Pulmonary Disease

Occupationally-related airway diseases, including asthma and chronic obstructive pulmonary disease (COPD), have emerged as having substantial public health importance. Nearly 30% of COPD and adult asthma may be attributable to occupational exposure. Occupational asthma is now the most frequent occupational respiratory disease diagnosis. More than 20 million U.S. workers are exposed to substances that can cause airway diseases. Research is needed to clarify the prevalence, risk factors, and exposure-disease relationships, to refine techniques for monitoring worker health and the job environment, and to develop effective and practical means for preventing work-related airway diseases in at-risk workers.

Importance

Asthma and chronic obstructive pulmonary disease (COPD—primarily chronic bronchitis and emphysema) are diseases of the lung airways. More than 20 million workers are potentially exposed to occupational agents capable of causing these diseases— including nearly 9 million workers occupationally exposed to known sensitizers and irritants associated with asthma. Occupational asthma is now the most frequent occupational respiratory disease diagnosis among patients visiting occupational medicine clinics.

Asthma and COPD accounted for nearly 18 million physician visits in 1985 and an estimated 800,000 hospital admissions in 1987. In 1992, asthma and COPD caused nearly 92,000 deaths in the United States, making airway diseases the fourth leading cause of death overall. Mortality from asthma and COPD is increasing annually. Estimated yearly costs for occupational asthma are approximately $400 million.

Asthma currently affects more than 10 million individuals in the United States and is increasing in prevalence. Recent evidence suggests that as many as 28% of adult asthma cases may be attributable to work settings. In addition to those who develop occupational asthma as a result of workplace exposure to sensitizers or irritants, many workers are unaware that pre-existing asthma may be worsened by the work environment. Each year the number of asthma cases is increasing, and major new problem areas are emerging. For example, as a result of increased use of protective gloves (which is due to the introduction of universal precautions and the OSHA regulations on bloodborne pathogens), latex allergies have become a major problem for health care workers. A significant number of these workers (2.5% in one study) have developed latex-related asthma. Morbidity from occupational asthma is preventable. Early diagnosis holds substantial promise for effective intervention. Complete resolution of symptoms and pulmonary function abnormalities is most likely when an affected individual's exposure is terminated early in the course of the illness; so early diagnosis holds substantial promise for effective intervention.

Worker exposed to dust while cutting paving bricks.

The relationship of COPD to workplace exposures is also well documented in studies of several occupational agents (e.g., coal dust, grain dust, and cotton dust). Investigations of the health consequences of particulate exposure in the general environment—where exposures are at a far lower level than in the workplace—also suggest that COPD resulting from generally dusty conditions may be an important cause of preventable disease and death. Those with lung disease from other causes are especially vulnerable to occupational respiratory hazards. Although cigarettes remain the primary cause of pulmonary diseases in the United States, many occupational and environmental exposures (both by themselves or in combination with smoking) are known to cause COPD. One estimate of the proportion of COPD attributable to occupational exposure in the general population is 14%.

Research Opportunities

Disabling effects of asthma and COPD may in many cases drive a person out of a line of work or out of work completely. The machinist who becomes asthmatic from breathing droplets of cutting fluids and the nurse allergic to latex may have to relinquish their skilled professions. An agricultural worker with an obstructive lung disease may become unemployable. These personal effects have serious business consequences beyond issues of medical costs and workers' compensation. Employee turnover in highly skilled professions is especially costly. Scientists associating dust exposures in specific work operations with high levels of COPD can test alternative approaches to dust suppression, evaluate the impact of providing workers with respirators, and determine the benefit of medical screening in reducing disease effects. There has been little research to evaluate the potential impact of occupational risk information on smoking among workers at risk. Research that investigates how workers become sensitized to substances causing asthma, (e.g., such as latex) may enable employers to screen for biomarkers or other early indications of risk before workers become disabled; such studies may also enable researchers to develop methods to replace or control exposures to the sensitizing agent. Development of tests to identify substances and processes that may cause asthma would have enormous benefits, enabling health scientists to work with product designers to assure the safety of new materials before they are introduced to the workplace, preventing disease before any cases occur, and avoiding the need for employers to implement additional prevention programs.

Fertility and Pregnancy Abnormalities

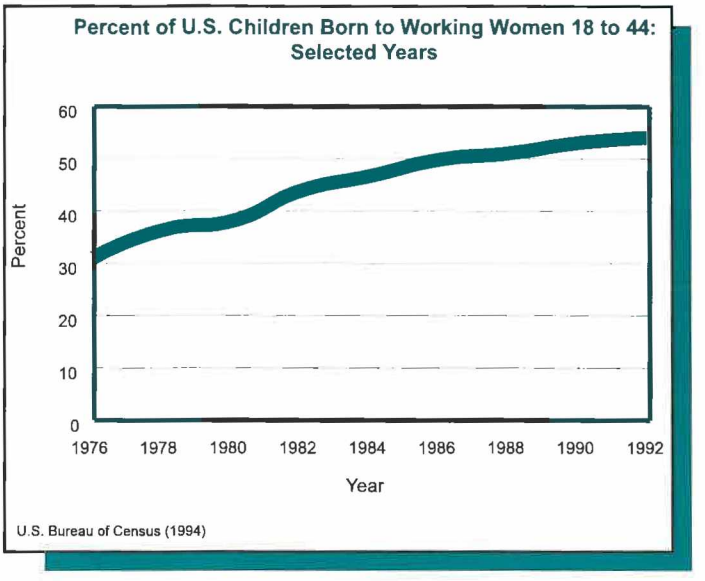
While more than 1,000 workplace chemicals have shown reproductive effects in animals, most have not been studied in humans. In addition, most of the 4 million other chemical mixtures in commercial use remain untested. Physical and biological agents in the workplace that may affect fertility and pregnancy outcomes are practically unstudied. The inadequacy of current knowledge coupled with the ever-growing variety of workplace exposures pose a potentially serious public health problem. Over the next 10 years, research priorities should include expanding surveillance systems, studying working populations thought to be at risk, increasing the understanding of fundamental biological processes underlying normal and abnormal reproductive function or outcomes, and enhancing methods to identify hazards before placing human populations at risk.

Importance

Disorders of reproduction include birth defects, developmental disorders, spontaneous abortion, low birth weight, preterm birth, and various other disorders affecting offspring; they also include reduced fertility, impotence, and menstrual disorders. Infertility is currently estimated to affect more than 2 million U.S. couples (one in 12 couples find themselves unable to conceive after 1 year of unprotected intercourse). Though not all infertile couples seek treatment, it is estimated that about $1 billion was spent in 1987 on health care related to infertility. In 1991, physician visits for infertility services numbered 1.7 million. Although numerous occupational exposures have been demonstrated to impair fertility (e.g., lead, some pesticides, and solvents), the overall contribution of occupational exposures to male and female infertility is unknown. Moreover, observed global trends in men's decreasing sperm counts have elevated concerns about the role of chemicals encountered at work and in the environment at large.

Birth defects are the leading cause of infant mortality in the United States, accounting for 20% of infant deaths (more than 8,000) each year. Every year about 120,000 babies are born in the United States with a major birth defect—about 3 per 100 live births. The 1992 costs for 17 of the most clinically important structural birth defects and for cerebral palsy were estimated to be about $8 billion. Neural tube defects (which include spina bifida and anencephaly), affect 4,000 pregnancies each year, with each new case of spina bifida having a discounted lifetime cost of $294,000 (1992 dollars). Seventeen percent of all children in the United States have some type of developmental disability. The major developmental disabilities of mental retardation, cerebral palsy, hearing impairment, and vision impairment affect about 2% of all school-age children.

Most birth defects and developmental disabilities are of unknown cause. The overall contribution of workplace exposures to reproductive disorders and congenital abnormalities is not known. Although some specific reproductive hazards have been identified in humans (e.g., lead, solvents, and ionizing radiation), most of the more than 1,000 workplace chemicals that have shown abnormal reproductive effects in animals have not been studied in humans. In addition, most



of the 4 million other chemical mixtures in commercial use remain untested. Substances and activities that upset the normal hormonal activity of the reproductive system—such as shift work or pesticides that possess estrogenic activity—also need evaluation. Similarly, the effects of physical factors (such as prolonged standing, reaching, or lifting) or the interactive effects of workplace stressors and exposures on pregnancy and fertility have not been rigorously investigated.

Although the total number of workers potentially exposed to reproductive hazards is difficult to estimate, three-quarters of employed women and an even greater proportion of employed men are of reproductive age. More than half of U.S. children are born to working mothers. The vast number of workers of reproductive age together with the substantial number of workplace chemical, physical, and biological agents suggest that a considerable number of workers are potentially at risk for adverse reproductive outcomes.

Although the causes of reproductive disorders and adverse pregnancy outcomes are poorly defined, lost productivity and deep suffering by affected individuals and families are evident. The contribution that may be made by occupational factors is largely unexplored, since the reproductive health of workers has only recently emerged as a serious focus of scientific investigation. Identifying reproductive hazards in the workplace has the potential for significantly reducing the multibillion-dollar costs and alleviating the personal suffering associated with disorders of reproduction.

Research Opportunities

Substantial research is required to advance from the current high level of concern about the role of the workplace to a broad understanding of the most important hazards, their impacts, and prevention. That research must span the entire range of human clinical research, surveillance, and targeted field investigations of populations at risk. These studies could serve to identify preventable effects in workers or their offspring, such as field studies like those that detected reduced semen quality in men occupationally exposed to glycol ethers, or increased spontaneous abortions in semiconductor workers. Research may also serve to allay fears and avert unnecessary expense, for example, epidemiologic studies such as the sentinel one which showed that working with computer screens is not associated with miscarriage. Research is needed spanning the entire range of laboratory investigation from basic biology to the development and application of techniques to detect potentially hazardous conditions or agents. For example, improved understanding of basic biology (such as the actions of hormonal disrupters) will enhance prevention of reproductive disorders. Success on these fronts will allow reproductive hazards in the workplace to be recognized and removed; it will allow new or emerging hazards to be identified before large numbers of workers are placed at risk; and it could allow significant reductions in the currently heavy social, economic, and personal burdens imposed by reproductive disorders.

Hearing Loss

Occupational hearing loss may result from an acute traumatic injury, but it is far more likely to develop gradually as a result of chronic exposure to ototraumatic (damaging to the ear or hearing process) agents. Noise is the most important occupational cause of hearing loss, but solvents, metals, asphyxiants, and heat may also play a role. Exposure to noise combined with other agents can result in hearing losses greater than those resulting from exposure to noise or other agents alone. Research is needed to define further the causal contributions of these hazards (alone or in combination) and to implement and evaluate methods for early detection and hearing conservation programs.

Importance

Occupational hearing loss is the most common occupational disease in the United States: it is so common that it is often accepted as a normal consequence of employment. More than 30 million workers are exposed to hazardous noise, and an additional 9 million are at risk from other ototraumatic agents. Occupational hearing loss knows no boundaries with respect to industries. Any worker,young or old, male or female, risks hearing loss when exposed to ototraumatic agents. Once the loss is acquired, it is irreversible.

Although noise-induced occupational hearing loss is the most common occupational disease and is the second most self-reported occupational illness or injury, it has not been possible to create a sense of urgency about this problem. Efforts to prevent occupational hearing loss have been hindered because the problem is insidious and occurs without pain or obvious physical abnormalities in affected workers.

Problems created by occupational hearing loss include the following: (1) reduced quality of life because of social isolation and unrelenting tinnitus (ringing in the ears), (2) impaired communication with family members, the public, and coworkers, (3) diminished ability to monitor the work environment (warning signals, equipment sounds, etc.), (4) lost productivity and increased accidents resulting from impaired communication and isolation, and (5) expenses for workers' compensation and hearing aids.

Because no national surveillance or injury-reporting system exists, no generalizable data are available regarding the economic impact of occupational hearing loss.

Research Opportunities

A great deal of information exists about the most important cause of hearing loss—high levels of damaging types of noise. Scientists are just beginning to understand how other

New types of hearing protection screen out harmful loud noises but allow conversation among workers to take place.

factors such as exposure to solvents and heat affect hearing ability (acuity). However, many critical practical problems associated with stopping noise-induced hearing loss are largely unstudied. There have been no recent studies of the hearing status of contemporary workers. Reliance on data collected 30 years ago results in predictions that underestimate the amount of hearing loss that is due to occupational noise, especially for those with intermittent noise exposures. Moreover, factors such as heat and chemicals are only now emerging as recognized threats to hearing. Existing hearing conservation measures provide no guarantee to workers that occupational hearing loss will be prevented by the simple use of hearing protectors. For example, removing hearing protection for 15 minutes of an 8-hour work shift can cut protection effectiveness in half; yet we know little about why protection is not worn. Likewise, a poorly-fitting hearing protector will not prevent hearing loss. Research will give employers and employees strategies to identify and overcome barriers to the use of hearing protection. It will provide new methods to reduce noise exposure— such as ways to block noise at its sources and to assure that hearing protection fits the wearer. Research will also determine the impact of other risk factors for hearing loss and will examine why some people seem to be susceptible to hearing loss. In addition, research will also: (1) redefine the risk of occupational hearing loss, taking into account exposure times, exposure events, exposure agents, and the use of personal protective equipment; (2) develop and test new strategies for identifying exposure hazards; (3) develop and implement new technologies for controlling noise and improving hearing protector effectiveness; and (4) initiate new methods to improve the efficiency of biological monitoring for hearing loss and the effectiveness of hearing loss prevention programs.

