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Occupational Health Research in Developing Countries: Focus on U.S.–China Collaboration

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THE NEEDS FOR OCCUPATIONAL HEALTH RESEARCH

Over the past four decades, there has been unprecedented population growth in developing countries. Presently, the developing countries constitute more than 70% of the world's population. According to United Nations information,[1] the world's population is likely to double in 50 years even under the most optimistic projections. This increase, however, will not be evenly distributed around the globe. Rather, it will occur mainly in developing countries. At the same time, industrial activity has evolved significantly in developing countries. In both urban and rural areas, industrial development has been shaped by new energy sources, new technology, government policy, foreign aid, and entrepreneurial decisions. Profound changes have occurred in many industries, including mining, mineral processing, basic manufacturing, oil refining, copper and steel production, food processing, and agriculture, with increasing diversification of both processes and products. The rapid expansion of labor forces, including women and children, and rapid industrial transformations have created tremendous needs and imposed great challenges for occupational health service and research in developing countries.

The history of the developed countries has witnessed numerous industrial disasters.[2] It has also shown the crucial role of research in protecting workers' health and in accelerating overall socioeconomic development. About 95% of all health research projects are conducted in developed countries, while only 5% take place in the developing countries.[3] It is very important for the developing countries to utilize the existing information, to learn from the experiences, and not to repeat the mistakes made in the early stages of industrialization in the developed countries. In addition, one must realize that the occupational health issues faced by the developing countries today are well beyond the classic occupational diseases. They are far more complex and broader in scope.[4]

The types, the intensities, and the durations of exposures may differ between developing and developed countries. Workers in developing countries are more likely to have higher levels of exposures due to lack of occupational health and safety regulations and protective measures, as well as outdated equipment. For example, the widespread use of pesticides is a problem worldwide. However, due to lack of appropriate regulations, equipment, and training, acute pesticide poisoning remains a major health problem in the developing countries, while chronic exposure to low levels of pesticides is of major concern in the developed countries.[5] Many multinational companies are moving to developing countries with cheap labor and less strict governmental regulations, thus relocating occupational and environmental health problems to these countries. Many small factories in developing countries are located in the middle of or near residential areas. Because of limited employment opportunities and lack of education, workers in developing countries also tend to work in adverse conditions over extended periods of time.

Exposure–response relationships may differ between developing and developed countries. The workers in the third world are confronted with work-related problems as well as the usual public health problems of the poor nations, including poor sanitation and living conditions, malnutrition, infectious/parasitic diseases, and lack of access to health care.[6] The latter problems may increase the workers' susceptibility to work-related hazards. Therefore, one must be cautious in applying exposure–response curves obtained in the developed countries to developing countries. Much research is clearly needed to elucidate the interactions between these two sets of health risks.

The rising use of chemicals in industrial and agricultural production has created a whole new spectrum of hazards for workers, the environment, and the general population in both developing and developed countries. Many of these chemicals did not exist half a century ago. According to a U.S. National Academy of Science report,[7] 82% of major industrial chemicals are not subject to even minimal testing for their toxic properties or their links to specific diseases. Few of the thousands of commonly-used chemicals have been ade-

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quately tested for their abilities to cause or promote cancer. Even fewer have been evaluated for effects on critical organs such as the neurologic, immunologic, and reproductive systems.

With the concurrent introduction of modern technology and automated plants, many developing countries have begun to face occupational health problems typical of post-industrialized countries, such as those caused by working with video display terminals, by repetitive motion, and by sedentary work. Workforces and occupational health professionals are often not well equipped to cope with these new demands.

