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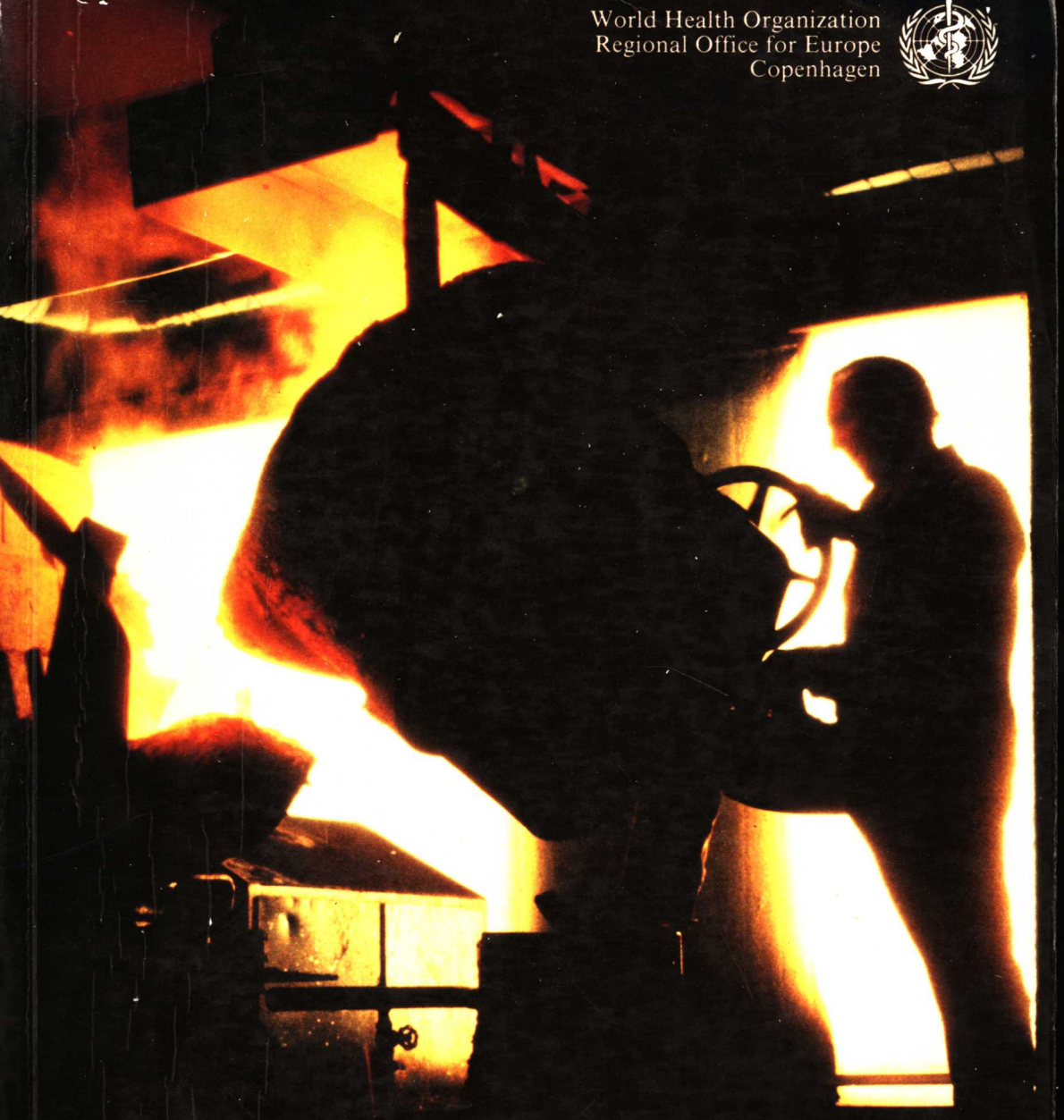