Infectious Diseases

Health care workers are at risk of tuberculosis (TB), hepatitis B and C viruses, and the human immunodeficiency virus (HIV). Social service workers, corrections personnel, and other occupational groups who work regularly with populations having increased rates of TB may also face increased risk. Laboratory workers are at risk of exposure to infectious diseases when working with infective material. Research is needed to determine the extent of occupational transmission of these infectious diseases, to understand the barriers to the use of safe work practices and vaccines, and to develop and evaluate new control methods.

Importance

Infections acquired in the work setting are a diverse group with many different modes of transmission. Of particular concern are infectious diseases transmitted by humans (e.g., from patient to worker or from worker to worker) in a variety of work settings. Bloodborne and airborne pathogens represent a significant class of exposures for the 6 million U.S. health care workers. Occupational transmission of bloodborne pathogens (including the hepatitis B and C virus and the human immunodeficiency virus [HIV]), occurs primarily by means of needle-stick injuries but also through exposures to the eyes or mucous membranes. The risk of hepatitis B virus infection following a single needle-stick injury with a contaminated needle varies from 2% to greater than 40%, depending on the antigen status of the source patient. Similarly, the risk of hepatitis C virus transmission also depends on the status of the source and ranges from 3.3% to 10%. Before widespread use of hepatitis B virus vaccine, approximately 8,700 acute cases of hepatitis B virus infection were reported among health care workers each year. Although the incidence of occupational hepatitis C virus infection among these workers is unknown, antibody to hepatitis C virus (evidence of previous infection) is found in 1% of hospital-based health care workers. As of June 1995, the Centers for Disease Control and Prevention reported 143 U.S. health care workers with documented or possible occupational transmission of HIV.

Transmission of tuberculosis (TB) within health care settings (especially multidrug-resistant TB) has re-emerged as a major public health problem. Since 1989, outbreaks of this type of TB have been reported in 14 hospitals and at least 17 workers have developed active drug-resistant TB. In addition among workers in health care, social service, and corrections facilities who work with populations at increased risk of TB, hundreds have experienced tuberculin skin test conversions. Reliable data are lacking on the extent of possible work-related TB transmission among other groups of workers at risk for exposure.

Some cases of influenza and other communicable respiratory infections are surely due to exposure to infected persons at work. These are not generally considered occupational diseases, and the proportion acquired at work (from coworkers, patients, customers, clients, and the general public) is unknown. The cost of lost work time and decreased productivity is likely to be substantial.

Research Opportunities

Occupation is a major risk factor for nearly all communicable infections among adults. There are great demands for research on occupational transmission of infectious diseases occurring in the health care industry, where workers may often be exposed to populations with high prevalences of TB, HIV, or other bloodborne pathogens. Intervention research is especially needed. For example, many new needle-containing devices are marketed for improved safety, but there has been little evaluation of their effectiveness. Latex rubber gloves are routinely used as part of an overall strategy to prevent transmission of bloodborne infections. These gloves are the primary type of hand protection available to health care workers, yet glove wearers must also worry about increasing reports of latex allergies following their use. As with other regulations, the implementation and effectiveness of the OSHA "bloodborne pathogens" standard should be evaluated, as should the CDC *Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health Care Facilities*. The resurgence of TB and the increase in multidrug-resistant strains have made it difficult to assure the safety of health care workers. Research is needed to design interventions and to evaluate the protection achieved by using ventilation and air filtration, ultraviolet germicidal irradiation, and respirators.

In addition to posing a risk for health care providers, work exposures may also be a major risk factor for many communicable infections among adults in a variety of workplace settings. Hence, research is also needed to define the incidence, prevalence, and impact of occupational infectious diseases such as acute respiratory illness and vaccine-preventable illnesses.

Low Back Disorders

Low back musculoskeletal disorders are common and costly. Although the causes of low back disorders are complex, substantial scientific evidence identifies some work activities and awkward postures as significantly contributing to the problem. In the United States, back disorders account for 27 percent of all nonfatal occupational injuries and illnesses involving days away from work. Prevention activities should be undertaken based on current knowledge, but important new research efforts are needed to assure that work-related low back disorders are successfully prevented and treated. For some occupations and tasks, there is a pressing need for more information about safe levels of exposure and for further validation of promising intervention approaches such as mechanical lifting devices for nursing aides.

Importance

Back pain is one of the most common and significant musculoskeletal problems in the world. In 1993, back disorders accounted for 27% of all nonfatal occupational injuries and illnesses involving days away from work in the United States. The economic costs of low back disorders are staggering. In a recent study, the average cost of a workers' compensation claim for a low back disorder was $8,300, which was more than twice the average cost of $4,075 for all compensable claims combined. Estimates of the total cost of low back pain to society in 1990 were between $50 billion and $100 billion per year, with a significant share (about $11 billion) borne by the workers' compensation system. Moreover, as many as 30% of American workers are employed in jobs that routinely require them to perform activities that may increase risk of developing low back disorders.

Despite the overwhelming statistics on the magnitude of the problem, more complete information is needed to assess how changes implemented to reduce the physical demands of jobs will affect workplace safety and productivity in the future. A tremendous opportunity exists for prevention efforts to reduce the prevalence and costs of low back disorders, since a significant number of occupationally related low back disorders are associated with certain high-risk activities. For example, female nursing aides and licensed practical nurses were about two and one-half times more likely to experience a work-related low back disorder than all other female workers. Male construction laborers, carpenters, and truck and tractor operators were nearly two times more likely to experience a low back disorder than all other male workers.

Lifting over a barrier and in an awkward position may increase the risk of low back disorders.

Research Opportunities

Every worker whose job involves stressful lifting tasks or awkward postures is at risk for a low back disorder. Countless times each day the health aide in a nursing home lifts and physically assists elderly or disabled residents. Many construction laborers, agricultural workers and others spend their days lifting and carrying awkward loads. Often their productive work is interrupted by weeks of disability, pain, and costly therapy, yet little is known about the pathophysiology of low back pain. For some occupations and tasks, the risks are not well defined. How much weight is too much? How many lifts per day are too many? What are the material handling jobs with the highest risk of back injury? These are interrelated risk factors. They represent one broad challenge of research: to develop approaches by which employers, workers, design engineers, and others with a role in prevention can confidently identify hazardous and safe work tasks. Another challenge for those tasks and occupations involving recognized hazards is intervention research. Evaluation of rehabilitation and return to work strategies will be useful. Current studies are testing ways to reduce risks to nursing aides by the use of mechanical lifting devices, training, and reorganizing tasks. Studies of this type (including those testing the effectiveness of back belt use) are needed in other work settings. Research to redesign materials, loads, and equipment can improve the safety of workers in many occupations.

Musculoskeletal Disorders of the Upper Extremities

Musculoskeletal disorders of the upper extremities (such as carpal tunnel syndrome and rotator cuff tendinitis) due to work factors are common and occur in nearly all sectors of our economy. More than $2 billion in workers' compensation costs are spent annually on these work-related problems. Workers' compensation costs undoubtedly underestimate the actual magnitude of these disorders. Current scientific research has provided important insights into the etiology and prevention of these disorders, but important questions remain unsolved. Research needs include better methods of exposure characterization and greater understanding of basic pathophysiologic mechanisms.

Importance

Musculoskeletal disorders of the neck and upper extremities due to work factors affect employees in every type of workplace and include such diverse workers as food processors, automobile and electronics assemblers, carpenters, office data entry workers, grocery store cashiers, and garment workers. The highest rates of these disorders occur in the industries with a substantial amount of repetitive, forceful work. Musculoskeletal disorders affect the soft tissues of the neck, shoulder, elbow, hand, wrist, and fingers. These include the nerves (e.g., carpal tunnel syndrome), tendons (e.g., tenosynovitis, peritendinitis, epicondylitis), and muscles (e.g., tension neck syndrome). The costs associated with these disorders are high. More than $2.1 billion in workers' compensation costs and $90 million in indirect costs (hiring, training, overtime, and administrative costs) are incurred annually for these musculoskeletal disorders.

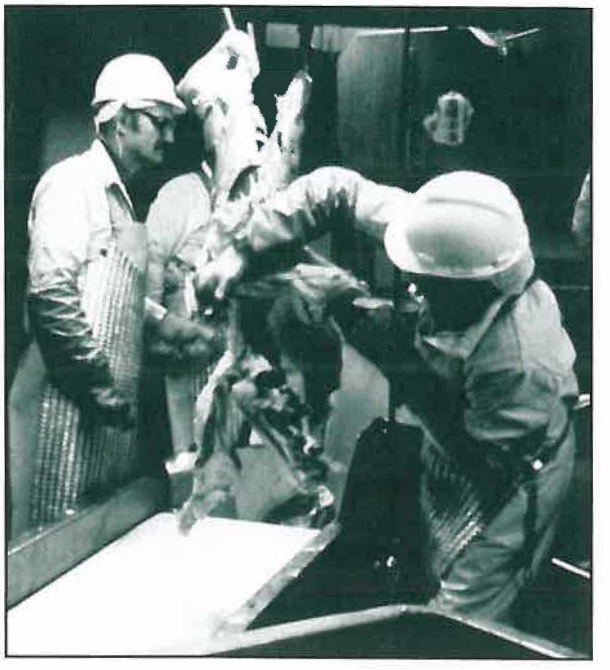
In 1994, 332,000 musculoskeletal disorders due to repeated trauma were reported in U.S. workplaces. This figure represents nearly 65% of all illness cases reported to the Bureau of Labor Statistics—an increase of nearly 10% compared with 1993 figures and more than 15% relative to 1992 figures.

The most frequently reported upper-extremity musculoskeletal disorders affect the hand/wrist region. In 1993, carpal tunnel syndrome, the most widely recognized condition, occured at a rate of 5.2 per 10,000 full-time workers. This syndrome required the longest recuperation period of all conditions resulting in lost workdays, with a median 30 days away from work.

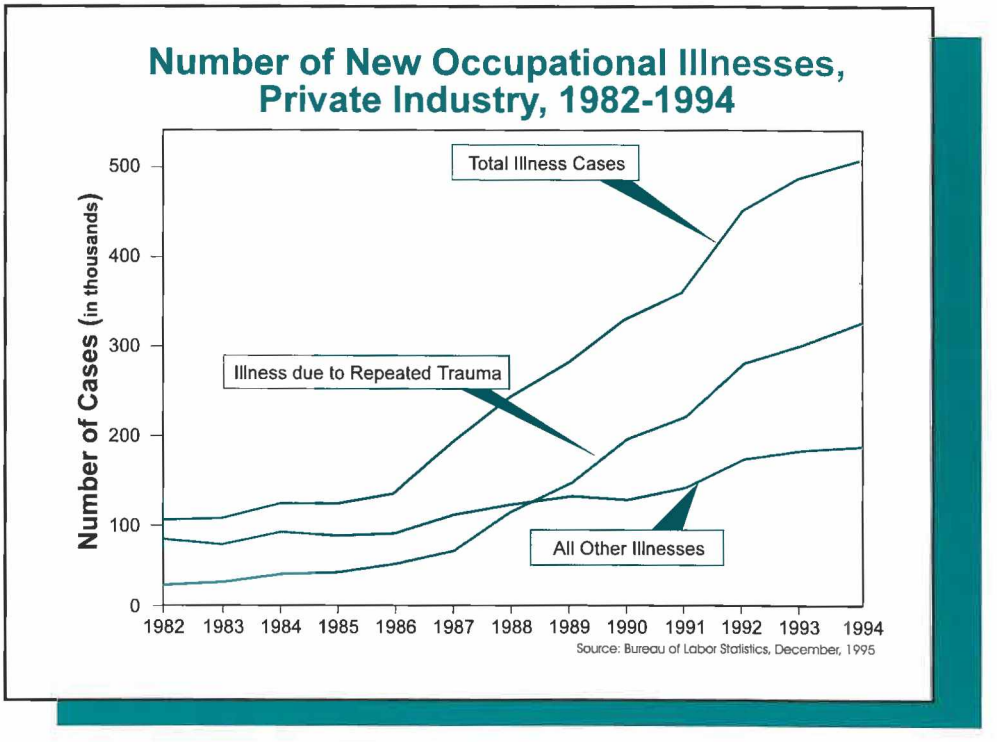
Research Opportunities

Research has made important gains by establishing widespread recognition of work-related musculoskeletal disorders of the upper extremities and identifying much about their principal causes and approaches to prevention. This research has instigated a wide field of prevention efforts at worksites throughout the United States. But research is still needed across the gamut of possible concerns, including basic research that clarifies the pathophysiologic mechanisms of chronic musculoskeletal injury. Employers and workers want to know: "How can these

problems be solved cost effectively?" "What is causing the problem?" "How can we bring people back to work without being reinjured?" "How can these problems be solved with better cost-effective tool and equipment designs, work-rest periods, or changes in the organization of work?" Health care providers want reliable clinical methods to diagnose musculoskeletal disorders, identify them before they become severe, and rehabilitate disabled workers as fully and rapidly as possible. These many challenges are being met with varied and sporadic success. There is a large role for research to improve and standardize successful ways to address these challenges. This effort will require unraveling the ways in which different factors combine to cause a hazard, providing better approaches by which employers and workers can identify hazards before they cause injury, and developing and proving the effectiveness of interventions and treatment. This scientific work has an integral role in the occupational safety and health community's efforts to reverse the trend of the large and growing problem of upper-extremity musculoskeletal disorders.



In a meat processing plant, working at a fast pace in cold environments while using forceful motions in awkward postures places individuals at risk for musculoskeletal disorders of the upper extremities.