In industrialized societies, the "company gate" became the boundary for defining occupational health risks and responsibilities. However, there is no such company gate in many developing countries, where workplace, home, and general community are often mixed together. Therefore, industrial pollution affects not only workers but also their families, the community, and the natural environment. Its impact may be local, but sometimes can be national, and even global. For example, a large amount of CO_2 emission contributes to global warming. Research suggests that continuation of the current atmospheric warming trend could have severe public health effects. The ozone layer has been affected by release of chlorofluorocarbons (CFCs) into the atmosphere. Depletion of stratospheric ozone affects the filtering of the sun's ultraviolet radiation, which presents potentially significant health risks.[8]

Even among developing countries, many problems are unique to national circumstances. There are considerable variations in socioeconomic development, cultures, lifestyles, diets, and climates and geographic conditions. The distributions, compositions, and intensities of occupational hazards depend on various sectors of the economy and working practices that vary widely across nations. These and many other factors make research in occupational health necessary for each individual country. Ongoing research projects in occupational and environmental health in developing countries have recently been summarized by Levy et al.[5,9] Most projects were descriptive or cross-sectional epidemiologic studies or industrial hygiene and exposure-assessment studies.

OBSTACLES TO OCCUPATIONAL HEALTH RESEARCH IN DEVELOPING COUNTRIES

As discussed above, the complex and diverse occupational health problems pose very high demands on occupational health researchers in developing countries. However, researchers in developing countries are facing numerous obstacles in undertaking sorely-needed research activities.

The well-recognized role of occupational health research and the demonstrated benefits of improved working conditions in many industrialized countries have created powerful forces to establish special scientific policies for the promotion of research, for setting priorities and standards, for coordinating major research endeavors, for research training, and for the evaluation of research programs. Unfortunately, occupational health research in developing countries has rarely received priority attention from policymakers, and, as a result, research policy may not be well defined.

The priorities for research in developing countries have not always been determined by their own needs. Very often, priorities have been determined by the values of large international research centers and communities, which have used criteria relevant to the scientific communities in developed countries rather than developing countries. Such an approach frequently results in the research undertaken in developing countries consisting merely of follow-up activities to research previously undertaken in industrialized countries, rather than a systematic effort to target on those countries' urgent needs.

Financial support for research projects may be scarce, sporadic, and unstable. There is a shortage of experts in the area. For example, the number of research scientists and engineers per 10,000 labor force is one-third to one-half that in developed countries.[3] Overloading and overcommitment of the research staff may affect the implementation of programs. There may be severe problems in facilities and supplies, e.g., the stability of electricity and the availability of pure water, pure gases, reagents, and other materials. Researchers may encounter incredible delays in purchasing materials and equipment. Available instrumentation may be inappropriate: either too sophisticated or outdated. Spare parts and special materials may be difficult to obtain. Access to computers may be extremely difficult to obtain. Transportation and communication by mail or phone may be an obstacle, particularly in remote areas. There may be obstacles to timely access to scientific journals and conferences. The low educational level and the need to use local languages in the study population may be an extra burden for field study. Difficulties are often encountered in collaboration, particularly across the borders of domestic administrative sectors.

These obstacles may affect research programs to various extents, depending on their nature and severity. This difficulty underscores the need for realistic planning of objectives and operations, particularly considering the need for more time and effort than one would normally anticipate for such research projects. It also underscores the importance of introducing and using technology appropriate for the field setting. For epidemiologic studies, most of the above-named obstacles can, with patience and persistence, be overcome.[10,11]

RESEARCH STRATEGIES IN DEVELOPING COUNTRIES

Setting Research Priorities

Not all research proposals can be actually put into place. This is particularly true for developing countries, where resources are scarce and needs are urgent and compelling. To meet a nation's urgent need and to maximally utilize available resources, one must focus on problems that are of utmost importance for occupational health, or that have great impact on other national development efforts. To set up research priorities, there are at least three important aspects to consider. The first is scientific value, i.e., the logic of the scientific paradigm, the clarity and logic of the hypothesis, the contribution to new knowledge, and the validity, reliability, and currency of the methods. The second is social impact, i.e., the value of the research from the societal point of view—the need for it and its credibility, acceptability, societal consequences, and timing as perceived by the government, industries, workers, and general population. The third is feasibility, i.e., the probability of success in implementing the proposed study and in applying the results in practice, cost–effectiveness, and time-span. Several methods for priority setting have been developed,[12] for example, measuring the severity, occurrence, distribution, trends, sensitivity, and economic aspects of occupational health problems or of solutions proposed on the basis of research results. Although a large amount of data is needed for a comprehensive priority-setting process, prioritization can still be undertaken when all the relevant data are not available, if the purpose is solely to ascertain the relevance and the likely impact of research efforts. Whenever possible, a pilot study should be done to collect data for prioritization. Consultations with experts in the field and the responsible authorities should be included in the priority-setting process.