Epidemiology of occupational health

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Preface

Many definitions of epidemiology have emerged over the last few decades, in keeping with the rapid development and broadening of the science. According to the Dictionary of epidemiology *edited by John M. Last in 1983, epidemiology is "the study of the distribution and determinants of health-related states and events in populations, and the application of this study to control of health problems". Epidemiological methods have been widely used in the field of occupational health to describe the health status of specific working populations, to study their morbidity in relation to the type of occupation, to identify specific occupational hazards, to generate and test hypotheses on cause–effect relationships, and to evaluate interventions. When the relationship has proved to be quite strong and specific, such studies have been very successful in increasing our knowledge of the effects of occupational hazards. In many cases, however, epidemiological studies have led to controversial and confusing results. This may have been due to the use of inappropriate methodology, but may also have been the result of overestimating the power of epidemiological and statistical methods. Those engaged in resource consuming studies must be well aware of the limitations of the tools they are using. In the particular field of occupational health there are limitations due to the characteristics of the population under study, which is usually rather small, selected, and subject to change over time with regard to exposure to occupational hazards. Other limitations arise from the type of hazards concerned, very often combined with other exposures that may or may not be related to occupation, and also with long latency periods for any outcome from the exposures. In addition, there are methodological limitations due to the lack of proper assessment of exposure and health effects. Retrospective studies may be subject to inappropriate information on exposure to the suspected hazard, as well as to other confounding environmental or behavioural factors. Prospective studies may overcome this type of problem but, besides their relatively high cost, they have their own methodological biases too, such as those linked to the quality of the reference groups, observer errors, and changes induced in the study population by the study itself.*

Such limitations should not be seen as an obstacle to the use of epidemiology, but rather as justification of the use of sound and standardized methods. The present manual tries to respond to the specific needs of occupational health

epidemiology. The WHO Regional Office for Europe, after a decade of work in this field, has secured the collaboration of leading experts to present and discuss in a practical way different approaches and methods and their application to specific problems in occupational health. Rather than a comprehensive review of the subject, the book presents a series of articles. The first four chapters deal with general principles and definitions in occupational epidemiology, and describe the work-related hazards and diseases. Chapters 5, 6 and 7 deal with information collection and the use of data in the assessment of health risks and in descriptive epidemiology. General methods for epidemiological studies are discussed in Chapters 8–10. The following chapters address specific aspects such as the study of combined effects (Chapter 11), the statistical analysis of epidemiological data (Chapter 13), the validity aspects of epidemiological studies, including consideration on the problems of "false positive" and "false negative" results and the basis for causality judgement (Chapter 14), or the particular interest of experimental epidemiology in occupational health (Chapter 15). Chapters 12 and 16 cover two special issues of importance to workers' health, namely occupational stress and the epidemiology of accidents. Chapter 17 gives an excellent overview of the uses of epidemiology in occupational health, and the last chapter presents a concrete case study, with an assessment of the use made of epidemiological methods. There are unavoidable repetitions and overlaps throughout this manual due to the way in which it was compiled, but it gives very useful and practical information to those interested in epidemiological research applied to occupational problems.

All this work was done in collaboration with the office of occupational health at WHO headquarters in Geneva.

It is hoped that this book will encourage and facilitate sound and reasonable application of epidemiology to the identification of hazards, assessment of risks and evaluation of control measures in the working environment, thus contributing to the achievement of the European target[a] *calling for effective protection of people in the Region against work-related health risks. It is also hoped that it will have worldwide value in the development of epidemiological tools for the purposes of occupational health.*

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[a] *Targets for health for all.* Copenhagen, WHO Regional Office for Europe, 1985.

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Epidemiology in the context of occupational health

M. Karvonen[a]

Epidemiology is a science concerned with morbidity and mortality: it studies the distribution of states of health and disease in the community as well as the distribution of health-related events and their determinants.

As applied to occupational health, epidemiology thus has the dual task of describing the distribution of deaths, accidents, illnesses, and their precursors in the various sections of the occupationally active population and of searching for the determinants of health, injury, and disease in the occupational environment.

The succinct definition requires some words of explanation. The preamble to the Constitution of the World Health Organization defines "health" as a state of complete wellbeing—physical, mental, and social—but "health" is also often used to encompass the entire continuum extending all the way from the ideal state of complete wellbeing to death. It should also be made quite clear at the outset that epidemiology, although it uses statistical methods, is not a mere application of biostatistics, but one of the two basic approaches in medical science, the other being concerned with disease mechanisms.

Epidemiological methods are increasingly used also for studying the functions of health services. Though obviously a sound and useful development, this aspect will not be discussed in the present volume.