Traumatic Injuries

Injury exacts a huge toll in U.S. workplaces—on an average day, 16 workers are killed and over 17,000 workers are injured. The associated economic costs are high—about $121 billion per year. Research should focus on leading causes and high-risk groups. Priorities are deaths caused by motor vehicles, machines, violence, and falls, as well as traumatic injuries caused by falls and contact with machines, materials, equipment, and tools. High-risk groups include construction workers, loggers, miners, farmers, farm workers, adolescents, and older workers. Multiple factors and risks contribute to traumatic injuries, including the characteristics of workers, workplace/process design, work organization, economics and other social factors. Research needs are thus broad, and the development of interventions involve many disciplines and organizations.

Importance

Fatal Occupational Injuries

During the period 1980 through 1992, more than 77,000 workers died as a result of work-related injuries. This means that an average of 16 workers die every day from injuries suffered at work. The leading causes of occupational injury fatalities over this 13-year period were motor vehicles, machines, homicides, falls, electrocutions, and falling objects. There were four industries—mining, construction, transportation, and agriculture—with occupational injury fatality rates that were notably and consistently higher than all other industries. Motor-vehicle-related deaths in the transportation sector, machine-related deaths in agriculture, electrocutions and fatal falls in construction, homicide in retail trade and public administration, and deaths due to falling objects in mining and logging appear to be important because of particularly high rates of death from injury.

Nonfatal Occupational Injuries

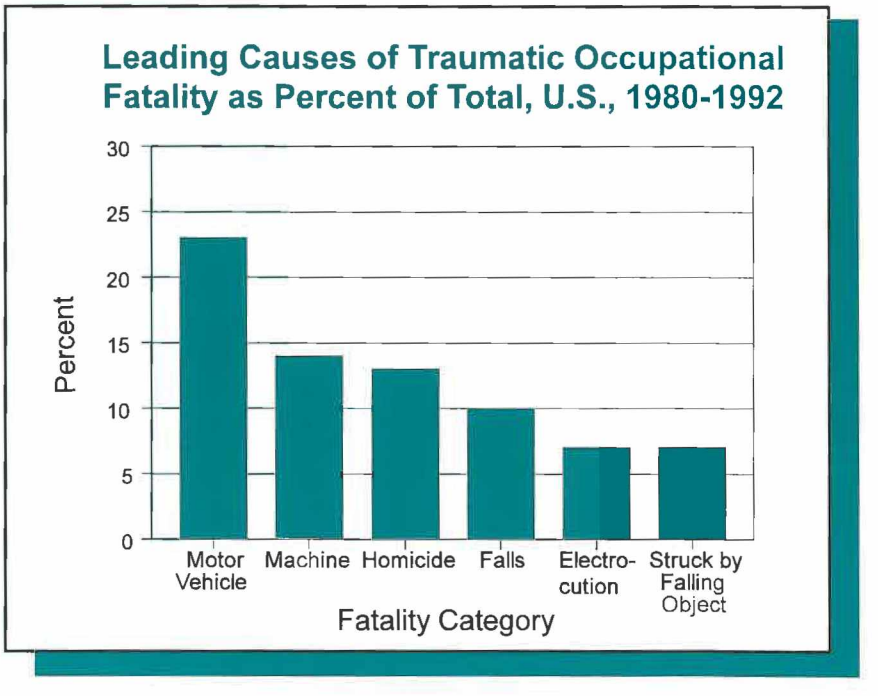
In 1994, 6.3 million workers suffered job-related injuries that resulted in lost work time, medical treatment other than first aid, loss of consciousness, restriction of work or motion, or transfer to another job. The leading causes of nonfatal occupational injuries involving time away from work in 1993 were overexertion, contact with objects or equipment, and falls to the same level. Industries experiencing the largest number of serious nonfatal injuries include eating and drinking places, hospitals, and grocery stores. Industries facing higher risks of serious nonfatal injuries are concentrated in the manufacturing sector and include workers in shipbuilding, wooden building and mobile home manufacture, foundries, special products sawmills, and meat packing plants.

Clearly, work-related injuries and fatalities result from multiple causes, affect different segments of the working population, and occur in a myriad of occupational and industrial settings. The total cost of work-related injuries and fatalities to industry and to society at large has not been fully recognized, but is estimated to be greater than $121 billion annually. Efforts to set research

and prevention priorities in traumatic injury must be driven by data that illuminate the nature and magnitude of these injuries.

Research Opportunities

Relatively good general information is available on the overall burden of work injuries in the United States. There are expanding sources of information to identify the industries and occupations where they occur most frequently and with greatest severity. The challenge is to move beyond this broad understanding to specific strategies that actually prevent another warehouse employee from being crushed by an overturned forklift, prevent scaffolding from collapsing from under a mason, and keep convenience store clerks and taxi drivers from being shot or stabbed. At many worksites, such injuries are already largely prevented. The challenge is to develop information systems that allow new preventive efforts to target high-risk worksites and to develop solutions that fit highly specific hazardous circumstances. Specific strategies are needed within work sectors (e.g., agriculture and construction) that address the complex interplay between machines, tools, and behavioral and environmental factors causing injuries at a worksite. In many cases, understanding these factors will lead researchers to re-engineer work practices, equipment, and tools to eliminate hazards. For hazards that cannot be eliminated (such as exposure of fire fighters to fires, explosions, and toxic emissions), research will improve safety practices and the protective equipment and clothing worn by the worker.



NORA PRIORITY RESEARCH AREAS

Work Environment and Workforce

- Emerging Technologies
- Indoor Environment
- Mixed Exposures
- Organization of Work
- Special Populations at Risk

Five of the NORA priority areas fall in the category of work environment and workforce. Although seemingly very different, the research priorities represented here underscore the importance of the markedly changing nature of work—and who does it—in the United States today. Research is needed to understand the complex interactions between traditional risk factors and the various social and economic forces that operate within special populations at risk (e.g., older workers, adolescents, and minorities). Emerging technologies pose the challenge to anticipate and prevent the hazards with which they may be associated. Large numbers of office workers complain of symptoms related to the indoor environment, but ready diagnosis and control of these problems have been elusive. Most research in the field has targeted single exposures, but there is little understanding of the harmful interactions of mixed exposures (more than one chemical or physical agent). Aspects of the organization of work are increasingly recognized but little understood as risk factors for injury and illness and as threats to organizational efficiency and productivity.

Emerging Technologies

Advances in technologies provide opportunities to minimize the drudgery of work and to eliminate old hazards, but they may also create new, currently unrecognized risks to workers. Mechanisms are needed to anticipate the potential adverse health consequences of these technologies. Also needed are laboratory and statistical models to predict hazards, and surveillance systems that rapidly identify worker morbidity and mortality associated with new materials, tools, or processes. As emerging hazards are identified, the challenge shifts to development and application of effective control measures.

Importance

In highly competitive economies, the fast-paced development of new and improved products and services inevitably spurs the development of new technologies (new materials, tools, and processes). A major challenge facing occupational safety and health researchers and practitioners is the timely identification of emerging technologies to (1) assess their potential to cause harm to workers, (2) evaluate specific work sites, (3) develop effective control strategies where occupational hazards exist, (4) identify superior new technologies that diminish risk and (5) share information for the benefit of all persons at risk and those responsible for managing the risk. Ideally, workplace safety and health can become a key element in the design of new technologies in contrast with the more common approach of developing controls after a problem is identified.

One promising approach for identifying the potential hazards of emerging technologies is to examine those sectors of the economy that produce rapid growth and thereby drive innovation. A list of the 500 fastest-growing U.S. technology companies includes not only large corporations but also many small start-up companies. Nearly three-fifths of these rapid-growth companies are in information technology/telecommunications; about one-fifth are in the biotechnology/medical sector; and most of the others are roughly split (about 8 % each) between the manufacturing/materials and the instrumentation/electronics industries.

Programs such as the NIOSH Health Hazard Evaluation Program (HHE) and the Occupational Safety and Health Administration State Consultation Program are useful for identifying safety and health issues associated with evolving technologies. These programs have identified potential hazards related to new technology or new applications of existing technology. For example, they have found the following:

- Although sodium azide is not new, its production and associated explosion hazards have increased with recent requirements for automobile air bags.

- The new industry of recycling small household batteries (to reduce levels of mercury in landfills) is exposing workers to hazardous levels of mercury, a neurological poison.

- The cleaner-burning, reformulated (oxygenated) fuels now required by the U.S. Environmental Protection Agency in more than 100 areas of the United States are resulting in reports of respiratory irritation by service station attendants.

Research Opportunities

Research must address the challenge of predicting hazards associated with emerging technologies and modifying the risks to workers. Improved statistical tools and laboratory models are needed to generate predictive approaches for potential hazards before commercialization of new technologies. As new hazards are identified and characterized, substitutions or appropriate and effective control measures can be developed. To detect unanticipated morbidity and mortality patterns in workers using new materials and processes, improved surveillance systems are needed. These systems should include the use of workers' compensation and insurance data. Regional data collection from sources such as health maintenance organizations in high technology areas—Silicon Valley in California or the Route 128 Corridor near Boston—might also prove effective. The inclusion of safety and health principles in all stages of the development of new technologies (including concept development, engineering, production, and marketing) must be promoted. An overall systematic procedure for identifying, reviewing, and selecting new technologies for potential intervention will need to be developed by partnerships involving trade associations, national laboratories, universities, government agencies, labor unions, and industry consortia. Early identification and communication of information about hazards associated with emerging technologies will allow anticipation of potential exposure problems and development and assessment of new prevention strategies.

Indoor Environment

Since the energy crisis of the 1970s, a persistent epidemic of health complaints has appeared among workers in nonindustrial work environments. Reported problems have ranged from allergic and infectious diseases to nonspecific symptoms such as headaches and eye irritation. Current evidence suggests that better solutions to such problems will be possible with additional research efforts, including the development of improved measurement methods (particularly for microbiologic and chemical exposures), systematic clinical approaches to diagnosis and treatment, building maintenance and operation approaches, and, innovative multifaceted effective intervention strategies.

Importance

Traditionally, indoor nonindustrial occupational environments such as offices have been considered clean and relatively free of contaminants. In the last 20 years, however, reports of symptoms and other health complaints related to these indoor environments have been increasing. In some cases, recognized infectious or chronic diseases (such as Legionnaire's disease or hypersensitivity pneumonitis) have been diagnosed and attributed to improper design, operation, or maintenance of buildings. Yet the majority of health problems reported in buildings (namely, nonspecific complaints sometimes called sick building syndrome) cannot yet be attributed to specific exposures. Available evidence suggests that multiple factors are involved, including microbiological and chemical exposures not adequately characterized by current exposure assessment approaches; physical conditions such as temperature, humidity, lighting and noise; and social/psychological stressors.

More than half the U.S. workforce is employed indoors, and estimates of the proportion of indoor workers affected by these problems range up to 30%. Among the requests received annually by NIOSH for occupational health investigations, the proportion related to indoor nonindustrial environments has increased over the years, from 2% in 1980 up to 35% to 65% in recent years.

Although only a small proportion of the estimated 20 to 30 million U.S. workers who experience health problems may be seriously impaired, the large absolute numbers make the associated economic costs high. These are estimated by some at tens of billions of dollars per year, including the costs of health care and absenteeism, reduced worker productivity, building investigations and building improvements. These costs do not include the enormous costs of closure or renovation of many buildings each year in attempts to solve these problems. Furthermore, the office and indoor job sectors continue to expand along with the proportion of modern, energy-efficient buildings in which these health problems tend to occur.

Research Opportunities

A variety of research strategies will be necessary to identify adverse indoor exposures or conditions, characterize exposure and health effect relationships, and develop effective preventive measures. Intervention studies can identify appropriate building design, maintenance, and operation strategies to prevent indoor-related health problems, even before identification of specific causal exposures. Promising interventions include improving air filtration for contaminants and improving cleaning methods for indoor surfaces.

Epidemiologic studies can identify indoor exposures (whether microbiological, chemical, physical, or social/psychological) associated with adverse health outcomes. Improved, objective measurement methods for relevant health outcomes (including irritant or immunologic as well as infectious diseases) are crucial in the efficient identification of adverse exposures. Improved field and laboratory methods are necessary for measuring and interpreting complex indoor exposures. Particular challenges exist in assessment of viable and nonviable microbiological exposures, which may act through allergenic, irritant, or infectious mechanisms. Methods for accurate characterization of low-level complex chemical exposures are also needed. Such research strategies in indoor environments are essential to improve understanding and prevention of both recognized, building-related illnesses and nonspecific indoor-related symptom complaints.

Mixed Exposures

Agricultural, industrial, and other workers are commonly exposed to combinations of chemical or physical agents, but knowledge about the potential health effects of mixed exposures is limited. New approaches are needed to identify synergistic effects of multiple exposures, to better characterize the exposures of workers, to improve laboratory and statistical analysis methods, and to develop hazard controls that take into account the components in the mixture.