Choosing Research Topics

The most important justification of occupational health research in developing countries is its ability to generate new information about occupational hazards, which will, in turn, affect public policy and regulations, occupational health services, the quality of the working environment, and ultimately, workers' health. Useful objectives of occupational health research include:

1. to reveal the current status and trends of occupational health and safety problems in a country or region; and to investigate the origins, causes, and mechanisms of those problems;
2. to develop tools for occupational risk or exposure assessment;
3. to evaluate health effects of important occupational health and safety hazards, particularly those not studied in other countries or regions;
4. to provide a scientific basis for defining national priorities; for occupational health and safety regulations; for setting up health standards; and for establishing norms;
5. to generate new information about prevention and control of occupational health and safety problems and about improvement of occupational health and safety services;
6. to train research personnel in designing, conducting, analyzing, and reporting occupational health research; and
7. to educate the public about occupational hazards.

Taking Advantage of Unique Features

Developing countries have a number of unique characteristics that can provide invaluable information that might be otherwise difficult to obtain, and are of great interest to scientists from both developing and developed countries. We cite China as an example. In China there are wide ranges of exposure levels for many common hazards such as air pollution, organic solvents, heavy metals, pesticides, and dusts/fumes. This provides an opportunity to examine dose–response relationships with greater precision and power and to determine threshold values.[13–16] There are wide variations in diet between urban and rural areas and across the four seasons, which provide an opportunity to examine the interactions between nutrition and occupational hazards. It is relatively easy to identify families with large pedigrees, which makes it possible to examine the interaction between genetics and occupational hazards. The residential population and employment are fairly stable, which make it possible to study the chronic health effects of occupational exposure.[17] In China, the number of births in each community is planned and assigned by the family planning administration. Any woman who wants to have a child must first register and obtain permission from the local family planning administration. Prenatal care and delivery service are provided at designated hospitals. Therefore, all women who are planning to become pregnant can be identified and followed.[18] The social structure, administrative structure, and health service arrangements make it possible to obtain high rates of response and to minimize loss to follow-up in occupational health studies. In China, patients seek medical care in their designated local hospitals. Outpatient visits are unscheduled, that is, on a first-come, first-served basis. Visits to higher-level hospitals often require referral from primary care physicians in local community hospitals. Thus, records from a community-based hospital provide reliable information about morbidity for a geographically de-

fined population and offer an opportunity to conduct time-series studies of environmental exposures and health outcomes.[13,19,20] In addition, at present the cost of conducting epidemiologic research is much lower in China than in the developed countries, providing a high cost–efficiency for occupational health investigations.

Finally, the active industrial transformations in developing countries offer an exceptional opportunity for "natural experiment study." For example, one can study the impact of a new plant on the environmental and the population's health in a rural area; or the relationship between installation of a pollution control device and the population's mortality and morbidity.

Quality Control

Quality control is an integral part of any scientific research. It is particularly important for conducting research in developing countries, because of the lack of established guidelines, the shortage of well-trained personnel, the use of non-standard equipment, the overwhelming workload, and the low educational levels of the study populations. These problems may introduce considerable error or bias into a study, jeopardizing its sensitivity, specificity, validity, and reliability, as well as the generalizability of its results. To ensure optimal quality, the quality-control process should begin at the stage of study design with a clearly written study protocol and quality-control procedures. Before field implementation, research staff should receive adequate training and pass performance checklists according to the guideline. This implies that training should be a key element of every major research program. It is necessary to have quality-control staff, independent of the data-collection staff, constantly monitoring the data quality. Finally, error checking at the stage of data entry and analysis is also an important part of quality assurance.