Whereas clinical medicine is primarily concerned with sick individuals, epidemiology deals with communities. In an individual, the state of health can be described in terms of diagnosis and prognosis, but in a community rates are needed: e.g., the prevalence of ill subjects at a point—or short period—of time in a population, or the incidence of new cases in a population within a defined time, e.g., in a year. For mortality rates, the cases are deaths. The number of cases supplies the

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numerator for these rates, the size of the community in which the cases occur, the denominator.

The morbidity rates are community diagnoses. It is a further task of epidemiology to seek the determinants of these rates. Epidemiology is concerned with the causation of health and disease. The causes of ill health are to be sought (*a*) in the structural, functional, and behavioural characteristics of individuals, (*b*) in their physical, chemical, biological, and social environment, and (*c*) in the interactions between individuals and the environment. An epidemiologist searches for the causes by looking for individual and environmental variables that affect the morbidity and mortality rates. The mechanisms by which these causes exert their effects in the organism must be clarified by other means: by the study of pathogenesis. In clinical medicine, understanding of the nature of disease processes is being deepened essentially by biomedical pathogenetic studies, though epidemiological methods may sometimes also contribute to the analyses of mechanisms (see, for example, Ref. *1*). Where the aim is to analyse the causation of diseases, however, epidemiology is the key science. In the pursuit of knowledge, the study of epidemiology and the study of pathogenesis are complementary and not in competition. The two approaches continuously provide each other with stimuli and challenges and thus have jointly become a potent accelerating force for medical progress.

In addition to its role as the science of causes of ill health, epidemiology also fulfils other functions. As the epidemiologist is concerned with rates, his work necessarily implies collecting numbers, both for the numerator and for the denominator. Both these figures have several uses. By providing quantitative descriptions of morbidity and analysing its determinants, epidemiology serves the health services and also the community at large. Health planning, several aspects of social policy, food and agricultural policy, and even education can derive guidance from epidemiological studies. Changing the ways people live may affect their health for better or worse. Epidemiology has, indeed, the necessary tools for measuring the health impact on populations of control measures and other changes (interventions), planned or unplanned, be they medical, economic, technical, social, or cultural. For community health, epidemiology is a basic science, necessary for meaningful planning and evaluation.

Today, epidemiology is a rapidly developing member in the family of medical sciences. In recent years, its scope has been expanded so that, besides its traditional role of studying epidemics of infectious diseases, it now also examines the causes of chronic noncommunicable diseases, including occupational ones; in addition, new vistas have been opened up in the study and control of mental diseases, and directives have been developed for curbing the epidemic of road and industrial accidents. Epidemiology adopts and adapts a wide variety of methods from clinical and laboratory medicine. Its statistical tools are partly specific to the field, partly common to demographic or biomedical research, or even to econometrics.

Like many other medical sciences, epidemiology also exists as a discipline, with personnel and facilities for teaching and research. In most centres of learning epidemiology is still a newcomer. A shortage of competent experts and teachers is felt in many parts of the world. This applies both to developed and to developing countries. In some developed countries with old, established institutions, the forces of inertia may retard any novel approaches. Lack of competence in epidemiology soon adversely affects other medical disciplines, however well established, and leads to their stagnation or sometimes to diversion of efforts into areas with little relevance to the major problems of health and disease.

Occupational health is one of the environmental health sciences, concerned broadly with the health effects of work and of working conditions. Physical, chemical, biological, organizational, and social variables associated with occupation may affect the physical or psychosocial wellbeing of the worker adversely or positively. Any environmental health research, when systematically conducted, must be concerned with

— the general characterization of the environment,
— the characterization of those exposed,
— the duration and intensity of exposures to various environmental factors,
— interactions between variables in the environment and those exposed to them, and
— health-related changes in the subjects exposed.

In applying this model to occupational health, work has to be looked upon as an exposure that needs detailed, many-sided characterization. The concept of interaction may need some clarification. Consider a straightforward example: the etiology of stress fractures. Such fractures occur in the leg and foot bones during training when long marches are performed. The fractures have been shown to increase in frequency with leg length asymmetry (*2*). Another type of interaction between the marcher and the road is physically mediated by the footwear: evidently, this also deserves epidemiological study.