Importance

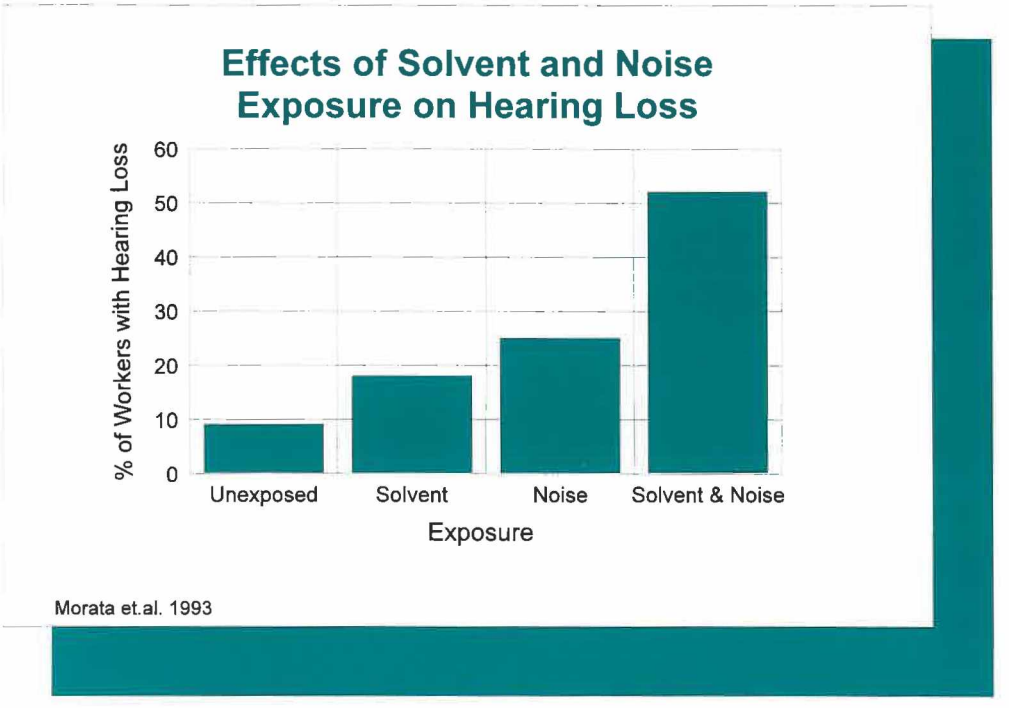
Workers are commonly exposed to multiple agents, either as mixtures of agents or as separate simultaneous exposures. For example, farm workers are exposed to multiple chemicals in pesticides, and welders face exposures to welding fumes from electrodes and flux materials. However, little is known about how individual agents in mixed exposures may interact to increase or otherwise modify the likelihood of adverse health effects.

Research has shown that physiologic interactions from some mixed exposures can lead to an increase in the severity of the harmful effect. For example, exposure to noise and the solvent toluene results in a two- to three- times-higher risk of hearing loss than exposure to either component alone (see figure). The problem is multifaceted, given the large number of different types of mixed exposures that occur every day in a variety of workplaces.

Examples of mixtures with potentially harmful interactions include solvent and pesticide mixtures, diesel and other fuels, indoor air, asphalt, irritants on dust, and hazardous waste. Examples of simultaneous mixed exposures include combinations such as welding fumes and nitrogen oxide compounds, radiation or noise and solvents, and asbestos and cigarette smoke. In most of these cases, too little is known about the combined exposure-response relationships to recommend new exposure limits or to plan effective exposure controls or interventions.

Research Opportunities

Research on mixed exposures can proceed in several directions and would benefit from interdisciplinary teams of investigators. To evaluate possible synergistic effects, laboratory studies of physiologic interactions at the target organs are needed, as are improved animal models for extrapolation to humans. Advances in molecular biology may permit new laboratory approaches to determine which agents within a mixture are hazardous and to evaluate substitutes. Improved field methods are needed to



characterize simultaneous exposures of workers. The combined tools of molecular biology and epidemiology can be used to assess worker exposures to individual agents as well as to identify biologic changes or health effects that may result from exposures. Statistical data analysis methods that have been applied to the mixed exposure problem (such as cluster analysis, pattern recognition, regression trees, and other multivariate methods) need to be improved. Such research strategies will lead to greater understanding of synergistic interactions, better controls for mixed exposures, and appropriate exposure limits for some mixed exposures.

Organization of Work

Organization of work refers to the way work processes are structured and managed. In addition to the long recognized job stress associated with aspects of work organization, studies are now identifying its contributions to other diverse health problems, including musculoskeletal disorders and cardiovascular diseases. Research is needed to better understand how work organization is being influenced by the changing economy and workplace and what the potential effects are on worker safety and health. Research opportunities include surveillance, etiologic studies of risk factors and intervention strategies to mitigate adverse work organization factors and outcomes.

Importance

The expression "organization of work" or "work organization" has come into increasing usage in the field of occupational health, but it lacks precise definition. In general, work organization refers to the way work processes are structured and managed, and it deals with subjects such as the following: the scheduling of work (such as work-rest schedules, hours of work and shift work), job design (such as complexity of tasks, skill and effort required, and degree of worker control), interpersonal aspects of work (such as relationships with supervisors and coworkers), career concerns (such as job security and growth opportunities), management style (such as participatory management practices and teamwork), and organizational characteristics (such as climate, culture, and communications).

Many of these elements are sometimes referred to as "psychosocial factors" and have long been recognized as risk factors for job stress and psychological strain. But recent studies suggest that work organization may have a broad influence on worker safety and health and may contribute to occupational injury, work-related musculoskeletal disorders, cardiovascular disease, and other occupational health concerns such as indoor air quality complaints. For example, work organization factors such as monotonous work, time pressure, and limited worker control have been linked to upper-extremity musculoskeletal disorders in a number of studies. Similarly, it is widely believed that the combination of low worker control and high job demands is a risk factor for cardiovascular disease. However, the manner in which work organization factors affect these types of health problems is not well understood.

Work organization is influenced by factors such as economic conditions, technologic change, demographic trends, and changing corporate and employment practices. Information and service industries are replacing manufacturing jobs. The workforce is aging rapidly and becoming increasingly diverse. Re-engineering and downsizing continue unabated, and temporary or part-time jobs are increasingly common. These trends may adversely affect work organization and may result, for example, in increased work load demands, longer and more varied

work shifts, and job insecurity. However, the actual effects of these trends on the conditions of work and on the well-being of workers have received little study.

Research Opportunities

Today's rapidly changing economy, with widespread corporate and government restructuring, has thrown the once low-profile issues of work organization into high relief. If a factory or service operates around the clock to maximize productivity or attend to customer needs, what strategies will both assure productivity and prevent the adverse effects of night or extended shifts on injury rates or sleep disorders? What management approaches translate employer and employee concern about safety into actions that effectively prevent injury? What impact does the holding of multiple jobs (an increasingly common effect of low pay) have on workers' health and health care utilization? How does it affect an industry's injury or illness rates? What biologic measures would indicate whether an employee's increased work load or reduced control over work is increasing his or her risk of cardiovascular disease? How do 12-hour work shifts or "de-skilling" of certain jobs affect rates of sick leave, employee turnover, workers' compensation, and health care costs? How can such costs be avoided? The limited research invested in work organization has outlined a whole host of issues. Scientists need to establish ways of identifying industries, occupations, populations, and specific worksites needing evaluation and assistance. Definitive research is needed to clarify the relationship between psychosocial stressors associated with work organization and safety and health concerns ranging from substance abuse to musculoskeletal disorders. Also, a wide range of research is needed to identify successful interventions and models of work organization that promote safety and health and that meet current and future demands for increasing productivity.

Special Populations at Risk

Occupational hazards are known to be distributed differentially, and workers with specific biologic, social, and/or economic characteristics are more likely to have increased risks of work-related diseases and injuries. The relative proportions of these special populations (such as older workers, women, and minorities) within the U.S. workforce are increasing, and it is important to focus on these populations, particularly as they have been largely underserved in the past. Research is needed to define the nature and magnitude of risks experienced and to develop appropriate intervention and communication strategies.

Importance

Certain populations of workers are more likely to experience increased risks of diseases and injuries in the workplace as a result of biologic, social, and/or economic characteristics such as age, race, genetic susceptibility, disability, language, literacy, culture, and low income. Specific directed efforts are needed to prevent work-related diseases and injuries in these special populations. As the U.S. workforce grows by the year 2005 to approximately 147 million (a 12% increase over the number of workers in 1994), it will become markedly older and more racially diverse. The number of workers aged 65 and older was 3.7 million in 1995. The number of workers aged 55 and older is expected to grow twice as fast as the total workforce for the next several years as the "baby boomer" population matures and life expectancy increases. Partly because of the passage of the Americans with Disabilities Act of 1990 (ADA), barriers are also being removed to allow people with disabilities to participate more fully in the workplace. In addition, by the year 2005, minorities will represent 28% of the American workforce compared with 24% in 1994. This figure will include the increase of the fastest growing sector, Hispanic workers, who will constitute 11.1% of the workforce in 2005 compared with 9.1% in 1994.

Older workers are at greatly increased risk of work-related injury fatalities. In 1993, the rate of fatal traumatic injuries was 15 per 100,000 workers aged 65 years and older compared to 5 per 100,000 workers aged 25 to 34. Older workers may also be more susceptible to chronic diseases. There were approximately 2.6 million working adolescents (aged 16 to 17) in the United States in 1995. Younger workers are at increased risk of work-related injury because they often have limited job knowledge, training, and skills. Private industry reported that in 1993, more than 95,000 illnesses and injuries that involved days away from work occurred in workers aged 16 to 19. An estimated 64,000 adolescents required treatment for work-related injuries in emergency rooms during 1992. The most serious of these injuries were burns occurring in the food service industry and sprains and strains due to overexertion. In addition, the number of children (aged less

than 16) who are working and the illnesses and injuries they experience are not well documented. The best documented examples are childhood traumatic injuries on the farm. However, less well–documented reports exist of injuries to children illegally employed in various manufacturing settings. Physical and psychosocial factors may also place young workers at increased risk of injury in the workplace, and children and adolescents, along with older workers, may have increased or different susceptibilities to chemical exposures.

Although the nature and magnitude of risks experienced by people of color have not been thoroughly studied, data on occupational injury deaths indicate that blacks have the highest rates per 100,000 workers compared with those of whites and workers of other races. Data on mortality (not necessarily occupationally induced) have consistently demonstrated higher cancer and overall mortality rates for blacks than for whites. In the limited number of occupational studies that can assess cancer risks in both white and black men, the latter were twice as likely to demonstrate significant excesses of cancer. Environmental justice issues are also important, as initial research indicates that workers of color or low income may disproportionately work in unsafe and unhealthful conditions without appropriate notification of risks, training, or protection.

Little is known about a number of other factors that may increase the risk for occupational disease and injury, including the role of gender, genetic susceptibility, culture, and literacy. Many high-risk populations have been underserved by the occupational safety and health research community, with the result that important unanswered questions remain about the profile of hazards they face, the incidence of work-related injuries and illnesses, the mechanisms of these injuries and illnesses, and the optimal approach to prevention.

Research Opportunities

Scientists are only beginning to recognize the full range of biologic and social factors that may influence a worker's risk for developing disease or becoming injured in the workplace. Research is needed to determine where special populations at risk are working, the conditions of work, and the extent and severity of disease and injury among these workers. This information is especially elusive for migrant and seasonal workers, day laborers, part-time workers (including working youth), and self-employed contract and temporary workers. The assessment of the impact of susceptibilities on the development of effective interventions will be challenging. Little is known, for example, about the physical resilience and capacity of older workers or the effectiveness of traditional workplace safeguards for workers with disabilities. The development of reliable exposure histories is difficult for transient workers or workers living and working in contaminated environments. Research is needed on the interaction between psychosocial stressors (such as low pay and racial conflict) and other work factors such as musculoskeletal stressors or safety practices. The development of intervention prevention strategies will undoubtedly require innovative approaches. How is a hearing-impaired construction worker alerted to safety hazards? What training and communication approaches and other prevention strategies are most effective for workers for whom English is not a native language or who have limited reading ability, or for workers of different races, ages, cultures, and socioeconomic circumstances? How should rehabilitation strategies be tailored for different populations? Research is also required for intervention approaches that address issues of genetic susceptibility; such research should consider ethical issues such as the societal, economic, and health consequences of screening and potentially excluding susceptible populations from employment.

NORA PRIORITY RESEARCH AREAS

Research Tools and Approaches

- Cancer Research Methods
- Control Technology and Personal Protective Equipment
- Exposure Assessment Methods
- Health Services Research
- Intervention Effectiveness Research
- Risk Assessment Methods
- Social and Economic Consequences of Workplace Illness and Injury
- Surveillance Research Methods

Because workplace safety and health issues are broad in scope and diversity, research aimed at improving worker safety and health demands the application of numerous scientific disciplines. Traditional research approaches have identified much of what is now known about occupational safety and health, but much has gone undetected because of deficiencies in the tools available to date. Further advances in identifying current hazards, controlling recognized hazards, and identifying and preventing the adverse consequences of emerging hazards will rely on the development and application of innovative research methods and approaches. This section of the Agenda addresses and identifies eight priority areas that can be categorized as research tools and approaches needed for meeting the challenges facing the occupational safety and health community.