Multidisciplinary and International Collaboration

The complexity and broad scope of occupational health problems make it necessary to seek multidisciplinary and international collaborations. This can be achieved by careful planning, consultations, and negotiations to ensure the full commitment of all those involved. It is important to ensure good collaborative links in advance. Agreements on collaboration and all commitments of involved parties should be well documented, and the administrative body responsible for each sector should be clearly identified. International collaboration, particularly in the form of research training, information support, and technical aid, should be strengthened to encourage and ensure the development of sustainable self-reliance in research.

TWO PRACTICAL EXAMPLES

An 11-year Longitudinal Occupational Health Study of Textile Workers in Shanghai

In 1981 a collaborative research project on the respiratory health of textile workers was initiated as part of a two-way academic exchange program in public health between Harvard University School of Public Health and Shanghai Medical University (SMU; formerly Shanghai First Medical College) in Shanghai, China. The study was designed by Dr. David Christiani and conducted with collaborators from SMU and the Shanghai Textile Bureau's Medical Department. In 1981–1982 a cross-sectional study of 1,000 cotton and silk textile workers was done using standardized techniques, materials, and quality-control procedures for air sampling, questionnaire development and administration, and pulmonary function testing. The study was the first large-scale survey of respiratory health among textile workers in China and led to several important findings, including a significant prevalence of byssinosis among cotton (but not silk) workers, a high prevalence of chronic bronchitis among cotton versus silk workers, and a greater-than-additive effect of smoking and dust exposure for chronic bronchitis among male cotton textile workers.[21] The investigators also found that cotton workers suffered larger across-shift drops in FEV_1 than did silk workers, and this response increased in prevalence among workers with longer work tenures.[22] These results were largely confirmatory of those in the West. However, we also examined cotton-dust and gram-negative bacterial endotoxin exposure–response relationships and found the first reported evidence for an effect of chronic endotoxin exposure on the prevalence of chronic bronchitis.[23]

This cross-sectional study became the basis for longitudinal research that has continued to the present. Our last sampling occurred in 1992 (11 years after the work began). A brief summary of the scientific findings from this study includes:

1. Symptom reporting variability was substantial, but subjects who consistently reported symptoms on multiple surveys had greater longitudinal drops in FEV_1.[24]
2. Across-shift drops in FEV_1 of only 5% or more were associated with accelerated long-term declines in pre-shift FEV_1. This was the first study to demonstrate this acute–chronic association for textile workers.[17,25]
3. After adjusting for confounders, cotton-dust exposure was associated with a significant long-term loss in FEV_1.[25]
4. At 11 years, cumulative cotton-dust level predicted long-term loss in pulmonary function better than did cumulative endotoxin level.[26]

The most important aspect of this study, however, is illustrated by the fact that the Chinese government reduced the permissible exposure limit for cotton dust by tenfold in the mid-1980s as a direct result of its findings. The health officials, while recognizing the importance of the longitudinal study to address scientific questions that are generated in the international community, nevertheless took the public health action on the basis of the (confirmatory) cross-sectional study.[27]

This study illustrates the points that international collaborative research in occupational health can contribute to global scientific knowledge about the health effects of workplace exposures; to research training in the host country; and to important public health actions in the host country in the short term.

Ideally, where the developed nation has not yet set or revised standards relevant to a particular exposure, efforts leading to such actions may occur simultaneously in both nations.

A Population-based Respiratory Epidemiologic Study in Beijing

A national survey of mortality showed that respiratory diseases were the second leading cause of death in the overall population in China. Air pollution and occupational exposures are thought to be the most important risk factors of respiratory diseases. With rapid urbanization and industrialization, air pollution and occupational exposure have become an increasing problem in China. However, epidemiologic evidence from which one can estimate how much the mortality and/or morbidity can be attributed to these exposures has not yet been available. Data from air-monitoring stations suggest that concentrations of total suspended particulate matter (TSP) and sulfur dioxide (SO_2) are quite high nationwide and yearround, with northern cities having higher levels than southern cities and winter higher than summer.[28,29] According to the monitoring results from 60 cities of China, the daily mean concentration of TSP was as high as 660 $\mu g/m^3$.[30] On the other hand, indoor air pollution caused by coal combustion for cooking and heating, and by smoking in crowded households, was also of great concern. With this background, a large environmental epidemiologic study, led by Dr. Xiping Xu in collaboration with faculty members of Beijing Medical University, was deigned to investigate the effects of major environmental and occupational risk factors on respiratory health in adults in the residential, industrial, and suburban (control) areas in Beijing in 1986. Of a total of 3,746 subjects selected and invited to participate, 3,590 (95.8% of the sample drawn) responded. The total cost for field survey and air sampling was approximately 20,000 U.S. dollars. This study led to several important scientific findings:

1. A significant exposure–response relationship was demonstrated between outdoor air pollution level and chronic respiratory symptoms and pulmonary function in never-smoking adults after controlling for important confounding factors.[13]
2. A significant association was demonstrated between indoor coal combustion and chronic respiratory symptoms and pulmonary function in never-smoking adults.[20]
3. A significant effect of cigarette smoking on pulmonary function was found in both men and women and the gender differences in smoking effects were compared and demonstrated.
4. A significant interaction between the effects of air pollution and cigarette smoking on pulmonary function was demonstrated.[19]
5. A significant exposure–response relationship between passive smoking and pulmonary function in never-smoking adults was demonstrated.[31]
6. There was a significant association between outpatient nonsurgical hospital visits and air pollution.[32]
7. A significant exposure–response relationship between occupational exposure to dusts and gases or fumes and chronic respiratory symptoms, pulmonary function, and doctor-diagnosed asthma was demonstrated.[14–16]

The materials published in international journals have been rewritten in simpler format, translated, and submitted to Chinese scientific journals for publication. The study demonstrated the practicality and utility of adapting epidemiologic techniques and questionnaires used in Western countries for studies in China. The information obtained from this study has been used as important scientific evidence in revision of China's air-pollutant– emission law by China's National Environmental Protection Agency and in cost–benefit analysis by the World Bank. Over 15 faculty members and 60 students in Beijing Medical University participated in the study, updating their knowledge of environmental epidemiologic study design, and improving their technical skills in air monitoring, in pulmonary function testing, and in the administration of standardized questionnaires, data analysis, and the documentation of data reporting. The techniques and documents specifically designed for training the field team have been broadly used as teaching materials in several national environmental epidemiologic workshops and classes in schools of public health.

The two collaborative research projects conducted in China have produced unique and significant results in the study of environmental and occupational exposures and respiratory health, and may be a paradigm for developing other collaborative research projects in environmental and occupational epidemiology in China.

SUMMARY

Research is an important tool for the development of occupational health in developing countries, providing a

scientific basis for policy making, priority setting, problem solving, professional training, and evaluation. There are both tremendous challenges and opportunities for occupational health research in developing countries. The population growth and industrial transformation in these countries are unprecedented. Their occupational health problems are both complex and broad in scope, consisting of both classic problems experienced by the developed countries decades ago and brand-new hazards due to introduction of modern technology, compounded by poor socioeconomic conditions. A most difficult challenge for international occupational health today is the conflict between the uncertainty of the scientific base and the potential for cataclysmic human health effects. Numerous financial, informational, technical, personnel, institutional, and political obstacles have blocked the effective implementation of occupational health research. Nevertheless, there is great potential in conducting occupational health research in developing countries. Researchers in the area can enhance their chances of success by identifying priorities, selecting important and feasible topics, taking advantage of a country's unique features, and paying attention to quality control. In addition, the strengthening of research institutions, particularly institutes of occupational health and medical universities, would ensure institutional support for occupational health research. Multidisciplinary and international collaboration, particularly in the form of research training, information support, and technical aid, should be encouraged and expanded.

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