Until recently, the concept of occupational disease denoted a specific clinical and pathological syndrome caused by a hazard specific to a particular type of work or the work environment. Epidemiological studies have, however, somewhat shaken the concept of specificity. On the one hand, the occurrence of occupational diseases may be affected by non-occupational factors, such as nutritional state. On the other, the prevalence and incidence of several common diseases may also be influenced by occupation. This is known to apply, for example, to some forms of cancer, which are not in the lists of occupational diseases, to a variety of common respiratory diseases, and to miscarriages, congenital malformations, and ischaemic heart disease. When work contributes to the causation, the term "work-related diseases" is being used.

The demographic concept of "social class" is often based on pooling together occupations considered similar in type, such a grouping of occupations being called a "social class". The breadwinner's family is included in his/her class. "Social class" differences in morbidity are thus often occupational differences, at least in regard to the breadwinner. Obviously, in comparing any two occupations—or groups of occupations like the "social classes"—there are generally differences also in education, income, housing standards, life habits, etc. The incidence of premature death from most major causes is connected directly or indirectly with the person's occupation (see Table 4.9 in Ref. *3*). Occupational differences in morbidity may thus be ascribed to "social class" differences, as has been customary in traditionally stratified communities. However, marked occupational differences in total mortality, without a systematic "social class" pattern, are being observed in communities with a rather turbulent recent demographic and social history (*4*).

With modern technology, many hazardous exposures at work have been reduced. As a result, manifest occupational diseases are becoming rare, at least in the more economically advanced countries. For assessing the potential risk, new indicators are therefore needed. Clinically inapparent alterations in physiological variables, e.g., in lung function and in nerve conduction velocity, may be measured in groups of exposed workers and in suitably selected unexposed reference populations, the "controls". Sensitive indicators of incipient ill health have also been sought for in various subjective symptoms. The frequencies of headache or of complaints related to the musculoskeletal or gastrointestinal system have been found to vary according to the work situation. These differences deserve careful investigation.

Evidence of a health-related response to work or the work environment is much strengthened if no information gap remains regarding interactions between the environment and the worker. Sometimes the required information can be obtained with the aid of an experimental exposure test. With chemical hazards, the gap may often be narrowed by determining the substance or its metabolites in blood, urine, expired air, or even in hair. With physical hazards, bridging the gap by direct measurement is sometimes possible (e.g., in exposure to vibration), but with hazards that are psychosocial in nature such measurements have seldom been attempted. Often an exposure can be verified only by studying the work environment and organization. Occupational Exposure Limits, Threshold Limit Values (TLV), and Maximum Allowable Concentrations (MAC) offer empirical guidelines for controlling the work environment. When recommendations for such values are being made nationally or internationally, epidemiological data on exposure–response relations are essential.

Accidents are a major cause of health loss in many occupations. It is commonly believed that their incidence may be affected by such factors as organization of work, proper training, ergonomics, and safety campaigns. However, the amount of epidemiological research on

accidents at work and on their prevention has been meagre in relation to the importance of the problem.

Some studies of the unemployed have demonstrated that lack of work may also be a health hazard. Insufficient effort has yet been devoted to identifying those features of work that promote health. The present movement of "work enrichment" deserves as its companion proper epidemiological study.

What occupational health services offer to the epidemiologist

An occupational health service caters for a defined population. Thus, denominators for rates are fairly easy to define. The service usually records information on the state of health of the workers and hence is able to take care of some numerators. Complementary information on sickness absenteeism, pensions, and even mortality may be secured.

In some occupations and enterprises, the working population once established is remarkably stable. Longitudinal studies, historical or prospective, find a fertile field in such an environment, where both the subjects and their health records are easily available. Even a truly prospective cohort study can, with little extra effort, be organized within an occupational health service, but only if those leaving work can later be traced.

Records exist not only for working populations and their health but also for their exposures. Industrial hygiene measurements may have been performed routinely or occasionally. If not, it is often possible to reconstruct an approximate grading of exposures with the aid of the work record and skilled help. Whether a study is cross-sectional or prospective, an adequate sampling strategy of exposures should be built into the study plan from the very beginning. Epidemiological principles should not remain foreign to the industrial hygienist.

Occupational health epidemiology often faces problems similar to those in environmental health at the community level: air pollution, noise exposure, etc. The study strategy, however, may be rather different. The occupational health epidemiologist generally has to contend with smaller and selected populations, but this is amply compensated for by much higher exposures and sometimes even by their documentation in the past.