Cancer Research Methods

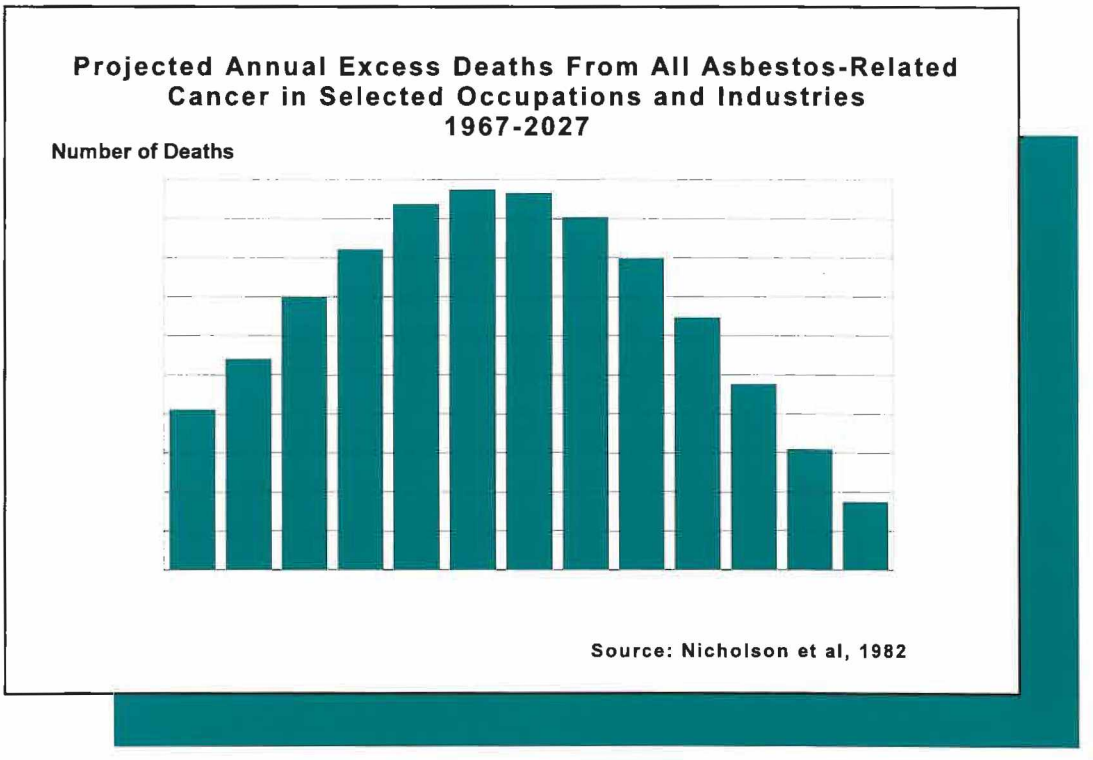
Of the approximately 500,000 deaths from cancer in the United States each year, 4% (20,000) are thought to be related to exposures in the workplace. Although exposures to a number of recognized occupational carcinogens have been reduced or eliminated, many workers continue to be exposed to suspected cancer-causing hazards. Prevention of occupational cancer requires the ability to identify exposures that have carcinogenic potential and eliminate or sharply reduce their presence in the workplace. Epidemiologic research must provide the identification of selected new cohorts to enable correlation of specific exposures with human carcinogenicity. New biological markers of exposures and/or cancer-related outcomes need to be identified and integrated into epidemiologic studies. Because epidemiologic data regarding the carcinogenicity of many exposures are not currently available, research methods to evaluate and improve on the predictive value of animal and in vitro *systems must be aggressively pursued.*

Importance

Of the approximately 500,000 deaths from cancer in the United States each year, 4% (20,000) are thought to be related to exposures in the workplace. Although exposures to a number of well-recognized occupational carcinogens have been reduced or eliminated, many workers continue to be exposed to known or suspected cancer-causing agents. For example, several million U.S. workers are potentially exposed to substances classified by the International Agency for Research on Cancer (IARC) as human carcinogens. It is estimated that about 10% of lung cancers, 21% to 27% of bladder cancers, and nearly 100% of mesotheliomas in the general U.S. population are related to occupational exposure to recognized carcinogens. For workers with documented exposure to specific carcinogens, the percentage of site-specific cancer attributed to the exposure may be even higher, approaching 100% for vinyl chloride in the development of angiosarcoma of the liver, and 50% for asbestos in the development of lung cancer. Although there have been great advances in the treatment of some cancers, methods to prevent cancer are limited. Because of the lack of methods for ready identification of carcinogens among the approximately 4 million chemical mixtures presently in commercial use, and because of limited models for extrapolation of results from animals to humans, it has been necessary to rely on epidemiologic evidence of excess cancer among exposed workers. By the time such evidence is available, thousands to millions of workers may have been exposed to carcinogens. For example, it was estimated in 1982 that before the late 1970s (when convincing epidemiologic evidence of the carcinogenicity of asbestos was already well established), at least 27 million U.S. workers had been exposed to asbestos, resulting in 8,000 asbestos-related cancer deaths per year until well into the next century. Unfortunately, for most chemicals in use today, the epidemiologic evidence that might trigger voluntary or mandatory actions to reduce exposure does not exist or is sufficiently limited or disputed that workers continue to be exposed to potential carcinogens.

Research Opportunities

Progress in occupational cancer research has had an enormous impact not only on the protection of workers, but also on the entire field of environmental health (because best estimates of community risks are derived from data in occupational studies). However, this history is built on alarming tolls of dead workers. Today, the revolution in molecular biology has fortunately opened powerful new research approaches that may lead to information that could be used to take protective measures before workers suffer the consequences of these exposures. Advances in understanding the mechanisms of cancer causation are beginning to improve the ability of scientists to use laboratory research to evaluate the carcinogenic potential of a substance and to describe the hazard to humans with ever-increasing accuracy. More research is needed on comparative mechanisms of toxicity and on the development of rapid and inexpensive test systems to complement or modify traditional animal toxicity tests. Validated biomarkers of exposure and effect should be developed and used as part of the effort to determine the human burden of chemicals and their possible health consequences. Tools of molecular biology should be used to understand interactions of chemicals with critical target genes and to develop more accurate and less expensive methods to estimate worker exposure to chemicals. The characterization of the human genome will lead to a catalogue of human susceptibility genes, raising questions about how genetic differences influence individual response to agents encountered in the workplace.



Control Technology and Personal Protective Equipment

Recognized safety and health hazards can be managed by a variety of engineering, administrative, and worker protection techniques. These may include design changes to equipment, modifications to training efforts, or the use of personal protective equipment. Basic and applied research is needed to identify, evaluate, and develop control strategies for specific hazards and to assure their practicality and usability in workplaces.

Importance

All occupational safety and health research should have as its ultimate goal the reduction of worker exposures to hazards. Exposures to occupational hazards can be managed by the application of engineering controls, administrative policies, and personal protective equipment. Engineering controls include substitution of a safe material for a hazardous one, design changes to equipment, or modification of work methods to eliminate or reduce hazards. Changes in work practices and management policies and training programs are examples of administrative controls. In some cases where it is not otherwise possible to maintain a healthy work environment, personal protective equipment (PPE) such as respirators and protective clothing can be used to isolate workers from the hazard.

Although a great deal of research has been conducted to develop ways to control workplace hazards, the need for research in control technology and protective equipment research continues to be crucial. Limited information exists to predict the effectiveness of existing or proposed engineering controls. For many hazards and hazardous industries, control measures have not been developed because of lack of awareness of the hazard or insufficient technical and financial resources. Also, as new workplace hazards are identified, new control measures must be developed. In some cases, control measures have been proposed, but they have not been evaluated, or may not be commercially available. Often, existing controls may reduce or eliminate exposures to safety and health hazards when they are properly used; but they may not be used because of a lack of acceptance, or they may be perceived to be cost-prohibitive. In many cases, only a few parts of a job contribute most of the actual exposure and identification of the specific hazardous points would focus efforts to control exposures. In jobs where personal protective equipment is the only available control option, it must be not only be effective, but also practical for use in the workplace. It must not introduce a hazard greater than the one it is intended to prevent, a concern that has been raised by health care workers who have developed significant allergic responses to latex as a result of wearing latex gloves to prevent bloodborne infectious exposures. Personal protective equipment must also be designed

Personal protective equipment such as respirators, gloves, and goggles is important during pesticide application activities.

and made available to properly fit and protect the growing numbers of female and minority workers.

Research Opportunities

Research in control technology and personal protective equipment can have widespread, direct impact on the safety and health of workers. A new low-cost approach to exhausting airborne lead fumes is reducing hazardous exposures in radiator repair shops across the country. The substitution of plastics for glass in bottled goods is helping prevent low back disorders among workers who are handling and transporting beverages. Respirators with improved filters are increasing the safety of workers in workplaces ranging from health care facilities to metal fabrication shops. Rapid advances in technology are dramatically increasing opportunities for improved worker protection. Robotics, computers, and satellite navigational systems might allow dangerous tasks involved in pesticide application and hazardous waste remediation to be carried out without exposure to workers. They might also allow for the elimination of many physically injurious tasks. Microsensing devices might assess workers' exposure to environmental contaminants, notify workers before chemicals break through protective clothing, and identify failures in containment systems for hazardous materials. New materials in clothing would improve the protection of fire fighters from burns, explosions, and hazardous chemicals. Opportunities abound for improving worker safety and health through new efforts in this underinvested field of occupational research.

Exposure Assessment Methods

Exposure assessment is a multidisciplinary field central to deciding whether and how to use resources for reducing workplace exposures, and to defining exposure-response relationships in epidemiologic studies. Rapid, inexpensive measurement tools and improved data analysis methods are needed for the collection of adequate exposure data and for effective intervention. These advancements will lead to (1) better identification of at-risk workers, (2) better identification of the most cost-effective control and intervention strategies, (3) better understanding of exposure-response relationships, and (4) improved baseline data for standard setting and risk assessment.

Importance

Exposure assessment is a rapidly evolving, multidisciplinary research activity. Its purpose is to provide environmental data with which to decide whether and how to reduce workplace exposures, and to define exposure-response relationships in epidemiologic studies. Imprecise estimation of exposure is often cited as the major limitation in epidemiologic research, hampering the ability to detect environmental causes of disease. Improved exposure assessments will lead to more precise characterization of exposure-response relationships for chemical, physical, and biological agents, and to more appropriate exposure limits for hazardous agents. Employers often have insufficient exposure data to guide selection of exposure controls or to justify the necessary financial investments. Moreover, accurate exposure data are equally important in evaluating the effectiveness of those controls after their implementation. The lack of cost-effective methods and measurement tools that can be used by nonspecialists has been a major obstacle to collecting adequate exposure data and instituting effective controls.

In the past 15 to 20 years, the scope of occupational exposure assessment has broadened considerably as a result of changes in technology and increased attention to nonindustrial work settings. At least three major gaps in current methods will drive development of exposure assessment methods in the next decade: (1) the lack of sufficiently precise exposure assessments to support accurate epidemiologic studies in the complex environments of today's workplaces, (2) the lack of practical measurement techniques that can be applied at reasonable cost in many workplaces where hazards may exist, and (3) the lack of validated methods for measuring relevant exposure and total dose data directly from biological samples obtained by relatively noninvasive techniques.

Research Opportunities

Researchers from a variety of fields (including industrial hygiene, chemistry, physics, molecular biology, epidemiology, and medicine) will pursue a variety of research paths to develop exposure assessment

methods that are more precise, low-cost and easy to use, and more biologically based. For example, computer models may be developed to extrapolate information from historical data of limited exposure measurements to apply to large study populations, and to incorporate short-duration but high-intensity exposures such as leaks or spills into the models. Easy-to-use, direct-reading instruments and test kits will be developed to measure exposures rapidly and inexpensively in a variety of workplaces for routine monitoring, evaluating the success of control technologies, and providing data for research studies. Technological advances will permit measurement of low concentration of chemicals and biomarkers in biological specimens such as blood, urine, saliva and sweat, and research will link these concentrations to internal dose at the target organs. Laboratory analytical methods will be designed for inexpensively measuring numerous chemicals in a single sample. Research into improved measurement and interpretation of biomarkers will allow a more selective evaluation of the effects of structurally similar chemicals. Finally, research into exposure survey design and exposure data analysis methods will lead to more meaningful data for health risk assessments.

Such research will result in more clearly defined exposure assessment methods and strategies that can be recommended for wider adoption. More consistent use of well-designed exposure assessment methods will promote comparability among exposure data sets and enhance the utility of the data for a broad range of prevention activities. During the next 10 years, improved exposure assessment methods will lead to better identification of at-risk workers, better identification of the most cost-effective control and intervention strategies, better understanding of exposure-response relationships, and improved baseline data for standard setting and risk assessment, all of which are central to improving occupational safety and health.

Health Services Research

Health services research includes assessment of the way in which health care is organized and paid for and the effectiveness of the treatment and prevention of diseases and injuries. This research, which provides much of the data necessary for the formulation of health policy, is largely undeveloped when it comes to occupational safety and health. Diverse approaches are urgently needed to address important concerns about access to care for work-related problems, quality of care (including clinical and preventive practice guidelines), health professional needs and availability, and cost and service utilization patterns.

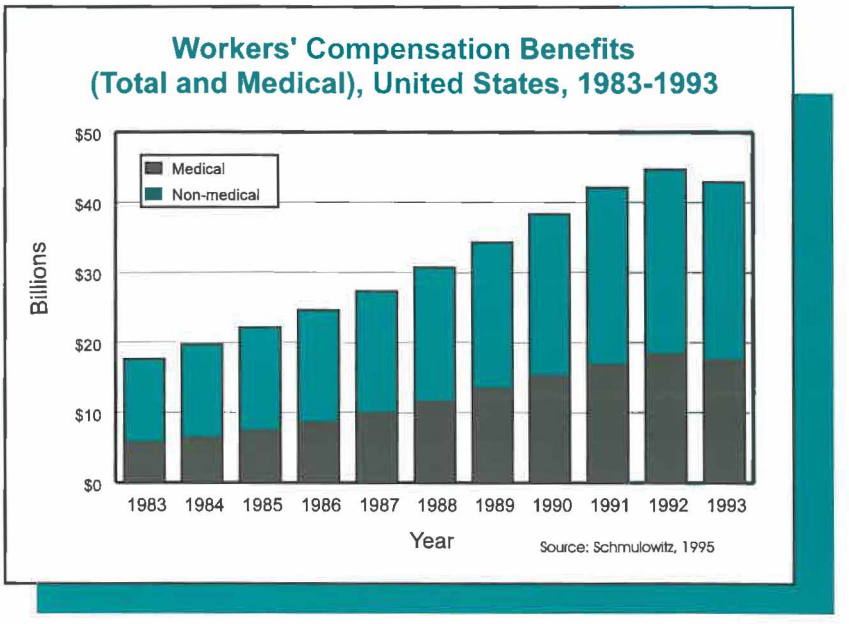
Importance

According to the Bureau of Labor Statistics, a total of 6.8 million non-fatal injuries and illnesses were reported in private industry workplaces during 1994, a rate of 8.4 cases for every 100 full-time workers. Nearly 3 million of the 6.8 million cases resulted in lost workdays or in restricted work activity. Since 1980, rates have varied within a range of 7.5 to 9.0 cases per 100 workers. It should be noted that these data are criticized for greatly underestimating occupational illnesses.

A portion of the costs of work-related injury and illness are captured in the workers' compensation system. The overall costs, including payments for health care, are huge and have grown tremendously in recent decades. Between 1983 and 1993, the proportion of total workers' compensation costs obligated for medical and hospitalization payments increased from 32% to 41%. In 1994, work-related injuries alone were estimated to cost $121 billion in medical expenses and losses in productivity and wages, a figure that excludes the cost of work-related diseases.

Given the magnitude of the problem, relatively little is known about delivering medical treatment for work-related conditions. For both emergency and nonemergency services, there is only limited information about the extent, quality, outcome, and costs of services provided by employer-based employee health services, private physicians, independent occupational health clinics, and hospital emergency departments.

Far too little is known about the experience of injured workers in the workers' compensation system. In an increasing number of States, employers are permitted to select the injured worker's medical care provider; but there have been few studies comparing the cost and quality of medical care and the extent of disability benefits provided to injured workers in employer-choice States versus employee-choice States. Although managed care is being used increasingly to provide workers' compensation medical services, it is not known how these services compare with those provided under the fee-for-service arrangements that traditionally have been employed in workers' compensation. The well-documented national shortage of occupational medicine physicians has unmeasured health and economic consequences. The increased use of managed care systems (particularly those without in-



house occupational health expertise) may further aggravate the limited accessibility to health professionals trained to recognize, treat, and prevent work-related disease.

Long-standing public policy debates have emerged about the advantages and disadvantages of integrating the medical component of workers' compensation into private health insurance; unfortunately there is little research to evaluate this issue effectively. Likewise, there are few empirical data to evaluate whether the financial incentives built into the workers' compensation system are successful in preventing injury and illness.

Research Opportunities

Occupational safety and health will benefit greatly from the concerted application of many of the scientific methods developed by health service researchers. For example, there are wide gaps in the published literature on the social and economic costs of occupational injury and illness, as well as the costs and benefits of regulation and other approaches to hazard prevention. Many treatments widely used in occupational medicine have not been evaluated for efficacy and cost, nor is there information on their frequency, costs, and impact (local, regional, or national). What is the most effective rehabilitation plan to restore the physical capacity of a worker with a low back disorder or carpal tunnel syndrome? What psychologic interventions are most effective in preventing post-traumatic stress syndromes for victims and witnesses of severe or fatal traumatic work injuries or violence at the worksite? How do the costs and benefits of alternative medical procedures for work injuries and illnesses compare, taking into account long-term effects on productivity, health care utilization, and employment? How fully can a worker's capacity be restored and what limitations should be placed on future activities to prevent reinjury? What supply of specialists is needed in occupational medicine, nursing, industrial hygiene, safety, and engineering? What extent of training for primary care providers would most cost-effectively promote prevention and improve medical care? The restructuring of the health care industry offers critical new opportunities for health services research. Increasing data collection and analysis by health care insurance and provider organizations should dramatically improve the capacity of researchers to evaluate health care quality and cost issues in occupational safety and health.

Intervention Effectiveness Research

The goal of occupational safety and health interventions is to prevent disease and injury through combinations of techniques such as control technologies, exposure guidelines and regulations, worker participation programs, and training. The goal of intervention research is to determine the efficacy and effectiveness of these techniques and programs. New intervention research will assure better use of limited resources in workplace applications of prevention and control strategies. This research uses multidisciplinary approaches and focused field studies. Intervention model development, worker participation, cost effectiveness, hazard identification, and control evaluation are some of the key elements of this research.

Importance

The goal of intervention research is to develop practical strategies and techniques that effectively reduce or prevent workplace injuries and illnesses. Workplace safety and health interventions include but are not limited to developing and implementing specific engineering control technologies, process and work organization changes, information dissemination and health communication practices, worker/management participatory safety and health programs, safety and health training, selective use of personal protective equipment, and inspection and enforcement of protective exposure limits.

Intervention research is the testing and evaluation of interventions, programs, and policies. To date, a variety of approaches to intervention has been developed to protect worker safety and health across a broad spectrum of industries. Although there have been measurable improvements in worker safety and health, only a few interventions, alone or in combination, have been systematically evaluated. Consequently, many interventions are undertaken based on faith and expert judgment without convincing evidence that these approaches are effective. However, there are excellent examples of interventions that have been evaluated and shown to be effective. Successful interventions to reduce musculoskeletal disorders of the upper extremities include worker participation programs to identify problems, coupled with the development and implementation of process changes or engineering controls. Interventions to reduce toxic solvent exposure in dry cleaning establishments include retrofitting (adding parts or changing parts of) cleaning equipment, substitution of chemicals, and development of safety and health educational materials to reduce worker exposures. Hearing loss interventions have included regulations requiring auditory testing and noise control programs at the worksite. These programs can be effective when testing is done with care, when workers are educated about results and when the program is carefully maintained, updated, and implemented by a committed team of workers and management.

Although many intervention strategies have been applied to industrial settings, knowledge about what works best is limited. Many questions remain unanswered. What are the best techniques to evaluate the effectiveness of implemented control technologies? What are the barriers to the acceptance of new control technologies and approaches to eliminating or altering these barriers? What factors motivate

Nursery worker must constantly bend to lift pots of bushes.

This intervention, which was developed by a worker, helps to lift plants from the ground with reduced bending.

the voluntary adoption of protective work practices? What roles do researchers, consultants, trainers, worker organizations, and industry trade groups play as partners in intervention efforts? What organizational and economic factors predict success in prevention programs, and how can programs be tailored to take account of these factors? How can intervention efforts target areas of greatest need? Why do managers and workers in some organizations implement occupational safety and health programs when others do not?

Intervention research is a new and multidisciplinary field that requires skills and disciplines not traditionally applied to occupational safety and health research. Behavioral scientists, economists, organizational theorists, and engineers, among others, should be included in interdisciplinary efforts to identify, develop, and evaluate practical prevention and control strategies. Employers, public decision-makers, and workplace safety and health teams need this information to assure better use of limited resources by making informed decisions about which prevention strategies work best.

Research Opportunities

There has been little research evaluating the impact of interventions on safety and health outcomes. The Office of Technology Assessment evaluated selected OSHA standards. Several States have assessed the impact on injury rates of State requirements that companies establish safety plans and safety and health committees, and OSHA is evaluating new inspection programs such as Maine 200. Intervention research includes the development, implementation, and evaluation of control technologies and other methods to reduce worker exposures. The ultimate questions to be answered are what works best at enhancing worker safety and health and why it does or does not work. The lack of answers hampers the introduction and maintenance of public and private-sector occupational safety and health programs; these programs face increasing demands that they document cost-effectiveness and impacts on health. Corporate safety and health programs, regulatory requirements and voluntary consensus standards, workers' compensation policies and loss-control programs, engineering controls, and educational campaigns are among the types of interventions that need to be developed, implemented, and evaluated. Data collected from such research will direct effective strategies to improve the safety and health of workers.

Risk Assessment Methods

Risk assessment is essential for setting occupational safety and health priorities and for demonstrating health impairment when promulgating occupational standards. Risk assessment has been most often applied in assessing the risk of carcinogens, often with animal bioassay data. However, evaluation of these procedures has been limited, and questions abound as to whether the resulting risk estimates are reasonable. Risk assessment for noncarcinogens, particularly quantitative approaches, is even less well developed. Improved methods are needed for using animal bioassay data and human health effects data to generate risk estimates for cancer and noncancer effects and injury.

Importance

Risk assessment is a process in which hazard, exposure, and dose-response information are evaluated. These evaluations determine whether an exposed population is at greater-than-expected risk of disease (cancer or noncancer endpoints) or injury. Once this is established, the magnitude and nature of the increased risk can be explored further, using either qualitative or quantitative approaches. Qualitative risk assessments are generally descriptive and indicate that disease or injury is likely or unlikely under specified conditions of exposure. On the other hand, quantitative risk assessments provide a numerical estimation of risk based on mathematical modeling. For example, under given specific exposure conditions, it is expected that one person per 1,000 would develop a disease or injury.

Quantitative risk assessments require (1) data providing as much detail as possible on exposures relevant to the adverse health outcomes of interest, and (2) development of a mathematical model describing that exposure-response relationship. Risk assessments based on experimental animal and molecular biologic data provide detailed information on the exposure-response relationships. However, there is often substantial concern about the validity of using risk assessments based on susceptible animal species tested at high constant doses to estimate the risks to workers who may have much lower and more variable workplace exposures. Risk assessments based on epidemiologic, population-based studies may have real-world relevance to workers, but they generally suffer from a number of limitations. These include potential confounding by risk factors for exposures other than the exposure of interest, variability in workplace exposures for any particular substance or mixture of exposures, individual variability in health response, and detection of statistically significant changes in adverse health outcomes. The integration of mechanistic data, human data, toxicity testing data, and biomathematics can be useful for developing methods that strengthen the

scientific foundation on which risk assessments are based.

The risk assessment process has become increasingly formal and sophisticated over the past decade. There are many who support a greatly expanded and even more formal role for risk assessment in establishing national priorities and providing a justification for regulatory actions by Federal agencies. In occupational safety and health regulation, that process began when the U.S. Supreme Court ruled in the "benzene decision" [Industrial Union Department v. American Petroleum Institute, 448 U.S. 607 (1980)] that the Occupational Safety and Health Administration (OSHA) could not issue a standard without demonstrating a significant risk of material health impairment. The ruling allowed (but did not demand) that numerical criteria could be used to determine whether a risk is "significant." As a result of that Supreme Court ruling, risk assessment became standard practice in OSHA rulemaking for health standards, and quantitative risk assessments are preferred whenever data, modeling techniques, and biological understanding are adequate to support their development.

Research Opportunities

Research to improve risk assessment methods is needed from a wide range of scientific disciplines to provide more reliable methods for estimating the risk of adverse effects related to work. Substantial controversy surrounds currently available cancer risk assessment models, and models for noncancer effects are even less well developed. Lagging even more are methods for assessment of safety risks. Innovative and practical new approaches to modeling are needed. In addition, research needs to be directed to the following areas: designing epidemiologic and toxicologic studies that provide detailed and accurate exposure-response relationship data for specific hazards; generating more data on which to base models that include intake distribution, metabolism, and elimination; developing biologic markers for exposures and effects; and utilizing existing occupational safety and health data to ensure that human observations complement and validate risk estimates derived from animal data. Research efforts should also evaluate how risk assessment estimates are used in risk management, communicated to the public, and perceived by workers and employers.

Social and Economic Consequences of Workplace Illness and Injury

The 1993 workers' compensation cost of $57 billion reflects only a small portion of the social and economic consequences of occupational injuries and illnesses. Understanding the total human and economic impacts of occupational injuries and illnesses is crucial to setting priorities and shaping other components of the occupational safety and health research agenda. Social scientists have developed tools to describe and measure both the human and economic impacts of workplace injuries and illnesses and to evaluate the quality and effectiveness of health care. Research is needed to examine the impact of occupational injuries and illnesses on workers, their families, employers, communities, and the nation; describe and measure the effects of medical care on these costs; and target and evaluate the economic benefit of prevention efforts.

Importance

Each year, millions of occupational illnesses and injuries occur in the United States. Individuals affected by these health problems often become unable to work, or their ability to work is limited by physical impairment. The costs of work-related illness and disability (both in human and economic terms) justify devoting substantial resources to the control of workplace hazards; yet surprisingly little attention has been paid to describing and measuring these costs. Between 1972 and 1993, employer costs for providing workers' compensation rose from $6 billion to $57 billion, an annual growth rate of 12.5%. A 1991 study found that only 60% of persons reimbursed for work injuries received workers' compensation. Thus, it appears that only a fraction of health care costs and earnings lost through work injuries and illnesses is covered by workers' compensation. In addition to lost earnings and health care costs, the U.S. economy sustains other substantial costs that are hidden (i.e., unrecognized).

In addition to the direct costs of lost earnings and health care costs related to occupational injury and disease, there are numerous indirect economic costs. Employers sustain some of these, including additional hiring and training costs, disruption of work processes by workplace mishaps, and the effects of workplace injuries or exposures on the productivity of coworkers who feel at heightened risk. Other indirect costs are borne by the injured workers and their families—for example, reduced income, depletion of savings, and loss of homes; increased expenditures for professional counseling and purchased caregiver services in the home; home modifications and equipment related to disability; and deferral or loss of education for family members. Other costs may fall on the

community in the form of increased use of social service programs.

There are also substantial noneconomic consequences of workplace injuries and illnesses on quality of life. Physical and psychological functioning in everyday activities may be affected, self-esteem and self-confidence may be reduced, and an individual's role in the family and community may change. Even less research has been focused on these nonmonetary costs. Studies of unemployed workers and their families and of people with chronic illnesses and disabling injuries show that income and employment losses, illness, and physical impairment can have profound human consequences on both workers and their families. Better measures of both economic impacts (direct and indirect) and noneconomic impacts will help improve targeting of resources for research, prevention, and compensation.

The consequences of work-related injury and illness on the quality and length of life are mediated by health care; therefore, medical management and treatment of occupational conditions should include consideration of the impact on the worker's post-injury wages, overall quality of life, and ability to use valued skills and knowledge. Although the amount of health care provided to workers with occupational injury or illness is substantial, relatively little is known about whether and to what extent this care succeeds in improving functioning and quality of life.

Research Opportunities

What happens to the spouse and children of a farmer, migrant worker, or construction laborer who is seriously disabled or killed on the job? What are the health care costs to Medicare for retirees with work-related cancers and lung diseases? How much do social and rehabilitative services for treatment of work-related disabilities cost State and local governments? What portions of State taxes and private health insurance premiums are providing welfare or health care to injured and disabled workers who are not being reimbursed by workers' compensation? Until recently, there has been virtually no research on the economic or social impact of work injuries and illnesses in the United States. Furthermore, there has been little research that compares the costs (or benefits) of safety and health programs with the total economic and social costs of workplace injuries or fatalities. Industry and government often lack the analytic tools and economic information to assess the effect of safety and health investments on the bottom line. Furthermore, State and national policy-makers may rely on inadequate information to target the most damaging and costly occupational safety and health problems.

Developing and conducting research to fill this tremendous information gap will require the collaboration of industry, labor, management, government, academia and others. Research will provide comprehensive national estimates for the economic burden of all occupational injuries and illnesses and specific estimates for the burden on targeted groups (e.g., specific industries, income groups, minorities, and teenage workers). Research will also expand understanding of the impact of work injuries and diseases beyond workers themselves to include their families, particularly the welfare of their children. Research will quantify cost-shifting between State workers' compensation systems and other public and private health insurance systems, and it will assess the effectiveness of the implementation of NORA. Finally, research will provide a reliable new basis for targeting and evaluating the effectiveness of investments in prevention.

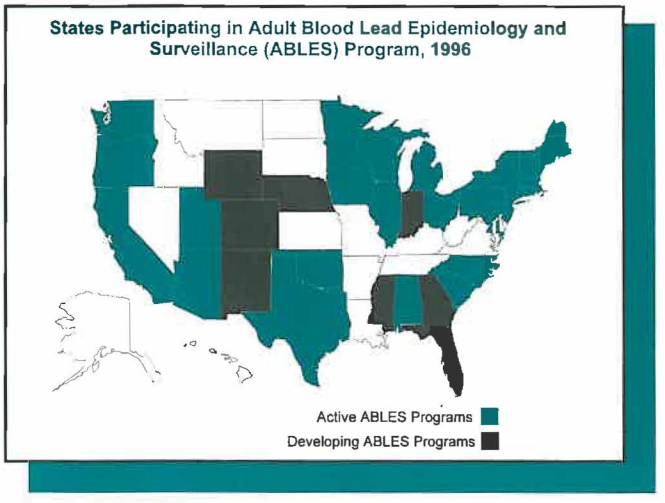
Surveillance Research Methods

Surveillance systems describe where occupational injuries or illnesses are occurring, how frequent they are, whether they are increasing or decreasing, and whether our prevention efforts have been effective. The public health community relies on surveillance information to set research and prevention priorities, but critical gaps in current systems limit their usefulness. These systems need to be updated and expanded, and new systems and methodologies need to be developed. Data from these systems will then effectively contribute to the recognition and elimination of work-related morbidity and mortality.

Importance

The prevention of occupational disease and injury depends on the implementation of a variety of activities including testing chemicals and tools before they are introduced into commerce, using engineering controls and personal protective equipment to limit exposures, and providing early diagnosis and effective therapy of injured or ill workers to minimize disability when preventive measures have failed. Surveillance is the key to this system. Occupational safety and health surveillance systems collect, analyze, and disseminate relevant information about hazards found in the workplace as well as about work-related diseases and injuries. Surveillance systems identify where the problems are and are not, how frequent the problems are, whether they are increasing or decreasing, and whether prevention efforts have been effective. The public health and occupational health communities rely on surveillance information to set priorities for prevention. Although there has been substantial progress in the last decade in development and field testing of new data collection systems for occupational disease and injury surveillance, much remains to be done. Methods and systems for hazard surveillance are much less well developed.

A number of ongoing national and State-based disease and injury surveillance systems yield data useful for targeting occupational injury and illness prevention activities. For example, the NIOSH National Traumatic Occupational Fatalities Surveillance System (NTOF) identifies occupational injury fatalities based on death certificates and allows description of causes of death and comparison of rates among industries and occupations as well as trends over time. The NIOSH Fatality Assessment and Control Evaluation Program (FACE) provides in-depth field investigations of individual occupational fatalities and is effective in identifying and disseminating prevention information. The quilt work of Federal and State programs for injury and disease surveillance is further extended by the National Health Interview Survey and the National Health and Nutrition Examination Survey of the National Center for Health Statistics, the Annual Survey of Occupational Injuries and Illnesses of the Bureau of Labor Statistics, the National Electronic Injury Surveillance System of the Consumer Product Safety Commission, and many other effective and newly developed surveillance systems. The State-based Sentinel Events Notification for Occupational Risks (SENSOR) Program



utilizes a diversity of sources to collect data about illness and injury among workers, including laboratory reports, hospital discharge information, workers' compensation reports, and physician reports. However, similar hazard surveillance systems do not exist.

Hazard surveillance could serve as the basis for the primary prevention of work-related morbidity and mortality because it is directed at earlier recognition of risks than are systems that simply tabulate injuries and illnesses once they have occurred. Hazard surveillance systems could help improve worker safety and health by: (1) identifying and quantifying exposure to occupational safety and health hazards associated with chemical, physical, and biological agents, biomechanical stress, unguarded machinery, elevated work surfaces, electrical energy, and psychosocial factors or job stressors; (2) targeting high-risk groups for interventions; (3) evaluating the effect of engineering technologies on the mitigation of exposures; (4) anticipating morbidity and mortality; and (5) disseminating important safety and health information. The lack of hazard surveillance systems creates a serious gap in the type of data necessary to prevent occupational disease, injury, and death.

Research Opportunities

Despite significant progress in developing and improving surveillance systems for work-related injuries, illnesses, and hazards, much remains to be done. For example, States participating in the Adult Blood Lead Epidemiology and Surveillance (ABLES) Program collect information about adult blood lead levels. This information permits intervention efforts to be targeted at high risk groups by identifying adults exposed to toxic levels of lead, such as workers involved in bridge painting.

Assorted data sources and models of surveillance exist in the public and private sectors, but most still await implementation as comprehensive, integrated national systems. This is an important research need, because NIOSH and its partners in the private and public sectors have limited data to assess nationally or locally the impact of intervention efforts on worker safety and health. Targeting high-risk populations for interventions using existing surveillance systems is also difficult.

The current restructuring of health care delivery systems throughout the United States provides a new opportunity to address these needs. Small research investments could link comprehensive health data systems to identify, track, and target occupational safety and health problems and provide information for decisions to develop interventions or to improve related medical care. Hazard surveillance remains the most compelling, least investigated approach. It promises to identify risks and exposures at worksites and industries, and risks accompanying prototypes of new technologies before injuries and illnesses occur.

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APPENDICES

APPENDIX A

MASTER LIST OF PRIORITY RESEARCH TOPICS*

Disease and Injury

Acute and Chronic Airway Disease
Chronic Diseases (selected)
Chronic Obstructive Pulmonary Disease
Contact Dermatitis
Depression and Anxiety
Fertility and Pregnancy Abnormalities
Hearing Loss Due to Noise and Nonauditory Exposures
Low Back Disorders
Molecular Correlates of Cancer
Musculoskeletal Disorders of the Upper Extremities
Occupational Asthma
Occupational Cancer
Occupational Skin Diseases
Stress
Traumatic Injuries

Work Environment and Workforce

Aging Populations
Behavioral Risk Factors
Changing Economy and Workforce
Construction
Emerging Technologies
Ethics
Health Care Workers
Indoor Air (Environment)
Inorganic Dusts
Interactions (Chemical)
Latex Allergy
Mechanical Stressors
Mineral and Synthetic Fibers
Mixed Exposures (includes Mixtures of Chemicals and/or Other Agents)
Motor Vehicles
Noise
Nonrespiratory Routes of Exposure
Oils and Related Products

** Topics identified by any working group as a potential priority*

Organization of Work
Pesticides
PM10 (particulate matter <10μm)
Premature Disability
Psychosocial Factors
Sector-Focused Research
Service Workers
Solvents
Small Businesses
Special Populations at Risk
Violence (Assaults)

Research Tools and Approaches

Clinical Methods Research
Critical Path Methods
Database Linkage
Disease Surveillance
Engineering and Technological Solutions
Exposure Assessment Methods
Hazard Surveillance
Health Services Research
Information Dissemination
Interaction (Work/Life/Health)
Intervention Effectiveness Research
Injury Surveillance
Risk Assessment Methods
Social and Economic Consequences of Workplace Illness and Injury
Surveillance Research Methods
Training Professionals/Impact

APPENDIX B

PARTICIPATING FEDERAL AGENCIES

Because of the critical role of other Federal agencies in the successful development and implementation of NORA, approximately 30 agencies, institutes, or centers with missions that involve protecting the safety and health of U.S. citizens (including workers), have identified liaisons to work on the creation or implementation of NORA. These agencies are as follows:

Consumer Product Safety Commission

Directorate for Epidemiology and Health Sciences

Department of Defense

Naval Medical Research and Development Command

Department of Energy

Office of the Environment, Safety and Health

Office of Worker Health and Safety

Department of Health and Human Services

Agency for Health Care Policy and Research

Agency for Toxic Substances and Disease Registry

Centers for Disease Control and Prevention

Epidemiology Program Office
International Health Program Office
National Center for Chronic Disease Prevention and Health Promotion
National Center for Environmental Health
National Center for Health Statistics
National Center for HIV, Sexually Transmitted Disease, and TB Prevention
National Center for Infectious Diseases
National Center for Injury Prevention and Control

National Immunization Program
Office of Minority Health
Office of Women's Health
Public Health Practice Program Office

National Institutes of Health

Fogarty International Center
National Cancer Institute
National Heart, Lung, and Blood Institute
National Institute of Arthritis and Musculoskeletal and Skin Diseases
National Institute of Environmental Health Sciences

Department of Justice

National Institute of Justice

Department of Labor

Bureau of Labor Statistics

Mine Safety and Health Administration

Occupational Safety and Health Administration

Wage and Hour Division

Department of Transportation

Federal Aviation Administration

Environmental Protection Agency

National Exposure Research Laboratory

Office of Prevention, Pesticides, and Toxic Substances

APPENDIX C

NORA DEVELOPMENT AND SYNTHESIS

Sources of Input

In developing NORA, NIOSH sought the expertise of all segments of the occupational safety and health community as well as the opinions of the general public. NIOSH obtained the involvement and input of employers, employees, health officials and other professionals, scientists, and various types of organizations (public health, advocacy, scientific, industry, and labor) through the assistance of the following:

- Three liaison committees (corporate, worker, and broad-based stakeholder outreach committees representing the companies, unions, associations, and groups listed in Table C-1)
- Federal agencies listed in Appendix B (regulatory and nonregulatory agencies with interest in occupational safety and health)
- NIOSH staff and the NIOSH Board of Scientific Counselors
- The Mine Health Research Advisory Committee
- The National Advisory Committee on Occupational Safety and Health

Summary of the NORA Process

This section briefly describes the NORA process. Figure C-1 illustrates how individuals and groups provided input and how the final research agenda was established.

Using a modified Delphi process (iterations of expert opinion), an initial planning working group of senior scientists from inside and outside NIOSH derived a framework and developed a list of 48 potential research topics. They also identified 21 of these topics as having high priority based on seven criteria: seriousness of hazard (based on death, injury, disease, disability, and economic impact), number of workers, magnitude of risk, potential for risk reduction, expected trend in importance of research area, sufficiency of existing research, and probability that research will make a difference.

The topic list was modified and increased to approximately 80 items—with input from four additional working groups (occupational safety and health researchers from outside NIOSH, NIOSH scientists, occupational safety and health professionals, and other professionals in the field) and oral and written comments from individuals and representatives of other institutions and organizations. The working groups met in public forums to provide input and help identify priority research topics. Each group was allowed to modify the list by adding or merging topics as deemed appropriate; they were then asked to arrive at a list of 15 to 25 priority topics, again using a modified Delphi process

(iterations of individually ranked priority areas). The priority list was not necessarily a consensus of the group, but it reflected the collective knowledge and opinions of individuals in the group. Appendix A lists all items identified by the working groups as potential priority research areas. All working group meetings (except for the NIOSH scientists meeting) were announced in the Federal Register, with the public invited to participate.

Town meetings were held in Chicago, Boston, and Seattle with the intent of capturing input directly from workers, their employers, and other interested individuals. Written comments were accepted throughout the entire process until March 6, 1996; they were received by mail, by facsimile, and in person at the working group and town meetings.

Final research priorities were determined on the basis of (1) the input from the initial planning working group and four other working groups, (2) written comments received, (3) oral comments made at the public and town meetings, and (4) comments made during deliberations throughout the entire process. The prioritization of research topics was not addressed quantitatively, but all input was evaluated with respect to the frequency of endorsement and the seven aforementioned criteria used by the working groups to identify high-priority topics.

A public meeting was held in Washington, D.C., to obtain responses on the draft NORA document. All liaison and advisory committees, agency representatives, working group members, interested individuals, and the public participated. The time line of these activities is shown in Table C-2.

Table C-1. Committee Representation

Name of Committee	Members
Corporate Liaison Committee	Campbell Soup Company Corning, Incorporated Eastman Kodak Company General Motors Corporation (Chair) IBM Corporation—USA Liberty Mutual Insurance Company Mobil Corporation
Worker Liaison Committee	American Federation of State, County, and Municipal Employees Communications Workers of America International Association of Fire Fighters International Brotherhood of Teamsters Laborers' International Union of North America 9 to 5 Oil, Chemical, and Atomic Workers International Union Service Employees International Union Sin Fronteras Organizing Project Union of Needletrades, Industrial and Textile Employees United Auto Workers (Chair) United Brotherhood of Carpenters United Farm Workers of America United Food & Commercial Workers International Union United Mine Workers of America University of California-Berkley: Labor Occupational Health Program
Outreach Committee	AFL-CIO American Association of Occupational Health Nurses American College of Occupational and Environmental Medicine American Industrial Hygiene Association American Psychological Association American Public Health Association American Society of Safety Engineers Association of Occupational and Environmental Clinics Association of Schools of Public Health Association of State and Territorial Health Officials Association of University Programs in Occupational Health and Safety Building and Construction Trades Department, AFL-CIO Chemical Manufacturers Association Industrial Safety Equipment Association National Association of County and City Health Officials National Consumers League National Migrant Resource Program, Incorporated National Safety Council (Chair) Organization Resources Counselors, Incorporated Public Citizens Health Research Group Semiconductor Industry Association

Figure C-1. Development of NORA

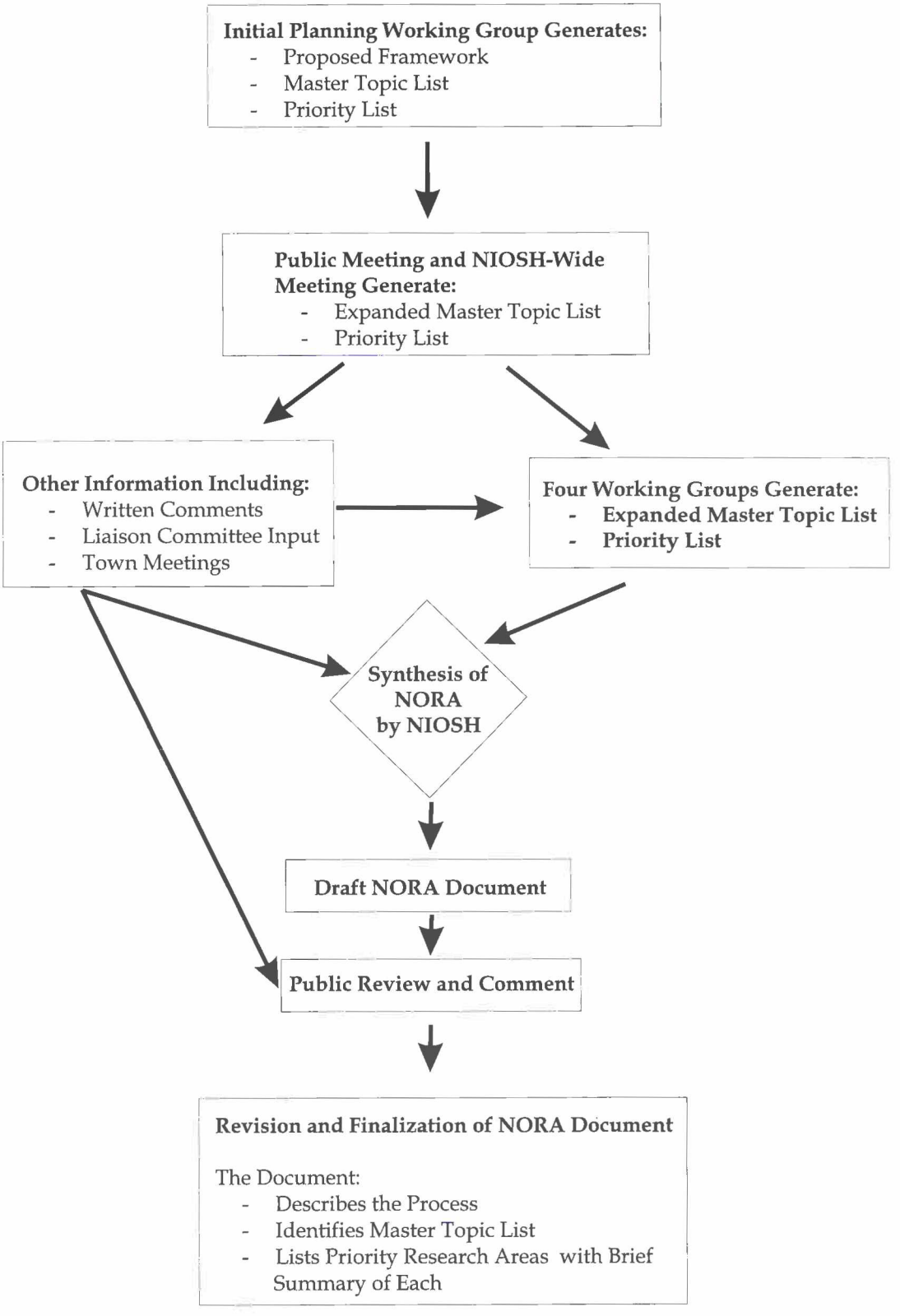

Table C-2. Time Line of NORA Activities

Date	Activity
July - November 1995	Board of Scientific Counselors Meeting National Advisory Committee on Occupational Safety and Health Meeting Partners Discussions Delphi Researchers Group Meeting
November 1995	External Stakeholders Public Meeting
December 1995	Internal Stakeholders Public Meeting Research Working Group (Public) Meeting
January 1996	NIOSH Internal Working Group Meeting Cross-Cutting Working Group (Public) Meeting Health Professionals Working Group (Public) Meeting
February 1996	Town Meetings (Chicago, Boston, Seattle) Draft document made available for review
March 1996	All Partners Meeting for input on draft agenda
April 1996	Final Agenda presented

Pam Langlitz * Donald V. Lassiter * Latex Allergy News * Richard L. Lawson * Tom Leamon * Pamela Tau Lee * David LeGrande * J.P. Leigh * Nancy Lessin * Charles Levenstein * Barry S. Levy * Kenneth Lewis * Carol Lewis * Lewis, Davidson and Hetherington, Ltd. * Henry B. Lick * Alan O. Link * Bryan Little * Benjamin * Y.H. Liu * Sue Lockwood * Gina Lombardi * Louisiana State University Medical Center * Kathryn J. Luchok * George W. Lucier * Gary W. Lundberg * Jerry Lynch * Joseph W. Lyons * Suzanne Mager * Mark C. Maher * Joseph Main * Robert J. Malooly * Management Association of Illinois * Carlos Marentes * Julie Marfell * Richard W. Marklin * Marquette University * Joan Martellotto * Massachusetts Campaign to Clean Up Hazardous Waste * Massachusetts Coalition for Occupational Safety and Health * Massachusetts Coalition on New Office Technology * Massachusetts Department of Public Health * Massachusetts General Hospital * Massachusetts Institute of Technology * Massachusetts Nurses' Association Committee on Air Quality * Martin Mathamel * Joseph W. Mathey * Jeffrey C. May * Donald May * Mayo Clinic * J. Davitt McAteer * Ronald J. McCann * Michael McCauley * Todd McCracken * Stephen McCurdy * Melissa McDiarmid * Karen McDonell * Vernon McDougall * McGill University * Patricia McGovern * Robert McKnight * Donna McLaughlin * Hugh McLoone * Theresa C. McLoud * Alan McMillan * Anne M. Meaney * Medical College of Ohio * Medical College of Wisconsin - VA Medical Center * Patrick J. Meehan * Louise Meehan * Meharry College of Medicine * James Melius * James A. Merchant * Kathleen K. Messmore * David Michaels * Microsoft * Midas International Corp. * Midwest Center of Occupational Health and Safety * Migrant Health Program * Mary Milken * J. Donald Millar * Mine Safety and Health Administration * Minority Health Professions Foundation * Franklin Mirer * Susan J. Misner * Nancy A. Mitchell * Clifford Mitchell * Paul Monahan * Richard Monson * John Moran * Morehouse School of Medicine * Rebecca Moreland * DI Morgan * Dan Morris * Sharon Morris * U.S. Senator Carol Mosely-Braun * Ivan Most * J. Michael Muhm * Christine Murphy * Dennis J. Murphy * Linda Rae Murray * Robert A. Musson * Mutual Aid Box Alarm System - Division III * Andrew J. Myer * National Black Lung Association * National Center for Farmworker Health * National Child Labor Committee * NCR * National Industrial Sand Association * NIH - International Training and Research * NIH - National Cancer Institute * NIH - National Center for Health Statistics * NIH - National Heart Lung and Blood Institute * NIH - National Institute of Arthritis and Musculoskeletal and Skin Diseases * NIH - National Institute of Environmental Health Sciences * National Institute of Justice * National Jewish Center for Immunology and Respiratory Medicine * National Mining Association * National Small Business United * Naval Medical Research and Development Command * Holly Nelson * New England Health Center * Carolyn Needleman * New York State Department of Health * Jeffrey Newman * Leslie Nickels * Phillip Nieburg * North American Insulation Manufacturers Association * North American Insulation Trade Association * North Carolina Occupational Safety and Health Program * North Carolina State University Industrial Extension Service * Northeast Center for Agricultural and Occupational Health * Northwest Association of Occupational and Environmental Medicine * Emily J. Novick * Pat O'Connor * Tom O'Connor * Margaret O'Malley * Occupational Health Clinic * Occupational Health Foundation * Occupational Health Systems * Occupational Safety and Health Administration * Office of the Cook County Public Defender * Lawrence E. Oldendorf * Gilbert S. Omenn * Options and Choices * Oregon Health Sciences University * Ana Maria Osorio * Owens-Corning Corporation * Owens-Corning Fiberglass Corporation * Gena M. Parkhurst * William B. Patterson * William F. Payonk * Pennsylvania State University * Alan S. Pierce * Vitas Piloplys * Chaya S. Piotrkowski * Susan S. Pitman * Jennifer Pitts * Plan de Salud del Valle * Public Health Service, Region VIII * Public Pulmonary Associates * Laura Punnett * Purdue University * Mark Purschwitz * Margaret Quinn * R. R. Donnelly and Sons * David P. Rall * Raja V. Ramani * Susan A. Randolph * Risto Rautiainen * Realtime Software Corporation * Mark S. Redfern * Deborah Reed * Regent Hospital Products, Ltd. * David Rempel * Responsible Industry for a Sound Environment * Kathleen M. Rest * Mariana Rhoades * Carol Rice * Rice Memorial Hospital * Charles Richardson * Frederick D. Rine * Knut Ringen * Robert C. Byrd Health Sciences Center * William Robertson * Rochester Council on Occupational Safety and Health * Jane Roemer * Bonnie Rogers * Vernon Rose * Frank Rosenthal * Mike Ross * Deborah Rothman * Mark Rothstein * Linda Rudolph * Barbara Runyon * Rural Coalition * Rush-Presbyterian St. Luke's Medical Center * Sarah Ryan * Safeskin Corporation * Mary K. Salazar * Lori E. Saltzman * Eric Sampson * W. Mitchell Sams, Jr. * San Jose State University * Cathy Sarri * Gerard Scannell * Ronald J. Schell * Andrew Scheman * Larry Schleifer * Jennifer Schmidt * Steve Schrag * Barb Schubert * Ruth Schubert * Ronald T. Schuler * Steve Schwendeman * Susan Scrimshaw * Seattle Firefighters Local 27 * Ruth Sechena * Richard Seegal * Margaret M. Seminario * Dave Setinc * Judy Sharstrom * Jay Dee F. Shattuck * Shell Oil Products Company * Philip Shellhaas * Elizabeth F. Sherertz * Daniel K. Shipp * Anita Shoup * Gary Shumate * Peggy Sietsema * Ellen K. Silbergeld * Michael Silverstein * Barbara Silverstein * Hugh Sloan * Thomas J. Smith * Gina M. Solomon * Mike South * Southern Center for Agricultural Health and Injury Prevention * Peter S. Spencer * State of California - Division of Workers' Compensation * State of California Department of Health Services * State of Georgia Department of Public Health * State of Idaho Department of Health and Welfare * State of New Jersey Department of Labor * State of North Carolina Department of Environment, Health and Natural Resources * State University of New York at Buffalo * Patricia Stein * Jeanne Stellman * Anthony Straka * Raymond A. Strikas * Sunnybrook Health Science Centre * William J. Swartz * George Swartz * Michael J. Symons * Daniel A. Tallon * Emmanuel A. Taylor * Andrea K. 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