The interface of man and work supplies essential information on health hazards. Many occupational exposures in an enterprise vary from task to task. The possibility of becoming acquainted with the entire spectrum of tasks carried out in an enterprise—with their varied exposures—is an asset to the physician in occupational health that his more clinically oriented colleagues do not share. It would be both poor epidemiology and poor occupational health practice not to know the exact nature of the work that is being done.

Work processes and work places change. The changes are mostly dictated by organizational, technical, or economic considerations. Sometimes an ergonomic improvement may also be the target. Whatever the motivation of the changes, the doctor or the ergonomist is seldom consulted or informed. Some of these "natural experiments" may, however, provide unique possibilities for evaluative studies. The occupational health epidemiologist should be on the alert for such interventions. The ergonomist, concerned with the products or the production, can also use the skills of epidemiology and apply them to ergonomic problems.

Changes may also be made to achieve health objectives. One approach would be to plan from the beginning a controlled study in one or several enterprises. Some epidemiologists think only in terms of double-blind randomized controlled trials. Such approaches can seldom—or never—be realized in an occupational setting and the results also have limited generalizability. It is consoling to remember that of the sum total of human knowledge, most has been gained by using less "perfect" strategies. Information from "natural experiments" or "quasi-experiments" is not to be frowned upon: there is a wide and growing experience in their utilization. The definition of new problems is at least as important a function of research as the solution of old ones. Handbooks of epidemiology or statistics do not include any orthodox, codified standard methods for charting the unknown. There is still scope for the innovative mind.

The occupational health service is a link in the work organization. Its *raison d'être* is the health of the workers. It should be able to serve them by a wide spectrum of activities, all the way from health education to curative medicine and rehabilitation. The inputs of time and money to the various tasks by the health service can be measured. What is gained in terms of health is, however, far from self-evident. Carefully planned epidemiological studies might be able to give at least some answers. Epidemiological studies provide the means for the critical self-appraisal of any institution delivering health services: a valuable guideline for optimizing the always limited resources.

How epidemiology helps protect workers' health

An occupational health epidemiologist does not work only in the crystal-clear atmosphere of pure science, but rather for human welfare in the world of labour where interests clash. The situation calls for a simple, well defined code of ethics. A code of values is essential, with rules of conduct and formulation of standard practices.

For the health professions, human life is high in the hierarchy of values. The general public also considers health a major determinant of the quality of life. Societal values have great importance in the world of labour, with its complex informal and formal social structures. Cultural values, both those of the workers and those of the community at large, have to be considered. Not least, the privacy and individuality of each worker deserve respect. Other, often competing, values (e.g.,

economic and political ones) must be taken into account, but they are not a primary concern of the epidemiologist.

In searching for guidelines for the relation between the epidemiologist and the population studied, the code of ethics of the doctor–patient relationship offers a well established parallel observed all over the world. However, since the epidemiologist is making a *community* diagnosis, the moral obligations of the community studied on the one hand, and of the epidemiologist towards the community on the other, need to be discussed, weighed, and codified. When being asked to take part in an epidemiological study, a worker should make his decision not only as an individual, but also bearing in mind his obligations to his fellow workers and to society. Agreement to participate may help to improve the health of present or future fellow workers.

More problematic are the ethical issues connected with third parties. The news media assume that everyone has the right to know everything. Such a creed obviously serves the profits of the information industry, but it raises serious questions of discretion and responsibility. As a natural and well founded reaction against large-scale breaches of privacy, steps are taken to protect the individual. Unfortunately, this has resulted in some ill-advised and unfortunate legislation, which has gravely handicapped the study of health hazards, particularly those that are long-term. It is quite evident that good long-term records on the individual's work and health are absolutely necessary for any scientific attempt to improve workers' health. This must be stated categorically to prevent irresponsible mismanagement of data and—even worse—the enactment of legislation that retards innovation in health.

The epidemiologist's role in occupational health

Research as an aid to decision-making

Scientific research serves two functions: it helps to extend human knowledge and this, in turn, can be used as an aid to making practical and administrative decisions. Scientists are rightly concerned with the quality of their work and prefer to exclude information of questionable value.

The manager, or administrator, on the other hand, must make decisions based on the best information available to him, often within a time limit, and therefore sometimes on insufficient evidence. In real life, even the common decision to continue the *status quo* seldom rests on scientific evidence. In other situations, the decision-maker may have to deal with conflicting evidence, often made worse by competing interests, e.g., those of health, power, and profit. Even in the health field, it would be unrealistic, impertinent, and illogical to require the decision-makers to limit themselves to deciding issues only when backed by faultless epidemiological studies.

Furthermore, a decision has sometimes to be made in a situation where alternatives are supported by results falling far short of the arbitrary 5% level of significance. In practical life, industry, and trade,

decisions are often made on evidence statistically "softer" than that required for acceptance in the realms of science. There would indeed be very little business life if new developments were launched only when the odds were 10 to 1 or higher in favour. Human lives have a high intrinsic value and, other things being equal, most of us would probably opt for any safe preventive or curative procedure that offered a reasonable chance of success—certainly far short of 95%. Measures aimed at improving work safety have until now seldom been based on hard epidemiological data; case histories of accidents, engineering skills, and cost-effectiveness considerations have been the main determinants.

Democratic communities and decision-makers need information. In deciding on health policies and programmes, they are best served by versatile *ad hoc* information systems combining various types of hard and soft health data. Pertinent epidemiological studies, if available, would rank high as providers of data for such systems. However, less certain data, often indirect in nature, can also contribute much, if intelligently used (*5*). No epidemiologist in occupational health can work in an ivory tower; he should have a wide grasp of the real world and its potential sources of information.

Epidemiology and planning

Goal setting

The first step in planning is to set goals. In the community at large, these are often codified through political decisions. This applies also to occupational health. The three partners in the labour market are workers, management, and government. In order to set feasible and reasonable goals for occupational health and safety, all three need information and advice. All the better if this is unbiased. A source serving all three is the International Labour Office, which has a quasi-legislative function, while the World Health Organization has contacts primarily with the ministries of health and tends to have a more advisory role. Sound data for goal setting in occupational health can be provided by epidemiologists; a country without them will not be able to develop its services independently.

Strategic planning

Once the goals have been set, decisions are to be made on means for attaining them. Further, information on hazards and on measures to control them (and on their effectiveness) will be needed. In other words, a national occupational health information system has to be developed. Both fixed and versatile elements may be included in such an information system. Some guidance may be obtained from a comprehensive occupational disease register (*6*) and from work accident statistics (see, for example, Ref. *7*). The keepers of such registers should obviously have proper epidemiological training and expertise.

Tactical planning

The tactics used in occupational health consist of measures for health promotion, prevention of illness and accidents, and treatment and rehabilitative measures. In all these areas, pertinent epidemiological problems can be formulated. Innovations are frequently introduced. Their value can occasionally be assessed with the aid of controlled studies. Even when this is not possible, the process of change should be assessed as a "quasi-experiment"—a task for a skilful and experienced epidemiologist.

Implementation

The above outline of the steps in occupational health planning implies that there is also a need for epidemiological knowledge in the implementation phase. A WHO Working Group has recently recommended that the evaluation of occupational health services should be a regular activity, fully integrated into the planning and implementation of occupational health and safety programmes (*8*). Social, technological, and economic factors should all be taken into account. The appropriate information systems clearly need a spectrum of skills to which an epidemiologist can contribute.

The social partners—the trade unions, and the employers' federations—need epidemiological expertise in order to be adequately informed about current questions of occupational health and safety. Whether these organizations prefer to have experts among their staff or to rely on outside institutions will vary from country to country. Major epidemiological investigations on occupational health in an industry are most effective if supported, at least morally, by both social partners, but an enlightened trade union, employer, or government department may alone sponsor a study organized in a manner likely to produce valid results. To date, most large-scale epidemiological studies of good quality in occupational health have been undertaken by universities or governmental research agencies (such as the Medical Research Council in the United Kingdom, the National Institute of Occupational Safety and Health in the United States, or the various institutes of occupational health in the Soviet Union). One good solution is to have an adequately supported, reasonably independent, many-sided national body with appropriate competence in epidemiology as well as in other fields.

Questions of "bias" are often raised, particularly when results are unpopular with one of the interested parties. However, disinterested parties really do not exist (this applies even to government agencies). In the end, scientific quality depends on the competence, training, financial independence, and character of the investigators, and on having all sides of industry well informed as to the nature and purpose of epidemiology.

All enterprises have need of epidemiological studies. The Joint ILO/WHO Committee on Occupational Health has recently outlined the educational requirements for the tasks of an occupational health physician (*9*). He should be able, among other things: