

Screening and surveillance of workers exposed to mineral dust

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Preface

Screening and surveillance are two complementary tools used by public health professionals to follow the status of and trends in the health of various populations. These tools enable health professionals to identify problems, assess them and plan appropriate interventions. Both screening and surveillance are of particular significance for occupational health professionals responsible for assessing the health of people at risk for disease as a result of exposure to hazards in the workplace.

Screening and surveillance provide information on the health of working populations and contribute to the collation of national occupational health statistics. Moreover, such information is necessary for the planning and implementation of occupational health and safety programmes directed at the reduction of harmful exposures, improvement in working conditions and prevention of occupational diseases and injuries. As these efforts are international in scope and are carried out under a variety of conditions, they can benefit from a harmonization of definitions, approaches and methodologies.

In response to this need, the World Health Organization (WHO) initiated a project resulting in the present publication. A meeting of an international group of experts (see Annex 1 for a list of participants) was held, where a consensus was reached on the need for and methods of screening and surveillance of workers exposed to mineral dust, and a draft text of the current publication was discussed and revised.

The first part of this publication provides the reader with definitions of screening and surveillance and describes the main elements of such programmes. The second part describes in greater detail practical aspects of the screening and surveillance of working populations exposed to selected mineral dusts. It is hoped that this publication will encourage the implementation of appropriate screening and surveillance programmes in WHO Member States.

Occupational respiratory diseases, particularly those induced by inhaling mineral dust, are prevalent in developing as well as many

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developed countries. Although the health impact of the so-called “silent epidemic” of occupational respiratory disease is significant, to know its true magnitude requires an improvement in diagnostic criteria and notification and reporting systems, all components of the screening and surveillance of working populations. In this respect, the present publication, written with the practitioner in mind, provides information that is useful for all health professionals, but particularly for occupational physicians, epidemiologists, occupational nurses, occupational hygienists and others like primary health care workers who are dedicated to protecting and promoting the health of working populations.

It is my great pleasure to acknowledge the work of all the experts who participated in the WHO Meeting on the Screening and Surveillance of Workers Exposed to Mineral Dust. In particular, I would like to thank Dr M. R. Becklake, who chaired the meeting and made valuable contributions to the manuscript, and Dr G. R. Wagner, who drafted the manuscript, served as rapporteur at the meeting and subsequently finalized the text. The contribution of the International Labour Office (ILO) and its representative Dr M. Lesage and the technical and financial support given by the National Institute for Occupational Safety and Health (NIOSH) in the United States are gratefully acknowledged. Special thanks are also offered to Dr F. He, the scientific coordinator of the project.

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CHAPTER 1

Introduction

Diseases caused by exposure to mineral dust persist in both developed and developing countries despite substantial knowledge about the means of their prevention. Disease prevention can be achieved by the application of engineering techniques that limit workers' exposure to mineral dust. Such technologies can also be supplemented by administrative strategies and by the use of personal protective equipment. An optimal distribution of public health resources would emphasize primary prevention through exposure control. Medical screening and surveillance are secondary strategies which are, however, integral parts of a disease prevention programme.

Exposure to mineral dust occurs in a variety of circumstances. Workers subject to exposure may be engaged in mineral extraction, refining and use, as well as in quarrying, tunnelling and construction. The social, political, public health and economic context in which exposure to mineral dust occurs is also diverse. Any programme for screening and surveillance of workers exposed to mineral dust should reflect the physical as well as the general legal and economic environment in which it is established.

This monograph provides information that would be useful for the establishment of an effective health screening or surveillance programme. The screening and surveillance of workers exposed to mineral dust are considered within the framework of generally accepted principles for screening and surveillance programmes. These principles are reviewed, and specific approaches to the screening and surveillance of workers exposed to mineral dust are then discussed.

Chapter 2 distinguishes screening from surveillance and describes the objectives and methods of each. In Chapter 3, important considerations for the design and implementation of screening programmes to identify the toxic effects of workplace exposure to mineral dust are reviewed. Chapter 4 enumerates the specific elements of a screening or surveillance programme. Chapter 5 reviews the diseases that are the

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targets of screening and surveillance programmes. Chapter 6 considers the characteristics of existing screening tests. Chapter 7 offers recommendations for the screening and surveillance of workers exposed to respirable crystalline silica, coal mine dust and asbestos dust. Technical guidance that will aid test administration and quality assurance is included in the annexes. A summary of the current practices of a limited number of selected screening and surveillance programmes is also annexed.

CHAPTER 2

Definitions

The terms screening and surveillance are often used interchangeably, with confusing results. Throughout this monograph, screening, described more fully below, denotes the use of medical testing for the presumptive identification of a disease in an individual at a time before medical care would ordinarily be sought, and when an available intervention can favourably affect the health of the individual (Wilson & Jungner, 1968).

Surveillance, on the other hand, involves the periodic collection, analysis and reporting of information relevant to health for the purposes of disease prevention (Halperin & Baker, 1992). In contrast to screening, surveillance is directed towards the improvement of the health of populations and is a component of public health practice. Medical surveillance should be distinguished from hazard surveillance.

Screening

Screening is the administration of a test or series of tests (such as laboratory tests, medical examinations and questionnaires) to individuals in order to detect organ dysfunction or disease at a point when intervention would be beneficial. Positive screening tests may indicate the presence of disease, or the strong likelihood of disease and the need for confirmatory testing. Screening is designed to detect disease before an individual would normally seek medical care; it should ideally detect disease in its “preclinical” stage. The objectives of screening in a particular workplace may vary. The goal of medical screening, however, should ultimately be the secondary prevention of disease, i.e. the identification of disease at a stage when its progression can be reversed, arrested or slowed (Wilson & Jungner, 1968; Matte et al., 1990; Weeks et al., 1991).

Screening in the workplace is primarily intended to benefit the

individual; however, screening may also be used to benefit others in the same or similar workplaces if cases of occupational disease are seen as “sentinel events”. In these instances, the recognition of an occupational disease such as silicosis indicates that exposure controls have failed and that further investigation is warranted. Investigation of the workplace and of the health of co-workers can lead to the discovery of previously unrecognized disease, the identification of the source of noxious exposure, and ultimately, the reduction or elimination of hazardous working conditions (Rutstein et al., 1983; Mullan & Murthy, 1991).

Detection of disease through screening reveals deficiencies in environmental controls that might otherwise go unnoticed. Periodic screening of workers should be tied to comprehensive efforts of environmental monitoring and control.

Surveillance

Surveillance is “continued watchfulness over the distribution and trends of [disease] incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data”, as well as the timely dissemination of data “to all who need to know” (Langmuir, 1963). Over time, the practice of surveillance has progressed from the passive documentation of disease to the active analysis of data in order to generate an appropriate public health response (Halperin & Baker, 1992). The usefulness of passive surveillance systems, such as death certificate counts for specific diseases, is substantially increased when the population at risk for disease is known or estimated and disease or death rates are calculated. This extension of passive monitoring permits a more useful assessment of disease trends over time and can help to focus preventive efforts on those populations where the incidence of disease is greatest.

The major components of surveillance programmes are: (1) the periodic identification and collection of health information; (2) the evaluation and interpretation of the information; and (3) reporting and intervention for the purpose of prevention (Ordin, 1992). Surveillance programmes may be conducted by government agencies, large companies and unions, or occupational medicine clinics.

Surveillance programmes are established to achieve one or more of the following goals:

- tracking trends in disease incidence across industries, over time and between geographical areas;
- defining the magnitude or relative magnitude of a problem;
- identifying new hazards, risk factors or populations subject to risk;

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- targeting interventions;
- evaluating efforts of prevention and intervention.

Information generated by screening can be the “raw” data of a surveillance programme if these data are collected over time, analysed periodically and reported to those in a position to advocate or act in support of change, as well as to those exposed. Other than screening, sources of data for surveillance systems include workers’ compensation claims, health insurance statistics, government records of worker illness and injury, hospital discharge information, disease registries, national health surveys, death certificates and physician reporting (Ordin, 1992). Effective health surveillance systems are characterized by simplicity, flexibility, acceptability and timeliness. Surveillance systems should be sensitive indicators of the level of disease in the population at risk (Klaucke, 1992).

The utility of medical surveillance is ultimately related to the level of participation in the programme and the adequacy of data collection, analysis, dissemination and intervention. Surveillance programmes are incomplete without the application of their results and conclusions to disease prevention and control. The dissemination of surveillance information so that it is generally available, for instance through computerized national and international databases, is an important step towards achieving prevention and control. Surveillance reports that are exclusively internal to an administrative agency, company or union do not fulfil this goal. Because of the cyclical, repeating process of data collection, analysis and reporting, the value of a surveillance system increases the longer it is in place.

In some countries it is required or customary to perform periodic health examinations of workers for a range of purposes which may include the assessment of overall health and fitness for hazardous work or the detection of occupational disease. Screening may take place as part of these examinations. If the data derived from such periodic health examinations are collected, analysed and reported for purposes of prevention, these efforts constitute medical surveillance. Surveillance programmes for workers exposed to mineral dust are established in a number of countries. Each programme operates with different strategies and methods for reporting, data analysis and information dissemination. Two programmes, the SWORD programme (Surveillance of Work-related and Occupational Respiratory Disease) in the United Kingdom and the SENSOR programme (Sentinel Event Notification System for Occupational Risks) in the USA, have been described (Baker, 1989; Meredith et al., 1991). Elements of other selected programmes are summarized in Annex 2.

CHAPTER 3

Screening for toxic effects of workplace exposure

Screening primarily benefits the individuals who submit to testing. Criteria applicable to the evaluation of medical screening tests performed in community settings (Wilson & Jungner, 1968; Preventive Services Task Force, 1989; Braveman & Tarimo, 1994) and in the workplace (Halperin et al., 1986; Matte et al., 1990; Weeks et al., 1991) have been described in detail. In general, the following conditions should be considered before a screening test is adopted.

The disease:

- causes significant morbidity and mortality;
- can be identified at a pre-symptomatic stage before the individual would ordinarily seek medical care;
- responds to acceptable, available and effective intervention and treatment;
- is prevalent in the population undergoing screening.

Moreover, the test:

- is acceptable to those at risk for disease;
- has adequate sensitivity, specificity and predictive value in the target population;
- is available at a reasonable cost;
- is sufficiently standardized to be performed with consistency, accuracy and reproducibility.

If these conditions are satisfied, the screening test can be adopted. Note that there are a number of qualitative terms in this list. What is considered “reasonable cost” in the workplace may differ from what is considered “reasonable cost” in a community setting (Halperin et al., 1986). “Acceptable” interventions and treatments may also vary according to regional or cultural practice. An “adequate” level of sensitivity and specificity may depend on the severity of the condition and the

benefit achieved through intervention. In general, sensitivity should be given priority over specificity in screening programmes.

In addition to focusing on appropriate diseases and identifying reasonable tests to use in screening, the administrator or institution responsible for establishing a screening programme needs to address other issues, including the availability of suitable personnel to administer screening tests and interpret results and the presence of the appropriate equipment and facilities to perform, interpret and follow-up on tests. The desired frequency of screening examinations should also be determined.

The relationship between the natural evolution, in the absence of intervention, of the disease for which screening is proposed and the duration of previous and current levels of the exposure that causes the disease should influence the timing of screening. Screening should be conducted when there is an opportunity to detect the disease or disease-related conditions. For example, if detectable disease indicators do not occur until at least 10 years after first exposure, intensive screening could be delayed until that time, once baseline examinations have been conducted. Knowledge of exposure levels would also influence the timing of screening, since some diseases progress more quickly with high exposures. In such a case, however, knowledge of high exposures should trigger action to reduce exposure levels. The course of disease progression following the cessation of exposure should also affect decisions about screening (e.g. after a change of job or retirement).

It is also necessary to consider the appropriate dividing point between normal and abnormal test results for the screened population, since often the difference is not clear-cut. This issue is considered more fully below in the discussion of tests of pulmonary function.

It is also important to assess the level of risk, if any, from the testing programme. Naturally, the risks and benefits of the tests that are performed must be considered and weighed in light of the seriousness of the disease being screened for.

Moreover, the perceived value of the programme to workers must be taken into account. Screening programmes that are perceived to have no value or benefit to the worker are likely to be poorly supported by the target population. Numerous examples have been reported of medical information being used to deny employment or dismiss employees without sound justification (Rothstein, 1984). Provisions should be adopted to protect the privacy of workers and to ensure that the screening programme does not result in the inappropriate use of medical data. Likewise, when screening is accompanied by educational programmes and concerted efforts to control harmful exposure, workers

are more likely to trust its intent. Lastly, screening programmes should be undertaken in light of the available resources.

The actions to be taken following abnormal test results should also be defined before the establishment of a screening programme. *Some actions should always be taken:*

- Confirmation of the test result. A screening test is the first level of evaluation; further evaluation may be required to confirm a positive screening test.
- Notification of the workers (in writing) of their test results and their medical significance. Workers should be informed of any legal implications of their test results, recommendations for changes in their work practices or exposure conditions, the predicted risk from continued exposure, the nature of any disclosure of test results to the employer and any sources of additional information about their medical condition. When removal from the work environment is medically recommended, notification of the workers should include personal counselling on options for alternative employment.
- Notification of the employer and workers of the aggregate results with personal information removed.

Additional actions and interventions may vary according to the judgement of the administrator of the screening programme as well as the social, economic, legal and political environment in which the programme is offered. *Additional actions and interventions include the following:*

- Workplace modification (i.e. redesign of the work process or changes in work practice) when a toxic effect is established or strongly suspected.
- Reduction of exposure for affected workers. This may be effected by changes in the work itself or by administrative controls such as job rotation. Occasionally the use of personal protective equipment may be warranted as a temporary measure.
- Worker and employer education.
- Medical treatment and counselling; periodic follow-up evaluations if the employee has disease without clinical manifestations.
- Notification of other workers in similar industries who are at risk for disease.

CHAPTER 4

Elements of screening and surveillance programmes

In addition to the selection and implementation of appropriate medical tests, an occupational medical service engaged in screening or surveillance activities should make provision for the programme components described below.

Qualified occupational health professionals

Programmes should be managed by health professionals with specific knowledge, training and experience in the disciplines of occupational health (toxicology, biostatistics, epidemiology, industrial hygiene and medicine) and who are knowledgeable about the relevant laws, regulations and rules. Moreover, the staff responsible for the medical testing, interpretation and communication of results, the analysis and reporting of data and quality assurance should have the skills and training appropriate for their roles. Training programmes that focus on a programme's specific features are useful for orienting staff and updating their skills. Local laws and regulations may dictate the licensing and certification requirements for programme staff.

Record-keeping

The security and confidentiality of medical records should be maintained. They should therefore be separated from general personnel and employment records. The medical records should include comprehensive information on employee exposure, and should be kept current by means of periodic examinations. Because of the long latency between exposure and onset for most diseases caused by mineral dust, records should be retained for an extended period (perhaps 30 years) beyond the date of last employment. Records may be kept by the employer, government agencies, the worker or employee representatives.

Information from the record should be available to the worker, to his or her health care provider and to public health authorities in a manner consistent with local law.

Surveillance programmes should maintain records of occupational exposure and medical screening so that data can be retrieved as needed and comparisons over time and between categories of workers can be analysed in a continual fashion.

Quality assurance

The efficient performance of medical testing requires ongoing and systematic quality assurance in order to increase the accuracy and validity of test results and to promote the comparability of results over time. The latter is critical for programmes of surveillance where group trends are of particular interest. Records of all quality assurance activities should be retained.

Confidentiality

Concerns about confidentiality, and the potential adverse consequences that can result if personal medical information is inappropriately disseminated, may discourage workers from accepting valuable testing services. The *International code of ethics for occupational health professionals*, adopted by the International Commission on Occupational Health (ICOH), provides the following guidance:

The obligations of occupational health professionals include protecting the life and the health of the worker, respecting human dignity and promoting the highest ethical principles in occupational health policies and programmes. Integrity in professional conduct, impartiality and the protection of the confidentiality of health data and of the privacy of workers are part of these obligations (ICOH, 1992).

The *Code of ethical conduct for physicians providing occupational medical services*, adopted by the American College of Occupational and Environmental Medicine (ACOEM), is similar:

Physicians should . . . keep confidential all individual medical information, releasing such information only when required by law or overriding public health considerations, or to other physicians according to accepted medical practice, or to others at the request of the individual; recognize that employers may be entitled

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to counsel about an individual's medical work fitness, but not to diagnoses or specific details, except in compliance with laws and regulations; communicate to individuals and/or groups any significant observations or recommendations concerning their health and safety . . . (ACOEM, 1994).

Those initiating or maintaining a programme of medical screening or surveillance should be able to answer the following questions:

- What is the purpose of the programme: screening, surveillance or both?
- Who is responsible for the design, conduct and evaluation of the programme?
- What exposures are creating a health risk?
- What disease or condition is the target of the programme?
- Which workers are eligible for participation?
- Is the programme legally mandated or voluntary? If mandated, is legal enforcement tied to programme performance?
- Is worker participation in testing voluntary or mandatory?
- Which tests are performed?
- What is the frequency of each test? How soon after initial exposure does testing begin? How long after cessation of exposure does testing end?
- Who performs the test, and under what conditions?
- What constitutes an abnormal test result?
- What actions are taken as a result of an abnormal test result?
- Are the actions mandatory or voluntary?
- How (and when) will programme effectiveness be assessed?

It may be possible to answer only some of these questions during programme planning; some it may be possible to resolve only after initial programme evaluation. The use of pilot programmes may help determine the most effective and efficient means to establish regular and ongoing programmes.

CHAPTER 5

Diseases associated with exposure to selected mineral dusts

The principles discussed in the preceding chapters should be used to evaluate proposals for the screening or surveillance of workers at risk for disease due to mineral dust exposure. This chapter considers the effects, for which screening might be appropriate, of respirable crystalline silica, coal mine dust and asbestos dust. In the next chapter, the tests available for the detection of disease are reviewed.

The effects of mineral dust include the pneumoconioses, cancer, chronic bronchitis and chronic airflow limitation. A programme of prevention should ideally encompass all the adverse effects of mineral dust.

The pneumoconioses have long been the focus of health surveillance and preventive efforts because their cause is uniquely occupational. The term “pneumoconiosis” has been defined by the ILO (1976) as “an accumulation of dust in the lung and the tissue reaction to its presence”. Most of the other dust-induced conditions described below are less easily distinguished from diseases with etiologies other than dust exposure, for example, exposure to tobacco smoke. Nevertheless, the well documented diverse effects of mineral dust inhalation require that broad preventive efforts be implemented (Becklake, 1985; Oxman et al., 1993; Becklake, 1994).

For the purpose of developing screening and surveillance strategies, the health effects induced by the inhalation of mineral dust will be discussed with reference to the disease characteristics listed in Chapter 3. Full clinical or epidemiological descriptions are beyond the scope of this book and should be sought from other sources, three of which are cited here (Merchant, 1986; Rom, 1992; Rosenstock & Cullen, 1994). Some of the medical conditions caused by the inhalation of mineral dust have also been reviewed in a recent ILO publication (ILO, 1991).

Diseases associated with exposure to crystalline silica dust

Silicosis is the pneumoconiosis resulting from the fibrotic reaction of lung tissue to the deposition of inhaled crystalline silica dust. The risk of silicosis has been related to the amount of cumulative dust inhalation. The size distribution, surface characteristics and crystalline structure of silica particles may affect their toxicity. The silica nodule, which is a characteristic pathological entity, results from the pulmonary tissue's response to inhaled and retained silica and is radiographically detectable. These nodules may coalesce with destruction of the intervening tissue and disruption of the normal intrathoracic architecture. This is known as *progressive massive fibrosis*.

Silicosis of rapid onset, occurring within a few years of the initiation of exposure, is sometimes referred to as accelerated silicosis. Silicosis with a more indolent progression, generally not identified until one or more decades after first exposure, is sometimes referred to as chronic silicosis. Accelerated and chronic silicosis most likely result from the same disease mechanisms, however, and differ only in their period of latency. Another condition, referred to as acute silicosis, may result from a different mechanism. It is a rapidly progressive disease which develops after the inhalation of high concentrations of fine silica particles. Acute silicosis has pathological characteristics similar to alveolar proteinosis.

All forms of silicosis can progress in the absence of continued exposure, and accelerated and chronic silicosis can both appear and progress after exposure ceases. Although silicosis is irreversible, there is some evidence that the likelihood of progressive impairment from either accelerated or chronic silicosis is diminished by the early identification of disease and the cessation of exposure (Westerholm, 1980). On the other hand, if acute silicosis occurs, interventions do not appear to influence favourably the outcome of the disease. Experimental therapies or interventions that are not widely available, such as whole lung lavage and lung transplantation, have been attempted for workers with acute silicosis and for some with total pulmonary incapacity due to progressive massive fibrosis.

The risk of *tuberculosis* is greater in workers with silicosis than in the general population. Moreover, it is probable that tuberculosis is more common in workers exposed to silica but without silicosis than in the general population. The risk of tuberculosis rises significantly in workforces exposed to silica where the background rates of tuberculosis are high. Tuberculosis can cause significant morbidity and mortality, particularly if unrecognized and untreated. While effective tuberculosis treatments are available, failures and relapses have been reported

more commonly in individuals with silicosis, though this may have changed with the use of modern treatment regimens (Cowie et al., 1989).

Bronchitis and *chronic airflow limitation* have also been shown to occur more frequently in workers exposed to silica than in the general population, and their risk is thought to depend on the total exposure to airborne contaminants in the workplace (Becklake, 1989). In general, these conditions cause significant morbidity and can cause premature mortality (Cowie & Mabena, 1991). The extent to which they cause significant levels of disease in the absence of silicosis has not been well studied. Early intervention with the control or cessation of adverse exposures (e.g. dust, tobacco smoke) may result in a reversal of bronchitis symptoms and presumably also diminish the rate of progression of airflow limitation.

Lung cancer resulting from silica exposure is currently the subject of intensive scientific investigation. The International Agency for Research on Cancer (IARC) has identified crystalline silica as a potential human lung carcinogen (IARC, 1987), and, in response to this possibility, NIOSH has recommended the greatest possible protection from silica exposure. Some investigators suggest that silicosis rather than silica exposure is the most important risk factor for cancer. In any event, as with lung cancer from asbestos exposure, there is no indication at present that lung cancers associated with silica dust differ from other lung cancers. No effective methods of early diagnosis leading to successful intervention have been identified. Because exposure to silica dust is widespread and lung cancer is a common cancer, even a small difference in the relative risk of lung cancer resulting from exposure to silica dust could imply a significant number of lung cancer cases of occupational origin.

Other conditions such as *scleroderma* and *chronic renal disease* have also been associated with silica exposure in some populations, although the overall levels of morbidity and mortality for these diseases are unlikely to be sufficient to justify active medical screening.

Diseases associated with exposure to coal mine dust

Coal workers' pneumoconiosis (CWP) is one of the lung diseases arising from the inhalation and deposition of coal dust in the lungs and the reaction of lung tissue to the dust. CWP is a chronic, irreversible disease of insidious onset, usually requiring 10 or more years of dust exposure before becoming apparent on routine chest radiographs. It is characterized by macular and nodular pigmented lesions which may be visible

radiographically as small or large opacities in the lungs. When only small opacities are present, the condition is called simple CWP. Coal mine dust may contain varying proportions of crystalline quartz. CWP may be indistinguishable from silicosis on chest X-ray.

Progressive massive fibrosis (PMF), or complicated CWP, is the term used when radiographic opacities greater than 1 cm in diameter attributable to coal mine dust exposure are present. PMF has been associated with pulmonary incapacity and increased morbidity and mortality.

The risk of CWP has been related to cumulative exposure to coal mine dust. CWP, in some instances, progresses after the cessation of exposure, although this seems to be less common and less likely to occur than the progression in pneumoconiosis resulting from retained asbestos or silica dust. Chest X-ray abnormalities may be visible in the absence of symptoms. Although reduction or elimination of exposure to coal mine dust for workers with chest X-rays showing category 1 CWP (see Annex 3) would presumably result in decreased progression of the disease and fewer cases of PMF, statistical modelling based on a large data set from the United Kingdom suggests that the benefit of exposure reduction may be limited once any degree of CWP is present (Hurley & Maclaren, 1987).

Dust control strategies in a number of countries have been directed at preventing miners from developing category 2 CWP because of the increased risk of PMF associated with higher categories of CWP. In the United States, miners with category 1 CWP have been offered work in environments with a maximum dust exposure of 1 mg/m^3 (time-weighted working-shift average). It was anticipated that this would result in the virtual elimination of PMF. The strategy has not been completely successful, however, in part because PMF can appear on an X-ray otherwise free of recognizable diffuse fibrosis or with only minimal fibrosis (ILO category 0 or 1) (Hurley et al., 1987; Jacobsen, 1990). The shortcomings of this approach to screening and intervention to prevent PMF are detailed in a recent review (Attfield, 1992).

Chronic bronchitis and *chronic airflow limitation* including accelerated loss of FEV_1 (Forced Expiratory Volume in 1 second) are more common in workers exposed to coal mine dust than in others with comparable tobacco-use habits. These conditions appear to be dose-related. Chronic bronchitis may be reversible if exposures are controlled early. Moreover, the rate of FEV_1 loss can presumably be diminished through a reduction or elimination of exposure, although the rate of loss that should trigger action and its optimal timing remain subjects of investigation. Chronic bronchitis, airflow limitation, CWP and *emphysema* all result from exposure to coal mine dust and may

occur in various combinations. The chest X-ray is not a reliable predictor of the likelihood of airflow limitation associated with dust exposure. In general, a diminished FEV₁ is associated with increased morbidity and premature mortality. Thus, dust exposure that does not result in the development of CWP or PMF may still cause or contribute to clinically significant airflow limitation (Marine et al., 1988).

Above-normal risk for the development of *stomach cancer* has also been associated with coal mine dust exposure (Ames & Gamble, 1983), although the level of increased risk is not great and the underlying population prevalence of this condition is generally low. Stomach cancers can potentially be detected in a preclinical stage through testing for faecal occult blood, and early surgical intervention may have a beneficial impact on mortality.

Diseases associated with exposure to asbestos dust

Asbestosis is a non-malignant lung disease caused by the inhalation and retention of asbestos fibres and the lung tissue's reaction to these fibres. The occurrence of asbestosis depends on the cumulative level of respirable asbestos fibre exposure. In environments where levels of airborne asbestos are low, several years of exposure are required to produce asbestosis. Although studies of animal exposure reveal the onset of disease within months after first exposure, in humans the signs and symptoms of asbestosis generally do not appear for years, or even decades, following initial exposure. Once recognized, the disease can have an indolent or a gradually or rapidly progressive course, even in the absence of additional asbestos exposure. Asbestosis can cause incapacity or death. Dyspnoea on exertion is usually the most prominent symptom of asbestosis and may precede any abnormalities noted through medical testing. Other symptoms include coughing and chest pain. No treatment or intervention has been shown to diminish or reverse the progression of asbestosis once the disease is established. There is, however, some evidence that cessation of exposure may diminish the rate at which radiographic change progresses and presumably the rate at which pulmonary disability develops (Becklake, 1991; Becklake, 1992).

Pleural fibrosis, in the form of discrete plaques or diffuse thickening of the pleura, can occur concurrently with or independent of pulmonary fibrosis. One or more discrete areas of fibrosis (plaques) may be recognized along the diaphragm or along the lateral chest walls. The occurrence of pleural fibrosis increases with the time from first exposure and with the age of the worker. Diffuse pleural fibrosis, with or without

blunting or obliteration of the costo-phrenic angle on chest X-ray, is less common than discrete plaques and is often associated with significant abnormalities in pulmonary function. Discrete plaques may also be associated with pulmonary dysfunction, even in the absence of radiologically determinable parenchymal disease (Schwartz, 1991; Ernst & Zejda, 1992). Pleural fibrosis may be present as an incidental finding on chest X-ray when there are no abnormal chest complaints. Pleural plaques that are visible on chest X-ray are quite common in certain occupations. For example, in shipyard workers and construction insulators, the incidence of pleural plaques often exceeds that of parenchymal radiographic change (Becklake, 1991). A common characteristic of these occupations is intermittent exposure to high levels of dust. In areas of high tuberculosis prevalence a determination of the etiology of pleural fibrosis by radiography alone may not be possible. Pleural disease is rarely of sufficient severity to justify intervention, although surgery has been used to treat diffuse pleural thickening in its advanced, disabling stages.

Benign pleural effusions lasting from weeks to months before spontaneous resolution occur in workers exposed to asbestos, often within the first two decades of initial exposure. These effusions are sterile and without malignant cells. Associated symptoms such as non-specific chest pain may be present. There are data that suggest an association between the development of diffuse pleural fibrosis and antecedent pleural effusions. The extent to which other morbidity may result from benign effusions is unknown. Although pleural effusions have been identified without associated symptoms, there is no clear "preclinical" stage to this condition, nor are there any reported studies evaluating the results of interventions.

Chronic bronchitis — defined as a persistent cough with phlegm — occurs more often in people who work in dusty environments than in those who do not when they are compared with others with similar smoking habits. This observation has been confirmed in some cohorts of workers exposed to asbestos (Ernst & Zejda, 1991). The association of chronic bronchitis with cancer or asbestosis in workers exposed to asbestos has not been well studied. If exposure to dust is eliminated in people with chronic bronchitis, it may, in some cases, lead to the resolution of symptoms.

Chronic airflow limitation due to the narrowing of small airways as a result of the inflammation and fibrosis of the respiratory bronchioles (demonstrable on spirometry as a reduction in mid-expiratory flow rates) is widely accepted as a manifestation of asbestos exposure, even in the absence of visible asbestosis on chest X-ray (Ernst & Zejda, 1991). *Pure airflow obstruction*, demonstrable as a reduction in FEV₁, probably

also occurs (Becklake, 1989; Bakke et al., 1991). Some studies report FEV₁ deficits in asbestos workers with pleural fibrosis (Schwartz, 1991). Others have demonstrated an association between airflow limitation and increasing parenchymal fibrosis visible on chest X-ray. Controlled intervention studies capable of providing guidance on the benefit of intervening at various stages during the loss of FEV₁ are unlikely to be carried out, and there is a dearth of observational reports. Nevertheless, control of adverse pulmonary exposures is likely to reduce the rate of loss in the FEV₁ and thus diminish morbidity over time.

Respiratory tract cancers are the most common cancers associated with occupational asbestos exposure. These are pathologically indistinguishable from other respiratory tract cancers. Cancers of the lung are seen more frequently in workers exposed to asbestos than in others with comparable smoking habits; the same is true with respect to laryngeal and pharyngeal cancer. When cancers occur, their period of latency averages about 25 years from first asbestos exposure. Exposure to both asbestos and cigarette smoke puts workers at considerably higher risk for the development of cancers of the respiratory tract (Rothwell, 1992). There is evidence that the cessation of smoking diminishes lung cancer risk within a decade in individuals with previous asbestos exposure, as compared with those who continue to smoke. In some cohorts of workers exposed to asbestos, lung cancer appears to be confined to those who have already developed pulmonary fibrosis. In other cohorts, lung cancer has been documented in subjects without radiographically visible pulmonary fibrosis (Wilkinson et al., 1995). The fact that the development of both fibrosis and lung cancer is related to cumulative exposure to asbestos has precluded clear resolution of the controversy whether fibrosis is a necessary step in the development of asbestos-related lung cancer. It is possible that more than one pathological process can result in lung cancer.

Lung cancer is the most common malignant cause of death for men in many countries. Intensive efforts to detect its early indicators through frequent sputum cytology and chest X-ray analysis have failed to have a favourable impact on the morbidity or mortality of high-risk groups (Marfin & Schenker, 1991).

Malignant mesotheliomas of the pleura, peritoneum or mediastinum, which may all occur spontaneously, are presumed to result from exposure to asbestos fibres if there is a credible history of asbestos exposure and a reasonable latency period. Malignant mesothelioma has been reported in association with apparently minimal exposure to asbestos after many years of latency. The expected exposure-response relationship may not always be clearly demonstrable, perhaps because of the competing risk of other malignant and non-malignant diseases,

with shorter latency periods, that are evoked by higher exposures to asbestos. The period of latency between first exposure to asbestos and the development of mesothelioma is, on average, longer than that for bronchogenic cancer, averaging 30–35 years. Such tumours grow rapidly and are invariably fatal, at least with current therapeutic options (i.e. surgery and chemotherapy).

Cancers of the gastrointestinal tract, including cancer of the oesophagus, stomach, pancreas, colon and rectum, have been observed to occur more frequently in some, but not all, populations with heavy exposure to asbestos. The risk of cancers of the gastrointestinal tract from asbestos exposure appears to be less than the risk of lung cancer. In populations without asbestos exposure, gastrointestinal tumours (both benign and malignant) have been identified in preclinical stages through testing for occult faecal blood and sigmoidoscopy; early detection and surgical treatment appear to have a favourable effect on morbidity and mortality (DeMers & Parsons, 1994).

Other cancers, including certain *lymphomas* and *kidney cancer*, have been observed more frequently in a few populations exposed to asbestos. The interrelationships between multiple pathogenic exposures may account for the diversity of malignancies associated with asbestos exposure. The morbidity and mortality resulting from lymphomas and kidney cancer are far less than those of the other cancers linked to asbestos exposure. There have been no reported studies of efforts for the early detection and treatment of these conditions in workers exposed to asbestos.

The risk of developing any particular disease varies in working populations according to the type of work performed, even when all workers are exposed to the same types of asbestos fibres, and exposure levels are taken into account. Patterns of disease also vary in relation to the particular type of asbestos fibre present in the work environment. The specific toxicity of fibre types is an active area of scientific investigation. Regardless of the additional information that may thus be yielded, it is clear that exposure to respirable asbestos fibres of all types must be considered hazardous. In many work settings (such as construction, repair and demolition), materials often contain a mixture of fibre types, and useful information about the specific composition is generally lacking. In such circumstances, prudent practice dictates that exposed workers should be afforded the highest level of health protection. Furthermore, various synthetic fibres are currently used in some work processes as substitutes for asbestos. The more closely these fibres resemble asbestos (in size, shape, durability and surface characteristics) the more likely they are to cause disease and thus the more intense control and surveillance efforts should be.

CHAPTER 6

Tests for detecting diseases induced by exposure to mineral dust

The tests commonly used to detect diseases related to mineral dust exposure include questionnaires, chest radiographs, spirometry and physical examination. Other tests include sputum examination, other imaging techniques, other measures of lung function, bronchoscopy, skin testing for tuberculosis and stool examination for occult blood (Balmes, 1990). A number of biological markers are under investigation with respect to their relationship to the occurrence of diseases caused by mineral dust.

Conventional chest radiography (X-rays)

Chest radiographs are the most important means for the detection of pneumoconioses (asbestosis, silicosis and coal workers' pneumoconiosis). As described above, responses to dust inhalation vary with the mineral inhaled. These differences are also reflected in the patterns of abnormality that are characteristically present on radiographs.

A standardized method of X-ray interpretation (see Annex 3) published by the International Labour Office (ILO) is often used to recognize and classify the pneumoconioses (ILO, 1980). With this method, opacities resulting from inflammation, dust deposition or scarring are classified according to their shape, size, location and profusion. Profusion is determined by comparing the worker's film with standard films distributed by ILO. Some exposures, such as to coal mine and crystalline silica dust, can result in the development of opacities greater than 1 cm in diameter. These are classified according to size. There are also conventions for classifying pleural abnormalities as well as for noting the appearance of changes suggestive of certain other diseases.

The ILO system was originally established to improve disease detection and achieve consistency in film interpretation during health sur-

veillance and epidemiological investigations. It has also been used for the determination of disability compensation and clinical evaluation, although it was not designed for these purposes. Despite efforts to achieve standardization in the interpretation of chest X-rays through the use of the ILO system, there remains significant inter-reader and intra-reader variability manifested as disagreement between readers, or the same reader at different times, on the presence or absence of abnormalities. Some interpretive variability can be reduced through attention to the production of consistent, high-quality radiographs. In addition, a programme of training, testing and certification of readers, such as the "B" reader certification programme in the United States, may be of value in improving reader consistency (Morgan, 1979; Attfield & Wagner, 1992; Wagner et al., 1992).

Radiographs may be insensitive to early changes resulting from exposure to dust. For example, it has been estimated that nearly 20% of workers exposed to asbestos with fibrotic pulmonary changes found on pathological examination have no detectable radiographic abnormalities (Kipen, 1987). Physicians untrained or inexperienced in the recognition of occupational lung disease may miss certain abnormalities, which are often quite subtle. Nevertheless, particularly at higher profusions of coal- and silica-induced lesions, there is a reasonable correlation between the findings of lung pathology and radiography (Ruckley et al., 1984).

Periodic chest radiographs reviewed for abnormalities consistent with pneumoconiosis are the primary means of screening for disease in workers exposed to mineral dust. This technique has been employed internationally. Surveillance reports based on the use of this tool demonstrate its utility (Attfield & Althouse, 1992).

Chest radiographs are not an adequate tool for surveillance or recognition of all occupational lung diseases. Bronchitis is not detectable on chest X-ray. Emphysema is accurately recognized only in advanced stages. Other methods of investigation are needed for these disorders as well as for the identification of functional changes associated with exposure to disease-inducing dusts. Periodic radiographs, alone or in combination with sputum cytology, have also been unsuccessful in identifying lung cancers at a stage sufficiently early to improve the outcome of therapy (Fontana et al., 1991).

Periodic chest X-rays are generally acceptable to those at risk for disease. They are widely available in developed countries and may be available in developing countries. In developing countries miniature films from tuberculosis screening programmes may be available even if full-sized radiographs are not (Cowie & van Schalkwyk, 1987). The ILO classification system was developed using full-size radiographs;

therefore, the use of miniature radiographs may result in a systematic under-recognition or over-recognition of disease (Fukuhisa et al., 1989). A relatively inexpensive Basic Radiological System capable of producing adequate full-size chest radiographs has been developed under the guidance of the World Health Organization (Holm et al., 1986). Additional technical guidance on the use and interpretation of chest radiographs can be found in Annex 3.

In summary, chest radiographs interpreted in a standardized fashion are the basic means for identifying workers with pneumoconioses. While acceptable to subjects and widely available, often at reasonable cost, the sensitivity, specificity and predictive value must be considered in the context of the circumstances in which screening or surveillance will take place. The uses and limitations of chest radiography in evaluating miners have been reviewed recently (Wagner et al., 1993).

Additional imaging techniques

Other imaging techniques have proved useful in the diagnosis and investigation of lung disease but are not recommended for screening or surveillance. For example, computed tomography of the chest, including high-resolution computed tomography (HRCT), has been a sensitive and specific tool both in the identification of pleural abnormalities resulting from asbestos exposure and in distinguishing them from normal lung structures such as pleural fat. "Thin slice" HRCT views of the lung have also been shown to identify interstitial fibrosis caused by asbestosis when the chest radiograph is ambiguous. The value of gallium scanning has also been promoted by some investigators as a means of identifying lung tissue inflammation associated with mineral dust inhalation. These techniques are generally acceptable to workers under investigation. At present there is no role for the use of these tools for screening or surveillance because of the high dose of radiation they entail, as well as high cost, lack of availability, and lack of standardization in the interpretation and reporting of abnormalities. Although some have suggested that, where available, a single "thin slice" HRCT which limits the radiation dose may eventually prove comparable in cost and be superior in sensitivity and specificity to conventional chest radiographs for screening and surveillance, this is not yet the case.

Measures of lung function

The most widely available tests of lung function (i.e. spirometry tests) record the volume of air a subject forcibly exhales in one second following a maximal inhalation (FEV_1) and the total volume exhaled without a time limit (Forced Vital Capacity (FVC)). These values, and their ratio (FEV_1/FVC), are compared with reference population averages for non-exposed individuals of the same sex, height and age and are reported both as absolute values and as a “percentage of predicted”. Criteria for the selection of appropriate reference populations are discussed in Annex 4. Subjects with diseases causing a limitation of airflow out of the lungs have a lowered FEV_1 but a well preserved FVC and are said to demonstrate an *obstructive defect*. Subjects with sufficient scarring of the lungs to diminish expansion during inspiration have reductions in the FVC and are said to have a *restrictive defect*. Often subjects with advanced lung disease have reductions in both the FEV_1 and the FVC. The FEV_1/FVC ratio, compared with average values, can suggest whether the defect is predominantly obstructive or restrictive. Significant airflow limitation can result in an inability to empty the lungs fully during forced expiration, resulting in “air trapping”. This may give the false impression that a restrictive defect is present, because the FVC will be diminished. Other diagnostic tests such as the measurement of total lung capacity (TLC) are necessary to determine whether the reduced FVC is due to air trapping or volume restriction.

There is no pattern of spirometry abnormalities that will distinguish lung diseases induced by mineral dust from those resulting from non-occupational causes. Spirometry alone cannot diagnose pneumoconioses or other occupational lung diseases, but it is useful in quantifying abnormalities and defining a pattern of response in exposed workers. Spirometry has been particularly useful in investigating the consequences of exposure to a suspected hazard by comparing groups of exposed workers with a group of non-exposed workers. In such an instance, the average lung function of exposed workers may differ significantly from the average of unexposed workers, even though values for most workers in both groups may fall within a “normal” range (ATS, 1991).

There is no clear or absolute separation between “normal” and “abnormal” values for lung function tests. Studies have indicated that many individuals with pulmonary disease as judged by other criteria will have spirometry values within the so-called “normal” range. Similarly, others without disease may fall in the abnormal range. How many are included in one group or another depends on where the line separating normal from abnormal is drawn, as well as which of the many available

reference values are used (ATS, 1991). People with jobs may have better lung function, on average, than people in the total population (which includes those too sick to work) (Becklake & White, 1993). For this reason, or because of pre-employment examinations or self-selection it is not unusual for working people to score above general population averages (i.e. above 100% of predicted) on spirometry tests.

The utility of periodic testing of lung function in individuals exposed to mineral dust has not been fully investigated. Clearly, there should be a point at which accelerated decline can be recognized and at which cessation of exposure might be expected to result in diminished morbidity. Using the individual worker as his or her own "control" for comparison purposes, rather than relying on population averages to define abnormality, is attractive. Variability in a subject's own test performance, however, can exceed the expected annual decline due to age and complicates the interpretation of longitudinal results. The point at which an apparent excess loss of FEV₁ or FVC predicts permanently increased morbidity or mortality has not been established. Concepts concerning the interpretation of longitudinal results have been presented recently (Hankinson & Wagner, 1993) and are discussed more fully in Annex 4.

Standardized methods for spirometry testing and specifications for equipment have been recommended by professional associations such as the American Thoracic Society (ATS, 1995) and the European Respiratory Society (Quanjer et al., 1993). Spirometry is generally acceptable to those at risk for disease and is widely available in developed and many developing countries. Inadequate calibration or standardization of test procedures may limit the value of spirometry. The sensitivity, specificity and predictive value depend on the cut-off points adopted and on whether population averages or prior results from the individual are used as the basis for comparison. Technical guidance concerning the performance and interpretation of spirometry is included in Annex 4.

Other tests of lung function in common use for diagnostic purposes include arterial blood gas testing (at rest and during exercise), body plethysmography (with measurement of intrathoracic gas volume and airway resistance), measurement of the diffusion capacity of the lung, measurement of lung compliance, and tests of bronchial reactivity. These tests may be useful if spirometry values are not reproducible or if the spirometry values differ significantly from those expected from symptom reports. Cost, availability, standardization and acceptability limit the value of these tests for screening or surveillance purposes.

Questionnaires

In clinical medicine, enquiring about a patient's symptoms is the usual first step in an evaluation. Those suffering from lung diseases may cough, wheeze or experience shortness of breath or chest pain with or without having significant abnormalities detectable by laboratory testing. Thus, asking people questions about respiratory symptoms in a systematic fashion and analysing the results has been one of the most powerful tools in the epidemiological investigation of occupational lung disease. The effectiveness of using questionnaires for screening purposes, independent of other medical testing, has not been well explored.

Questionnaires can provide important and useful information quickly and inexpensively. They are generally acceptable to those at risk for disease, although consideration needs to be given to the educational level and literacy of the target group. The quality of information resulting from a questionnaire depends upon the suitability of the questionnaire for detecting abnormality (sensitivity), correctly confirming the absence of abnormality (specificity), eliciting the same responses over time (consistency) and avoiding under-reporting or over-reporting of abnormality (bias) due to inappropriate wording or construction. Each of these characteristics of questionnaires may independently differ according to the specific circumstances and population in which the questionnaire is used.

Systematic questioning concerning the symptoms associated with exposure to mineral dust is aided by the use of standardized questionnaires, and the information they provide has been studied in a variety of settings over many years. Respiratory symptom questionnaires have a long history. Examples include a questionnaire used to investigate the natural history of chronic bronchitis (MRC, 1960) and a questionnaire developed by a committee organized by the American Thoracic Society (ATS) (Ferris, 1978) to study the epidemiology of airway disease. Questionnaires have been used frequently in the investigation of occupational lung disease, including one developed by the International Union Against Tuberculosis and Lung Diseases (IUATLD) (Burney & Chinn, 1987) to investigate asthma. Each presents a series of questions concerning respiratory symptoms, previous and current respiratory conditions and tobacco use. Some questionnaires include a work history to identify previous hazardous exposures in the workplace. The use of identical questions increases the comparability of data obtained from different groups, and hence the validity of comparisons between groups.

Questionnaires can be useful even when translated from their

original language. For example, the comparability of data derived from a French translation of the ATS questionnaire with those derived from the original version has been established, except for responses to certain translations of the term “wheezing” (Osterman et al., 1991). The ATS and MRC questionnaires have been modified by investigators at different times, usually by the addition of questions to meet the needs of particular studies. New questions should be incorporated into standard questionnaires so as to preserve as much as possible the original order of questions.

Of the conditions described above, few are amenable to early identification through questionnaires alone. Chronic bronchitis might be a candidate for screening using this tool. Dyspnoea and chest pain indicating the onset of problems can be identified through responses to questionnaires. Information concerning tobacco use, age and prior or current occupational exposures that can contribute to the targeting or timing of preventive interventions can also be ascertained by questionnaire.

Questionnaires are useful, if not essential, for the systematic elicitation of work and exposure histories. These data can be used to establish an index of potentially hazardous exposures and may be a useful guide in the selection of individuals for inclusion in programmes of medical screening and surveillance, through the defining and ordering of risk groups. In addition, exposure data reported on questionnaires can be used to investigate exposure–response relationships in epidemiological investigations of industries where objective exposure data are lacking (Fonn et al., 1993a).

In summary, questionnaires may provide useful information in conjunction with other medical testing when used in a programme of screening or health surveillance. Their value as an independent tool for the early identification of diseases attributable to exposure to mineral dust is unproved and, in fact, not asserted in the literature, although investigators have correlated the loss of lung function with questionnaire responses in populations exposed to mineral dust (Brodkin et al., 1993; Fonn et al., 1993b). Questionnaires administered over time in a standardized fashion may provide useful surveillance information including, in some circumstances, exposure information. Technical guidance concerning questionnaire use is given in Annex 5.

Physical examination

The physical examination is an important component of the health care services provided to individuals. The respiratory system can be exam-

ined by visual observation (inspection), touching (palpation), tapping (percussion) and listening with a stethoscope (auscultation). Abnormalities detectable by inspection, palpation and percussion tend to be either acute and unrelated to exposure to mineral dust, such as an asthma attack or lung infection, or chronic and fairly advanced, such as the barrel chest of a patient with emphysema. Auscultation can reveal abnormal lung sounds that are associated with lung dysfunction. For example, wheezing (during quiet or forced expiration) unassociated with an acute asthma attack may indicate airflow limitation due to the partial obstruction, narrowing or collapse of large airways, or due to the loss of elastic recoil caused by emphysema. All these abnormalities may be present as a result of coal mine dust exposure. Persistent fine crackles, called rales, may be caused by fibrosis of the lung parenchyma. These sounds are often heard in individuals with asbestosis and may be detected before there are definite radiological changes. For many individuals with lung abnormalities, however, physicians are unable to discern any changes in the breathing patterns or breath sounds on physical examination. Also, abnormalities noted by one observer at one time may be unrecognized by another observer or, at other times, by the same observer.

Physical examinations are generally acceptable to most workers. Examinations by trained personnel may be available at reasonable cost. Nevertheless, insensitivity, non-specificity, the lack of standard methods for recording findings, inter-observer variability and variability in the persistence of abnormal findings over time limit the value of physical examinations as a "stand-alone" tool for the surveillance or screening of workers exposed to mineral dust. Although such examinations remain the cornerstone of periodic health assessment and are an integral component of health services for workers in many locations, physical examinations are not recommended as an independent tool for screening or surveillance of workers exposed to mineral dust.

Sputum examination

Sputum can be examined for *Mycobacterium tuberculosis* or other infectious agents, malignant cells, asbestos bodies, and other biological markers. Cytology of induced or randomly produced sputum can, in some instances, identify malignant cells before tumours are visible on radiographs. Nevertheless, the benefit of sputum examination (in terms of increased life expectancy or increased lung cancer cure rates) has not been demonstrated in research evaluating the periodic screening of heavy tobacco users (Marfin & Schenker, 1991). In these screening

programmes, subjects were examined serially with chest radiographs and sputum cytology. While some cancers were detected earlier by cytological examination of sputum than they would have been by chest X-rays or symptoms alone, the cancers were on average sufficiently advanced at the time of detection that intervention brought no added survival benefit. It is reasonable to assume that sputum cytology might also fail to have a favourable impact on the life expectancy and cancer cure rates of workers exposed to mineral dust. The techniques of sputum induction may not be acceptable to some workers, and testing is expensive and not widely available. Sensitivity, specificity and predictive value all appear to be low.

Thus, at this time, the weight of evidence does not support the general use of sputum cytology for the early detection of lung cancer in workers exposed to asbestos or silica dust. In populations where tuberculosis infection is common, however, sputum examination or culture may be a valuable means of screening for tubercle bacilli in workers exposed to silica dust. Moreover, because of the incomplete protection against tuberculosis afforded by BCG administration, as well as the futility of tuberculin skin-testing in BCG-protected workers, sputum examination is useful in screening workers who have received BCG.

Asbestos bodies are often found in the sputum of exposed workers but rarely in the sputum of individuals who are not occupationally exposed to asbestos. Their presence has been shown to reflect cumulative exposure. The presence of asbestos bodies may therefore help determine who should be included in a programme of medical screening or surveillance where the level of exposure is in doubt. The absence of asbestos bodies does not, however, preclude the possibility of significant past exposure to asbestos.

Bronchoscopy and broncho-alveolar lavage

The utility of bronchoscopy, including ultra-thin bronchoscopy, and broncho-alveolar lavage for investigating workers exposed to mineral dust was considered by an expert group convened by the World Health Organization (WHO, 1990). These techniques were noted to represent an advance in diagnostic methodology and to have important implications for scientific investigations. Nevertheless, the value of these approaches for screening and surveillance are limited by their cost, acceptability and availability. Moreover, the sensitivity, specificity and predictive value of these tests are undetermined. Therefore, at this time neither bronchoscopy nor broncho-alveolar lavage is considered appropriate for use in screening programmes.

Tuberculin skin-testing

Standardized methods for tuberculin skin-testing of the general population have been recommended and adopted in countries where tuberculosis incidence is low and prophylactic treatment following primary infection is available. Results are more difficult to interpret, however, in individuals from populations where tuberculosis prevalence is high or BCG vaccination has been used for primary prevention. In these instances sputum examination may be necessary. Skin-testing is generally acceptable to workers, and skin-test conversion has been an effective method for the identification of an "at risk" population at a stage in the disease where intervention is effective. The increased risk for developing tuberculosis in workers exposed to silica should increase the benefit to be derived from testing and intervention in this population. However, the results of chemoprophylaxis in miners and other workers with silicosis have been somewhat disappointing (Cowie & Dansey, 1992; Hong Kong Chest Service et al., 1991).

Stool examination for occult blood

Test methods for the identification of occult blood in stool are readily available in most industrialized countries. Routine periodic performance of this test, in conjunction with sigmoidoscopy and digital rectal examination, has been recommended by the American Cancer Society (ACS, 1980) for people over the age of 50, regardless of occupational risk status, on the basis of studies showing the utility of screening for the early detection of colorectal cancer. Some groups in the United States have initiated colorectal cancer screening programmes in the workplace in response to these recommendations (Neale et al., 1989). However, a recent report from an expert group convened by the United States Public Health Service did not recommend either stool examination for occult blood or sigmoidoscopy for community screening (Preventive Services Task Force, 1989). The expert group did not specifically consider occupational groups at increased risk of colon cancer but stated that clinical prudence dictates that individuals over the age of 50 years with known risk factors for colon cancer should be screened. Colorectal cancer screening is directed towards the secondary prevention of large bowel cancer. The potential benefit for early identification of gastric cancer is less certain. Cultural and educational factors may influence the acceptability of the test. Its sensitivity and specificity vary with the specific methods employed and may also be influenced by factors such as diet, drug use, alcohol consumption and the prevalence of intestinal parasites.

CHAPTER 7

Recommendations

The prevention of diseases that result from exposure to mineral dust in the workplace depends primarily on compliance with health-protective exposure limits (WHO, 1986), supported by relevant legal standards and effective enforcement. Screening, an important secondary measure, can benefit workers who experience adverse effects from past or present exposures and can be a useful supplement to primary prevention efforts. As an outgrowth and extension of screening, surveillance activities can track trends in disease incidence, identify areas for intervention and aid in the evaluation of preventive efforts.

The development of screening and surveillance programmes is a complex task. Medical tests must be critically evaluated to determine whether they satisfy the appropriate criteria for screening tests and are able to accomplish the goals of the programme. The design of a screening and surveillance programme must also be specified in sufficient detail to determine whether it is economically, legally and politically feasible. Generally, feasibility will depend substantially on the material, financial, legal and cultural constraints in the country, region or industry where the programme will be conducted.

No single set of guidelines is applicable to the development and implementation of a programme for the screening and surveillance of workers exposed to mineral dust. Eligibility for and frequency of examination, the specific examination used, methods of interpretation and analysis of results, procedures for the reporting of data, the interventions that may be recommended, and the means of evaluation will all reflect local priorities, resources, laws, customs, language and public health infrastructure. In addition, the potential level of workplace exposure to hazardous dust and the exposure controls that are currently in place will affect the design of screening programmes.

Recommendations for the periodic screening and health surveillance of workers exposed to mineral dust are presented below. The recommendations assume that reasonably effective hazard control and

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monitoring systems are already in place. In arriving at these recommendations, the central issues were understood to be:

- Do the diseases for which workers are at risk as a result of exposure to mineral dust lend themselves to screening?
- Will screening by means of available tests permit the identification of disease at a point where useful intervention is possible?
- Can periodic screening provide information that is consistent with public health surveillance goals?

Efforts aimed at primary prevention are enhanced by the periodic collection, analysis and reporting of data generated by medical screening. Hence, it is strongly recommended that well thought-out surveillance programmes should be implemented in conjunction with all screening programmes. These recommendations are presented in the form of answers to the questions posed in Chapter 4.

- *What is the purpose of the programme: screening, surveillance or both?*
Screening and surveillance should be for non-malignant diseases due to exposure to mineral dust.
- *Who is responsible for the design, conduct and evaluation of the programme?*
A responsible individual with an appropriate organizational affiliation should be identified. Depending upon circumstances, the employer or a government agency should be responsible for health surveillance programmes.
- *What exposures are creating a health risk?*
Exposure to one or more mineral dusts should be known to occur.
- *What disease or condition is the target of the programme?*
Pneumoconioses, chronic airflow limitation and tuberculosis should be targeted.
- *Which workers are eligible for participation?*
All workers at risk for disease as a result of their exposure to mineral dust should be eligible.
- *Is the programme legally mandated or voluntary? If mandated, is legal enforcement tied to programme performance?*
The programme should be legally mandated, with legal enforcement tied to programme performance.
- *Is worker participation in testing voluntary or mandatory?*
In countries where participation is voluntary, disincentives to participation should be identified and removed, and incentives for participation should be considered. All programmes should aim at achieving complete participation.

- *Which tests are performed?*

A programme for the collection of screening information useful for the surveillance of workers exposed to mineral dust should include the following elements:

- a questionnaire that systematically enquires into work and exposure history; systematic enquiry into relevant health symptoms may also be desirable;
- a chest radiograph (highly recommended), systematically interpreted (e.g. using the ILO system);
- spirometry;
- tuberculin skin-testing for workers exposed to crystalline silica or coal mine dust, unless the workers have been immunized with BCG;
- a physical examination for workers exposed to asbestos.

- *What is the frequency of each test? How soon after initial exposure does testing begin? How long after cessation of exposure does testing end?*

Test frequency should depend on the level of health risk that is assessed on the basis of the intensity and duration of current and past exposure and disease patterns in the population. Although it might be desirable to quantify exposure on the basis of industrial hygiene data and to develop test schedules based on such an index, this is rarely possible. Test schedules, including the frequency of testing following the cessation of exposure, inevitably reflect local constraints. In particular, the availability of resources for the performance, analysis and reporting of tests may influence test frequency. Testing should not be substituted for aggressive exposure monitoring and control.

The following frequency recommendations assume that workers are free of symptoms or signs of disease and that effective exposure controls are in place:

Workers exposed to crystalline silica or coal mine dust. A baseline chest radiograph should be obtained at the start of employment, then after 2–3 years of exposure and every 2–5 years thereafter. Ideally, spirometry results and responses to an updated symptom questionnaire should be obtained annually, beginning with the start of employment; if this is not possible they can be obtained at the same frequency as the chest radiographs. Ideally, health surveillance, particularly for workers exposed to silica dust, should be lifelong.

Workers exposed to asbestos dust. A baseline chest radiograph should be obtained at the start of employment, then every 3–5 years thereafter for workers with less than 10 years since first asbestos exposure; every

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1–2 years for workers with over 10 years since first asbestos exposure; and annually for workers with more than 20 years since first exposure. These frequencies may be adjusted depending on the age of the worker and the intensity and duration of exposure. Ideally a respiratory symptom questionnaire, physical examination and spirometry should be performed annually; alternatively, they can be performed at the same frequency as the chest radiographs. Ideally, health surveillance for workers exposed to asbestos should be lifelong.

- *Who performs the test, and under what conditions?*

Tests should be performed by trained technical staff, using equipment and procedures as described elsewhere in this publication. Medical examinations should be provided free of charge to workers and carried out, as far as possible, during their regular working hours without loss of earnings.

- *What constitutes an abnormal test result?*

Radiographs are considered abnormal if they are consistent with the presence of pneumoconiosis (ILO category 1/0 or higher) or PMF. Spirometry is considered abnormal if the FEV₁ or FVC is below the lower boundary of the 95% confidence interval for the average value of an appropriate reference group. Reference values should take into consideration age, sex and height. Once a baseline is established, the loss of 15 percentage points from the baseline value is considered abnormal (e.g. a drop from 105% of predicted to 90% of predicted). (See Annex 3 and Annex 4 for further discussion of the interpretation of radiographs and spirometry.)

- *What actions are taken as a result of an abnormal test result?*

Workers should be notified of their test results in writing, and counselling should be provided concerning the significance of any abnormal results. In addition, workers should be informed of any legal implications of their test results, recommendations for changes in work practices or exposure conditions, their predicted risk from continued exposure, the nature of any disclosures to their employer and sources of additional information. When removal from the work environment is recommended, the notification of workers should include personal counselling on alternative employment options.

All reasonable efforts should be made to permit continued employment in an environment free of dust or with diminished dust exposure. More intensive environmental monitoring and the consideration of more frequent health monitoring is therefore a possible

result. Abnormal test results should also be reported to public agencies in accordance with national law and practice.

In addition, employers and workers should be notified of the aggregate test results with personal information removed.

Additional actions and interventions may be taken according to the judgement of the administrator of the screening programme as well as the social, economic, legal and political context in which the programme is offered. Such actions and interventions include the following:

- workplace evaluation and modification (redesign of the work process or changes in work practice) when a toxic effect is established, or strongly suspected, after an assessment of existing control measures;
 - reduction of exposure for affected workers. This may be effected by changes in work practice, process modification or administrative controls such as job rotation. Occasionally the use of respiratory protective equipment as a temporary measure may be warranted;
 - worker and employer education;
 - medical treatment and follow-up counselling; periodic follow-up evaluations if the employee has a preclinical state of disease;
 - notification of other workers in similar industries.
- *Are the actions mandatory or voluntary?*
The provision of preventive interventions should be mandatory.
 - *How (and when) will programme effectiveness be assessed?*
The adequacy of preventive efforts should be assessed by public health surveillance through use of the data generated by the programme. Compliance investigations should be regularly conducted to provide information on the implementation of screening and surveillance programmes.

A programme of medical screening can be part of a system of health surveillance and should be linked to effective engineering controls of exposure and not substituted for them. Large numbers of workers may have been harmed by workplace exposures before being identified by even the most intensive screening programme. Medical screening can identify people with disease but does not in itself prevent disease. Screening and surveillance programmes are futile if isolated from effective programmes of exposure monitoring and control. Recognition of the victims of excessive exposure should not be an end in itself but a means to improve future preventive efforts.

References

- ACOEM (1994) Code of ethical conduct for physicians providing occupational medical services. *Journal of occupational medicine*, 36:27–30.
- ACS (1980) Guidelines for the cancer-related check-up: recommendations and rationale. *Cancer*, 30:235.
- AKIRA M, YOKOYAMA K, YAMAMOTO S (1991) Early asbestosis: evaluation by high-resolution CT. *Radiology*, 178:409–416.
- ALTHOUSE RB, CASTELLAN RM, WAGNER GR (1992) Pneumoconioses in the United States: highlights of surveillance data from NIOSH and other federal sources. In: Berhett WS, Bascom R, eds. *Occupational medicine: state of the art reviews*, vol. 7, no. 2. Philadelphia, PA, Hanley & Belfus, pp. 197–208.
- ATS (1991) Lung function testing: selection of reference values and interpretive strategies. *American review of respiratory disease*, 144:1202–1218.
- ATS (1995) Standardization of spirometry, 1994 update. *American journal of respiratory and critical care medicine*, 152:1107–1136.
- AMES RG, GAMBLE JF (1983) Lung cancer, stomach cancer, and smoking status among coal miners: a preliminary test of a hypothesis. *Scandinavian journal of work, environment and health*, 9:443–448.
- ATTFIELD MD (1992) British data on coal miners' pneumoconiosis and relevance to US conditions. *American journal of public health*, 82(7):978–983.
- ATTFIELD MD, ALTHOUSE RB (1992) Surveillance data on coal miners' pneumoconiosis: 1970–1986. *American journal of public health*, 82(7):971–977.
- ATTFIELD MD, CASTELLAN RM (1992) Epidemiologic data on coal miners' pneumoconiosis: 1960–1988. *American journal of public health*, 82(7):964–970.
- ATTFIELD MD, WAGNER GR (1992) A report on a workshop on the NIOSH B reader certification program. *Journal of occupational medicine*, 34(8):875–878.
- BAKER EL (1989) Sentinel event notification system for occupational risks: the concept. *American journal of public health*, 79(suppl.):18–20.
- BAKKE PS et al. (1991) Prevalence of obstructive lung disease in a general population: relation to occupational title and exposure to some airborne agents. *Thorax*, 46:863–870.
- BALMES JR (1990) Medical surveillance for pulmonary endpoints. In: Rempel D, ed. *Occupational medicine: state of the art reviews*, vol. 5, no. 3. Philadelphia, PA, Hanley & Belfus, pp. 509–513.

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

- BECKLAKE MR (1985) Chronic airflow limitation: its relation to work in dusty occupations. *Chest*, 88:608–617.
- BECKLAKE MR (1989) Occupational exposures: evidence for a causal association with chronic obstructive pulmonary disease. *American review of respiratory disease*, 140:585–591.
- BECKLAKE MR (1991) Asbestosis and other fiber-related diseases of the lungs and pleura: distribution and determinants in exposed populations. *Chest*, 100:248–254.
- BECKLAKE MR (1992) The epidemiology of asbestosis. In: Liddell D, Miller K, eds. *Mineral fibers and health*. Boca Raton, FL, CRC Press, pp. 104–119.
- BECKLAKE MR (1994) The workrelatedness of airways dysfunction. In: *Proceedings of the IXth International Symposium on Epidemiology in Occupational Health*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 94-112), p. 1.
- BECKLAKE MR, WHITE N (1993) Sources of variation in spirometric measurements: identifying signal and dealing with noise. In: Eisen EA, ed. *Occupational medicine: state of the art reviews*, vol. 8, no. 2. Philadelphia, PA, Hanley & Belfus, pp. 241–264.
- BRAVEMAN PA, TARIMO E (1994) *Screening in primary health care: setting priorities with limited resources*. Geneva, World Health Organization.
- BRODKIN CA et al. (1993) Correlation between respiratory symptoms and pulmonary function in asbestos-exposed workers. *American review of respiratory disease*, 148:32–37.
- BURNEY MB, CHINN S (1987) Developing a new questionnaire for measuring the prevalence and distribution of asthma. *Chest*, 91(6):79S–83S.
- COWIE RL, MABENA S (1991) Silicosis, chronic airflow limitation and chronic bronchitis in South African gold miners. *American review of respiratory disease*, 143:80–84.
- COWIE RL, LANGTON ME, BECKLAKE MR (1989) Pulmonary tuberculosis in South African gold miners. *American review of respiratory disease*, 139(5):1086–1089.
- COWIE RL, DANSEY RD (1992) Short course multiple drug chemoprophylaxis for tuberculosis in gold miners with silicosis (abstract). *American review of respiratory disease*, 145(2 Pt 4):A813.
- COWIE RL, VAN SCHALKWYK MG (1987) The prevalence of silicosis in Orange Free State gold miners. *Journal of occupational medicine*, 29(1):44–46.
- DEMERS RY, PARSONS KC (1994) Colorectal cancer incidence in pattern and model makers: evidence from a screening program. *American journal of industrial medicine*, 26:33–45.
- ERNST P, ZEJDA J (1992) Pleural and airway disease associated with mineral fibers. In: Liddell D, Miller K, eds. *Mineral fibers and health*. Boca Raton, FL, CRC Press, pp. 121–134.
- FERRIS BG (1978) Epidemiology Standardization Project (American Thoracic Society). *American review of respiratory disease*, 118(6 Pt 2):1–120.
- FONN S et al. (1993a) An environmental and health survey of workers in a grain mill in the Johannesburg area, South Africa. *American journal of industrial medicine*, 24:387–400.
- FONN S et al. (1993b) Relationship of respiratory health status to grain dust in a Witwatersrand grain mill: comparison of workers' exposure assessments with industrial hygiene survey findings. *American journal of industrial medicine*, 24:401–411.

REFERENCES

- FONTANA RS et al. (1991) Screening for lung cancer: a critique of the Mayo Lung Project. *Cancer*, 67(4):1155–1165.
- FUKUHISA K et al. (1989) Digital X-ray images of pneumoconiosis and their evaluation. In: Tateno Y, Tinuma T, Takana M, eds. *Computed radiography*. Tokyo, Springer-Verlag.
- HALPERIN W, BAKER EL, eds. (1992) *Public health surveillance*. New York, Van Nostrand Reinhold.
- HALPERIN WE et al. (1986) Medical screening in the workplace: proposed principles. *Journal of occupational medicine*, 28(8):547–552.
- HANKINSON JL, WAGNER GR (1993) Medical screening using periodic spirometry for detection of chronic lung disease. In: Eisen EA, ed. *Occupational medicine: state of the art reviews*, vol. 8, no. 2. Philadelphia, PA, Hanley & Belfus, pp. 353–361.
- HESSEL PA, ZEISS E (1988) Evaluation of the periodic examination in the South African mining industry. *Journal of occupational medicine*, 30:580–586.
- HOLM K, PALMER PES, LEHTINEN E (1986) *Manual of radiographic technique: WHO Basic Radiological System*. Geneva, World Health Organization.
- HONG KONG CHEST SERVICE, TUBERCULOSIS RESEARCH CENTER, MADRAS, BRITISH MEDICAL RESEARCH COUNCIL (1991) A double-blind placebo-controlled clinical trial of three antituberculosis chemoprophylaxis regimens in patients with silicosis in Hong Kong. *American review of respiratory disease*, 145:36–41.
- HURLEY JF, MACLAREN W (1987) *Dust-related risks of radiological changes in coalminers over a 40-year working life: report on work commissioned by NIOSH*. Edinburgh, Institute of Occupational Medicine (Publication No. TM/87/09).
- HURLEY JF et al. (1987) Exposure to respirable coalmine dust and incidence of progressive massive fibrosis. *British journal of industrial medicine*, 44:661–672.
- IARC (1987) *Silica and some silicates*. Lyon, International Agency for Research on Cancer (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 42).
- ICOH (1992) *International code of ethics for occupational health professionals*. Singapore, International Commission of Occupational Health (unpublished document available on request from ICOH, Singapore 0511, Republic of Singapore).
- ILO (1976) *Encyclopaedia of occupational health and safety*, vol. 2. Geneva, International Labour Office, pp. 1085–1092.
- ILO (1980) *Guidelines for the use of ILO International Classification of Radiographs of Pneumoconioses*. Geneva, International Labour Office (Occupational Safety and Health Series, No. 22 (Rev. 80)).
- ILO (1982) *Sixth international report on the prevention and suppression of dust in mining, tunneling, and quarrying (1973–77)*. Geneva, International Labour Office (Occupational Safety and Health Series, No. 48).
- ILO (1991) *Occupational lung disease: prevention and control*. Geneva, International Labour Office (Occupational Safety and Health Series, No. 67).
- JACOBSEN M (1990) Dust exposure and coalminers' respiratory health. In: *Proceedings of the VIIIth International Pneumoconioses Conference: Part I*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 9-108), pp. 103–104.
- KIPEN HM (1987) Pulmonary fibrosis in asbestos insulation workers with lung cancer: a radiological and histopathological evaluation. *British journal of industrial medicine*, 44:96–100.

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

- KLAUCKE DN (1992) Evaluating public health surveillance systems. In: Halperin W, Baker EL, eds. *Public health surveillance*. New York, Van Nostrand Reinhold.
- LANGMUIR AD (1963) The surveillance of communicable diseases of national importance. *New England journal of medicine*, 268:182–192.
- LEBOWITZ MD, BURROWS B (1976) Comparison of questionnaires: the BMRC and NHLI respiratory questionnaires and a new self-completion questionnaire. *American review of respiratory disease*, 113(5):627–635.
- MARFIN AA, SCHENKER M (1991) Screening for lung cancer: effective tests awaiting effective treatment. In: Harber P, Balmes JR, eds. *Occupational medicine: state of the art reviews*, vol. 6, no. 1. Philadelphia, PA, Hanley & Belfus, pp. 111–131.
- MARINE WM, GURR D, JACOBSEN M (1988) Clinically important respiratory effects of dust exposure and smoking in British coal miners. *American review of respiratory disease*, 137:106–112.
- MATTE TD et al. (1990) Guidelines for medical screening in the workplace. In: *Occupational medicine: state of the art reviews*, vol. 5, no. 3. Philadelphia, PA, Hanley & Belfus, pp. 439–456.
- MRC (1960) Standardized questionnaire on respiratory symptoms. *British medical journal*, 2:1665.
- MERCHANT JA, ed. (1986) *Occupational respiratory diseases*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 86-102).
- MEREDITH SK, TAYLOR VM, McDONALD JC (1991) Occupational respiratory disease in the United Kingdom, 1989: a report to the British Thoracic Society and the Society of Occupational Medicine by the SWORD project. *British journal of industrial medicine*, 48:292–298.
- MILLAR JD (1986) Screening and monitoring: tools for prevention. *Journal of occupational medicine*, 28:544–546.
- MORGAN RH (1979) Proficiency examination of physicians for classifying pneumoconiosis chest films. *American journal of radiology*, 132:805–808.
- MULLAN RJ, MURTHY LI (1991) Occupational sentinel health events: an up-dated list for physician recognition and public health surveillance. *American journal of industrial medicine*, 19:775–799.
- NEALE AV, DEMERS RY, HERMAN S (1989) Compliance with colorectal cancer screening in a high-risk occupational group. *Journal of occupational medicine*, 31(12):1007–1012.
- NIOSH (1974) *Criteria for a recommended standard: occupational exposure to crystalline silica*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 75-120).
- NIOSH (1991) *Work-related lung disease surveillance report*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 91-113).
- ORDIN DL (1992) Surveillance, monitoring and screening in occupational health. In: Last JM, Wallace RB, eds. *Public health and preventive medicine*, 13th ed. Norwalk, CT, Appleton & Lange, pp. 551–558.
- OSTERMAN JW et al. (1991) Comparison of French and English revisions of the American Thoracic Society respiratory questionnaire in a bilingual working population. *International journal of epidemiology*, 20:138–143.

REFERENCES

- OXMAN AD et al. (1993) Occupational dust exposure and chronic obstructive pulmonary disease. *American review of respiratory disease*, 148:38–48.
- PREVENTIVE SERVICES TASK FORCE (1989) *Guide to clinical preventive services: an assessment of the effectiveness of 169 interventions*. Baltimore, MD, Williams & Wilkins, pp. 47–51.
- QUANJER PH et al. (1993) Lung volumes and forced ventilatory flows. Report Working Party, Standardization of Lung Function Tests, European Community for Steel and Coal. Official statement of the European Respiratory Society. *European respiratory journal*, 6(suppl. 16):5–40.
- ROM WN, ed. (1992) *Environmental and occupational medicine, 2nd ed.* Boston, MA, Little, Brown.
- ROSENSTOCK L, CULLEN MR, eds. (1994) *Textbook of clinical occupational and environmental medicine*. Philadelphia, WB Saunders.
- ROTHSTEIN MA (1984) *Medical screening of workers*. Washington, DC, Bureau of National Affairs, pp. 52–66.
- ROTHWELL K (1992) *The interaction of smoking and workplace hazards: risks to health*. Geneva, World Health Organization (unpublished document WHO/OCH/TOH/92.1; available on request from Occupational Health, World Health Organization, 1211 Geneva 27, Switzerland).
- RUCKLEY VA et al. (1984) Comparison of radiographic appearances with associated pathology and lung dust content in a group of coalworkers. *British journal of industrial medicine*, 41:459–467.
- RUTSTEIN D et al. (1983) Sentinel health events (occupational): a basis for physician recognition and public health surveillance. *American journal of public health*, 73:1054–1062.
- SCHWARTZ DA (1991) New developments in asbestos-induced pleural disease. *Chest*, 99:191–198.
- WAGNER GR, ATTFIELD MD, PARKER JE (1993) Chest radiography in dust-exposed miners: promise and problems, potential and imperfections. In: Banks DE, ed. *Occupational medicine: state of the art reviews, vol. 8, no. 1*. Philadelphia, PA, Hanley & Belfus, pp. 127–141.
- WAGNER GR et al. (1992) The NIOSH B reader certification program: an updated report. *Journal of occupational medicine*, 34(8):879–884.
- WAGNER GR, SPIELER EA (1990) Is the coal miner chest X-ray surveillance program succeeding in controlling lung disease? In: *Proceedings of the VIIth International Pneumoconiosis Conference: Part I*. Pittsburgh, PA, National Institute for Occupational Safety and Health (Publication No. 90-108), pp. 803–806.
- WEEKS JL, LEVY BS, WAGNER GR, eds. (1991) *Preventing occupational disease and injury*. Washington, DC, American Public Health Association.
- WESTERHOLM P (1980) Silicosis: observations on a case registry. *Scandinavian journal of work, environment and health*, 6:43–47.
- WHO (1986) *Recommended health-based limits in occupational exposure to selected mineral dusts (silica, coal)*. Report of a WHO Study Group. Geneva, World Health Organization (WHO Technical Report Series, No. 734).
- WHO (1990) *Control of pneumoconiosis: prevention, early diagnosis and treatment: report prepared by a WHO consultation, Geneva, 1–3 November 1989*. Geneva, World Health Organization (unpublished document WHO/OCH/90.1; available on request from Occupational Health, World Health Organization, 1211 Geneva 27, Switzerland).

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

WILKINSON P et al. (1995) Is lung cancer associated with asbestos exposure when there are no small opacities on the chest radiograph? *Lancet*, 345:1074–1078.

WILSON JMG, JUNGNER G (1968) *Principles and practices of screening for disease*. Geneva, World Health Organization (Public Health Papers, No. 34).

Annex 1

List of participants in the WHO Meeting on the Screening and Surveillance of Workers Exposed to Mineral Dust

Geneva, 21–23 September 1993

- Dr X. Baur, Research Institute for Occupational Medicine, Bochum, Germany
(representing the International Social Security Association)
- Dr M. R. Becklake, Department of Epidemiology and Biostatistics, McGill
University, Montreal, Quebec, Canada (*Chairman*)
- Dr P. Brochard, Department of Occupational Medicine, Intercommunity Hos-
pital Centre, Créteil, France (also representing the International Commis-
sion on Occupational Health)
- Mrs B. Goelzer, Occupational Health, World Health Organization, Geneva,
Switzerland
- Dr F. He, Occupational Health, World Health Organization, Geneva, Switzer-
land (*Secretary*)
- Mr M. F. Hellman, International Federation of Building and Wood Workers,
Geneva, Switzerland (also representing the International Confederation of
Free Trade Unions)
- Dr K. G. Hering, Department of Radiology, Mine Workers' Regional Hospital,
Dortmund, Germany
- Ms C. E. Herren, Occupational Health, World Health Organization, Geneva,
Switzerland
- Dr Y. Hosoda, Director, Institute of Radiation Epidemiology, Tokyo, Japan
- Professor S. H. Lee, Director, Catholic Industrial Medical Centre, Seoul, Re-
public of Korea (*Vice-Chairman*)
- Dr M. Lesage, International Labour Office, Geneva, Switzerland
- Dr D. Li, Director, Department of Occupational Diseases, Institute of
Occupational Medicine, Chinese Academy of Preventive Medicine, Beijing,
China
- Professor K. Marek, Head, Clinical Department, Institute of Occupational
Medicine, Krakow, Poland

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- Mr E. Manthey, Miners International Federation, Brussels, Belgium (also representing the International Confederation of Free Trade Unions)
- Dr M. I. Mikheev, Chief, Occupational Health, World Health Organization, Geneva, Switzerland
- Professor D. Muir, McMaster University, Hamilton, Canada (representing the International Council on Metals and the Environment)
- Dr N. P. Napalkov, Assistant Director-General, World Health Organization, Geneva, Switzerland
- Mr J. Pickering, Miners International Federation, Brussels, Belgium (also representing the International Confederation of Free Trade Unions)
- Dr T. Remé, Head, Occupational Medicine, Association for Public Health and Welfare, Hamburg, Germany (also representing the International Social Security Association)
- Dr J. Rochon, Director, Division of Health Protection and Promotion, World Health Organization, Geneva, Switzerland
- Dr D. A. Scarisbrick, Occupational Health Service, The British Coal Corporation, Mansfield, Nottinghamshire, England
- Dr P. Sebastien, Scientific Director, Quebec Institute for Occupational Health and Safety Research, Montreal, Quebec, Canada
- Dr C. Soutar, Chief Executive, Institute of Occupational Medicine, Edinburgh, Scotland
- Dr C. Tietboehl, School of Medicine, University of Rio Grande do Sul, Porto Alegre, Brazil
- Dr G. Wagner, Director, Division of Respiratory Diseases, National Institute of Occupational Safety and Health, Morgantown, WV, USA (*Rapporteur*)
- Dr J. L. Weeks, Division of Occupational and Environmental Medicine, George Washington University Medical Center, Washington, DC, USA
- Mr A. Wieder, International Confederation of Free Trade Unions, Brussels, Belgium

Annex 2

Examples of screening and surveillance programmes

Consideration of a few examples of selected programmes for the screening or surveillance of workers exposed to mineral dust illustrates the decisions that have been made in these instances. The programme summaries are necessarily brief, are intended only for illustrative purposes and do not do justice to the complexity of the technical, social, political, economic and legal considerations that determine the exact design of proposed or adopted programmes. The purpose of this annex is to illustrate how the principles presented in prior sections have been applied in practice.

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

	Australia ¹ (New South Wales)	Canada ² (Quebec Province)	China ³	Germany ⁴	Poland ⁵	United Kingdom ⁶	United States ⁷
What is the purpose of the programme: screening, surveillance, or both?	screening; however, surveillance and epidemiological studies have been performed and published	screening	screening and surveillance	screening and surveillance	coal workers: screening and surveillance silica/asbestos workers: screening, some surveillance; epidemiological studies have been performed	coal workers: screening and surveillance silica/asbestos workers: screening; data primarily screening, some surveillance	coal workers: screening and surveillance asbestos workers: screening; data potentially accessible for surveillance
What exposures are creating a health risk?	coal mine, silica dust	silica, asbestos dust	coal mine, silica, asbestos dust	coal mine, silica, asbestos dust	coal mine, silica, asbestos dust	coal mine, silica, asbestos (including chrysotile, crocidolite and amosite) dust	coal mine, asbestos dust

¹ Joint Coal Board, Occupational Health Service, New South Wales, Australia.

² Institut de Recherche en Santé et en Sécurité du Travail du Québec (IRSST), Canada.

³ Ministry of Public Health, Institute of Occupational Medicine, China.

⁴ Berufsgenossenschaftliches Forschungsinstitut für Arbeitsmedizin (BGFA), Germany.

⁵ Institute of Occupational Medicine and Environmental Health, Poland.

⁶ British Coal Corporation, Occupational Health Service, United Kingdom.

⁷ **Coal:** Attfield MD, Althouse RB (1992) Surveillance data on coal miners' pneumoconiosis: 1970-1986. *American journal of public health*, 82(7):971-977. **Asbestos:** United States Code of Federal Regulations. *Occupational safety and health administration: asbestos, tremolite, anthophyllite, and actinolite*. Washington, DC, Government Printing Office, Office of the Federal Register, 1989 (29 CFR 1910.1001).

	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
What disease or condition is the target of the programme?	chronic bronchitis, asthma exacerbated by dust, pneumoconioses, emphysema, smoking-related diseases	all forms of dust-related diseases (prognostic value low for malignant diseases)	all forms of pneumoconioses	coal/silica workers: pneumoconioses; chronic obstructive bronchitis, emphysema in coal miners (under consideration) asbestos workers: asbestosis, related pleural disease, mesothelioma and bronchial cancers	coal workers: pneumoconiosis, chronic bronchitis and silicosis asbestos workers: asbestosis, asbestos-related malignancies	coal workers: pneumoconiosis, impaired pulmonary function silica workers: silicosis asbestos workers: asbestosis, pleural changes related to asbestos	coal workers: pneumoconiosis, particularly PMF asbestos workers: asbestosis and asbestos-related malignancies
Which workers are eligible for participation?	current and retired workers in the New South Wales coal mining industry	exposed workers in designated industrial sectors	workers exposed to mineral dust; workers with a history of dust exposure	coal/silica workers: underground coal miners and ex-underground miners of coal ore, iron, uranium, etc; workers exposed to silica dust asbestos workers: workers with at least 3 months exposure to asbestos dust	current and retired workers exposed to silica dust or dust containing silica; underground coal miners and those exposed to coal dust on the surface; those exposed to asbestos-containing dust	coal workers: underground coal miners and those exposed to coal dust on the surface; ex-British Coal employees (chest X-ray only) silica workers: exposed workers (highly exposed workers may be targeted) asbestos workers: workers exposed over a continuous 12-week period to more than 120 fibre-hours/ml of chrysotile, or 48 fibre-hours/ml of crocidolite or amosite	coal workers: underground coal miners asbestos workers: workers with exposure to more than 0.1 fibre/ml as an 8-hour time-weighted average, or above 1fibre/ml averaged over a 30-minute sampling period

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	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
Is the programme legally mandated or voluntary? If mandated, is legal enforcement tied to programme performance?	preplacement medical examinations legally mandated (enforced by the Joint Coal Board through state and federal mining industry acts)	legally mandated	legally mandated (the department of employment in enterprises is responsible for arranging screening examinations)	coal/silica workers: legally mandated (controlled by state authorities) asbestos workers: legally mandated	employer is legally responsible for initial and periodic examinations	coal workers: legally mandated (enforced by the Health and Safety Executive (HSE)); no sanctions defined silica workers: not specifically legally mandated asbestos workers: legally mandated (enforced by HSE)	coal workers: legally mandated (enforced by the Mine Safety and Health Administration) asbestos workers: legally mandated (enforced by the Occupational Safety and Health Administration)
Is worker participation in testing voluntary or mandatory?	preplacement screening mandatory; subsequent health screenings a condition of service	mandatory, with a special emphasis on workers in mines and quarries	voluntary	coal/silica workers: mandatory asbestos workers: mandatory	mandatory, for initial and periodic examinations	coal workers: voluntary silica workers: voluntary asbestos workers: mandatory	coal workers: initial testing (chest X-ray and 3-year-follow-up chest X-ray) mandatory, with subsequent testing voluntary asbestos workers: voluntary; however, for many employers, participation a condition of employment

ANNEX 2

	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
Which tests are performed?	questionnaire, physical examination, spirometry and chest X-ray	questionnaire, work history, physical examination, chest X-ray and measures of lung function	<p>preplacement examination: questionnaire, including medical history, smoking habits and allergic history; physical examination</p> <p>periodic examination: questionnaire, including work history, exposure conditions and symptoms; chest X-ray, pulmonary function testing, other tests as necessary</p>	<p>coal/silica workers: physical examination, work history, questionnaire, lung function testing, chest X-ray (according to ILO standards)</p> <p>asbestos workers: preplacement examination, including physical examination, medical and work history, chest X-ray, spirometry (FEV₁, airway resistance)</p>	<p>medical history, physical examination, chest X-ray, spirometry (FEV₁, FVC)</p>	<p>coal workers: chest X-ray and spirometry</p> <p>silica workers: specific programmes vary; chest X-ray, pulmonary function testing, questionnaire, physical examination often used</p> <p>asbestos workers: medical examination, including medical and occupational history, questionnaire, chest X-ray, pulmonary function testing (FEV₁, FVC)</p>	<p>coal workers: periodic chest X-ray and brief employment history</p> <p>asbestos workers: preplacement examination, including medical and work history, physical examination, questionnaire, chest X-ray, spirometry, other tests as necessary; follow-up tests include questionnaire, chest X-ray, spirometry</p>

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
What is the frequency of each test?	preplacement examination, followed by screening on a 3-year basis; chest X-rays offered to underground miners at 5-year intervals and to surface miners at 10-year intervals	asbestos workers: less than 12 years exposure; testing every 3 years; 12–20 years exposure; testing every 2 years; greater than 20 years exposure: testing every year silica workers: less than 12 years exposure: testing every 3 years; 12–20 years exposure: testing every 2 years; greater than 20 years exposure: testing every year	workers exposed to silica dust containing >80% free silica: currently exposed workers: every 0.5–1 year, previously exposed workers: every year ≥40% free silica: currently exposed workers: every 1–2 years; previously exposed workers: every 2 years ≥10% free silica: currently exposed workers: every 2–3 years; previously exposed workers: every 3 years <10% free silica: currently exposed workers: every 3–5 years; previously exposed workers: every 5 years asbestos workers: currently exposed workers: every 0.5–1 year, previously exposed workers: every year	coal/silica workers: preplacement examinations; periodic examinations at 1–3 year intervals; after termination of employment, examination at 5-year intervals asbestos workers: examinations at 1–3-year intervals; least every 5 years after termination of employment	coal workers: baseline examination, then every 4 years silica workers: baseline examination, then at 1–4-year intervals according to exposure asbestos workers: baseline examination, examination after 4 years, then every 2 years; after 10 years of exposure, examination every year	coal workers: X-rays and pulmonary function tests offered at 4-year intervals silica workers: usually at 2-, 3- or 4-year intervals asbestos workers: examinations at least every 2 years	coal workers: chest X-rays within 6 months of employment, after 3 years, then every 5 years asbestos workers: baseline questionnaire and spirometry, repeated annually; chest X-ray every 5 years for workers with 10 or fewer years since first exposure or under age 35; every 2 years for workers 35–45 with over 10 years since first exposure; every year for workers over 45 with over 10 years since first exposure; physical examination yearly for all workers

	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
Who performs the test, and under what conditions?	occupational health nurses under the supervision of medical officers; some assessments performed during working hours; most miners granted 1-day leave every 3 years for medical examinations	physician-in-charge arranges test performance	tests: Institute of Occupational Medicine, hospitals of occupational disease, antiepidemic health stations; examinations free of charge diagnosis: panel authorized by public health authorities	coal/silica workers: physicians licensed by government mining authorities; examinations during working hours, free of charge asbestos workers: factory physicians or licensed medical doctors; examinations during working hours, free of charge	occupational physicians or others with authorization; examinations during working hours, free of charge	coal workers: company physician and trained technicians silica workers: occupational health services, mobile chest X-ray units, others; usually on-site asbestos workers: doctors approved by the HSE	coal workers: X-ray facilities meeting quality standards and certified by NIOSH asbestos workers: licensed medical doctors, free of charge
What constitutes an abnormal test result?	questionnaire: changes in reported health chest X-rays: ILO 0/1 level or higher, with appropriate exposure history	according to physician's judgement	pneumoconioses: according to Chinese Roentgeno-diagnostic Criteria for Pneumoconioses, issued in 1986	coal/silica workers: chest X-rays ILO 1/1 or higher; obstructive airway disease on pulmonary function test asbestos workers: ILO 1/0 or higher; pleural plaques or thickening; abnormal lung function parameters; bronchial cancer, mesothelioma	abnormal result according to ILO system; values for FVC or FEV ₁ less than 80% predicted	coal workers: chest X-rays ILO 1/0 or higher; values of FVC or FEV ₁ less than 80% predicted silica workers: defined by each programme asbestos workers: abnormal result according to ILO system; other tests interpreted by the responsible physician	coal workers: chest X-rays ILO 1/0 or higher, or with PMF asbestos workers: according to physician's judgement

SCREENING AND SURVEILLANCE OF WORKERS EXPOSED TO MINERAL DUST

	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
What actions are taken as a result of an abnormal test result?	<p>questionnaire: referral to medical officer</p> <p>chest X-rays: for ILO 0/1 level, counselling is offered; for 1/0 level, employee informed of radiographic changes; for ILO 1/1 or higher, employee notified and steps taken to remove employee from exposure</p>	<p>cases referred to "pneumoconiosis panel" for further examination; worker and employer informed</p>	<p>worker informed and arrangements made for a job without exposure; some compensation offered</p>	<p>coal/silica workers: actions determined by "job-capability matrix"; if transfer necessary, no wage reduction for a limited period</p> <p>asbestos workers: notification of worker and employer; highly abnormal chest X-ray and lung function parameters lead to job transfer with no wage reduction</p>	<p>notification of competent authority; job transfer depends on occupational physician's decision</p>	<p>coal workers: workers with ILO category 1 pneumoconiosis or higher and abnormal lung function seen by medical officers for full assessment; medical examinations including chest X-ray at 2-year intervals; workers with ILO category 2 or higher may receive disability benefits; also, possible reassignment to approved jobs with no wage loss</p> <p>silica workers: worker informed; referral to general practitioner, specialist or social security benefits agency</p> <p>asbestos workers: worker and physician informed</p>	<p>coal workers: confidential notification of worker; abnormal test confers right to work in a reduced-dust environment and to personal monitoring every 2 months; if job transfer necessary, no wage reduction</p> <p>asbestos workers: worker and employer are notified; records of tests and interpretations kept by employer for 30 years</p>

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	Australia (New South Wales)	Canada (Quebec Province)	China	Germany	Poland	United Kingdom	United States
Are the actions mandatory or voluntary?	health and safety interventions are mandatory, but enforcement seldom necessary	referral to "pneumococcosis panel" mandatory; preventive intervention at the discretion of field personnel	mandatory	coal/silica workers: employer mandated to conduct programme; employee/employer notification mandatory; intervention mandatory asbestos workers: employer mandated to conduct programme; worker, worker's doctor and employer notified on a mandatory basis	mandatory	coal workers: voluntary silica workers: notification of HSE mandatory; other actions voluntary asbestos workers: mandatory	coal workers: right to work in a reduced-dust environment and dust monitoring mandatory; notification of employer by miner voluntary asbestos workers: employer mandated to conduct programme; record-keeping and worker notification of test results mandatory
How (and when) will programme effectiveness be assessed?	no assessment	no assessment	environmental monitoring and health screening data collected and analysed by public institutions; Ministry of Public Health issues results annually	coal/silica and asbestos workers: periodic surveillance reports published; scientific evaluation of research on coal workers' pulmonary disease; number of miners receiving compensation monitored	assessment the obligation of the occupational physician; statistics for occupational diseases published every year	coal workers: programme reviewed annually and trend reports produced silica workers: HSE periodically reviews worker screening and surveillance; informal reporting through SWORD programme asbestos workers: statistics published	coal workers: surveillance reports, participation rates, numbers of compensated miners published asbestos workers: surveillance reports published periodically

Annex 3

Technical considerations in the use and interpretation of chest radiographs

An internationally accepted method for the classification of the chest radiographs of workers exposed to mineral dust, which is useful in screening and surveillance, has been published by the International Labour Office (ILO, 1980). The uses and limitations of chest radiography for the surveillance of miners exposed to mineral dust, which are applicable to all similarly exposed workers, have been reviewed recently (Wagner et al., 1993). This annex considers some methodological issues in the interpretation of radiographs and presents a synopsis of the ILO classification system.

Methodological issues in radiographic interpretation

A variety of factors that influence the value of chest radiography are discussed below, along with a summary of the efforts that have been made to overcome some identified problems.

Standardization of reporting and recording

In order to permit data aggregation and analysis, any screening or surveillance programme or epidemiological investigation depends on standardization of the reporting of test results. The International Labour Office (ILO, 1980) has published a standardized method to evaluate and record the changes in chest radiographs that are caused by respiratory exposures to dust. The system considers postero-anterior radiographs. Care must be taken to ensure that the benefits of standardized reporting are fully realized. Data should be entered on a standardized form that is organized for ease and reliability of data entry. It is best to organize the form so that all blank fields have to be completed, regardless of findings. Forms that permit negative findings to be left as blank fields can lead to uncertainty, as it is possible to confuse a blank

field with missing data. The provision of clerical help, allowing readers to dictate their classifications, can improve the reliability of recorded information.

Each reader should have a set of the current guidelines and standard radiographs of the ILO system and should be encouraged in written instructions to follow those guidelines exactly. It is important to stress that the ILO guidelines should take precedence over the reader's desire to diagnose medical conditions. Individual interpretation leads to increased inter-observer variation and thus reduces the quality of surveillance efforts. Interpretations should be confined to the "comments" section of the recording form set aside for that purpose. The readers should carefully compare each film with the standard radiographs before deciding on their classification. To facilitate this comparison, viewing boxes able to display at least three radiographs at a time should be provided. Readers should be selected from among those with a demonstrated ability to classify films for the pneumoconioses. While all-important for surveillance programmes, this approach is less important for the interpretation of X-rays for clinical purposes.

Film quality and technique

The classification of radiographs for screening or surveillance requires films of excellent quality. The best films for the classification of pneumoconioses are those that reveal fine details of pulmonary parenchymal markings, clearly demonstrate the costo-pleural junctions and show vascular markings through the cardiac shadow. High quality film, good film-to-screen contact, and proper use of grids are important to create radiographs of a quality suitable for interpreting the effects of dust on the lung. The desired technique, which provides good image contrast for evaluating the pulmonary parenchyma, may be less satisfactory for evaluating mediastinal structures or other chest abnormalities. Descriptions of the technique of chest radiography to evaluate the pneumoconioses are widely available and well summarized elsewhere (Sargent, 1982).

Film quality has a significant effect on the classification of radiographs for the pneumoconioses (Reger et al., 1972). In general, there is a tendency to read higher ILO categories for underexposed films, and conversely, lower categories for overexposed films. Although this can be partially overcome by experienced readers, the accurate classification of poor quality films remains a problem.

Reader skills and attitudes

The skills and attitudes brought to the process of reading chest radiographs in occupational medicine must differ from those brought to the clinical diagnosis of diverse pathologies. In clinical reading, the sole purpose is to interpret and understand the individual's condition, with the aim of effecting a cure or at least alleviating the problem. In this context, the aim is not the strict classification of disease in terms of the ILO guidelines but rather is an overall assessment in which the ILO system may have an important though not overriding part. This principle would extend to the reading of radiographs for compensation in the context of disability litigation. The assessment of disability should not rest absolutely on the mere presence or absence of radiological abnormalities, but should take into account other information pertinent to the person's medical condition.

In contrast, in reading for surveillance purposes, the objective is to be as precise and consistent as possible, especially if multiple readers are involved. Hence, diagnosis of disease should be de-emphasized in favour of classification based on strict adherence to the ILO guidelines and comparison with the standard films. In this respect, it is useful to note that superior knowledge of and experience with the radiology of the pneumoconioses has not always guaranteed good reader agreement, and well trained lay readers have been able to provide reliable classifications (Copland et al., 1981).

Insensitivity of radiographs for diagnosing pneumoconioses

No matter how good the film quality and how consistent the readers, chest radiographs have inherent limitations in their ability to demonstrate consistently the changes of pneumoconioses. Pathological-radiological correlation studies have shown beyond doubt that a considerable amount of pulmonary abnormality can be present before it is recognized radiographically (Gough et al., 1950; Gaensler et al., 1972; Ruckley et al., 1984). The chest radiograph is also an insensitive tool for detection of parenchymal fibrosis from asbestos. Up to 20% of workers exposed to asbestos who have negative films have pathological evidence of fibrosis that may be extensive (Kipen, 1987).

The International Labour Office classification system

The International Labour Office scheme for the radiographic classification of the pneumoconioses is central to a description of the extent and

severity of dust-induced lung disease in miners and other workers. Guidelines for use of the system are published by the ILO and are intended to be used with the standard films that illustrate the cardinal features of the classification system (ILO, 1980). The scheme is designed primarily to classify radiographic changes, often for epidemiological surveys, on the chest films of workers who are exposed to dust, with no pathological or etiological implication.

The system calls for the recognition and recording of both parenchymal and pleural abnormalities. Parenchymal abnormalities, essentially discrete radio-opaque regions, are classified for presence, shape, location and profusion. Pleural abnormalities are similarly described by type, site and approximate dimension.

Parenchymal opacities less than 1 cm in size are by definition small. Small opacities are divided into rounded and irregular types. If round, they are classified as *p*, *q*, or *r*, as defined by size ($p < 1.5$ mm, $q = 1.5$ – 3 mm, and $r = 3$ – 10 mm). Irregularly shaped opacities are classified as follows: *s* = fine linear opacities up to 1.5 mm in width; *t* = irregular opacities 1.5–3 mm in width; and *u* = irregular opacities 3–10 mm in width. Both round and irregular opacities can be seen and described on the same film. Two-letter combinations are used to designate the overall size and shape of small opacities. For example, if all lesions are rounded and 1.5 mm to 3 mm in diameter, the film is recorded as *q/q*. When opacities of different size or shape are present, another letter can be used. The film could be graded *s/q*, for instance, if there are predominantly irregular opacities up to 1.5 mm in width and a significant number of rounded opacities, 1.5 mm to 3.5 mm in diameter.

The profusion classification of opacities denotes the relative number of round and irregular opacities per unit area of lung and is determined after comparison with standard films. Major profusion categories are 0, 1, 2 and 3. These designations can be combined in binary fashion, where the first number is the category of standard film decided upon as most like the film being classified, and the second number is the alternative category considered but ultimately rejected. For example, a film can be 2/2 if it clearly resembles the standard film of category 2; however, a film can be 3/2 if it is most like the standard film of category 3, but the standard film of category 2 was seriously considered. There are also endpoint classifications $-/0$ and $3/+$, which, together with the numerical categories, complete the 12-grade ILO scale.

Large opacities are defined as those greater than 1 cm in size and are divided into A, B and C categories. "A" opacities are those greater than 10 mm in diameter, where the sum of the diameters does not exceed 50 mm. "B" opacities are large opacities where the sum of the diameters is greater than 50 mm, but the combined area of which is less than that

of the right upper lung zone. "C" opacities are large opacities whose combined area exceeds that of the right upper lung zone.

Pleural disease that can be described using the ILO classification system includes pleural effusions, pleural calcification, diffuse pleural thickening and pleural plaques (circumscribed pleural thickening). A scheme for recording pleural thickening in profile and face-on, as well as site, width, extent and calcification, is also part of the ILO classification scheme.

The system further requires the reader's opinion about the film quality to be recorded as 1, 2, 3 or unreadable. There is also a provision to note radiographic abnormalities that could be unrelated to dust exposure.

The ILO scheme has proved very useful as a method of classifying chest radiographs for epidemiological research, identifying health hazards and establishing exposure-response relationships. It is also useful for screening and surveillance programmes, which must try to recognize early radiographic abnormalities, to identify sentinel health events and to monitor trends over time. The text of the guidelines discourages use in the medico-legal and disability compensation arenas.

The standard radiographs used in the ILO system are periodically reviewed, and the system itself is occasionally revised following consultation with international experts. More information on current practice can be obtained from ILO (International Labour Office, 1211 Geneva 22, Switzerland). There is a trial currently under way of a new set of standard chest radiographs, which may reduce their number from 22 to 16. Nevertheless, purchasing in the 1980 ILO reference films is worth while since many of the films will be retained.

References

- COPLAND L, BURNS J, JACOBSEN M (1981) Classification of chest radiographs for epidemiological purposes by people not experienced in the radiology of pneumoconiosis. *British journal of industrial medicine*, 38:254-261.
- GAENSLER EA et al. (1972) Pathological, physiologic, and radiological correlations in the pneumoconioses. *Annals of the New York Academy of Science*, 200:574-607.
- GOUGH J, JAMES WRL, WENTWORTH JE (1950) A comparison of the radiological and pathological changes in coalworkers' pneumoconiosis. *Journal of the Faculty of Radiologists*, 1:28-39.
- ILO (1980) *Guidelines for the use of ILO International Classification of Radiographs of Pneumoconioses*. Geneva, International Labour Office (Occupational Safety and Health Series, No. 22 (Rev. 80)).

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- KIPEN HM (1987) Pulmonary fibrosis in asbestos insulation workers with lung cancer: a radiological and histopathological evaluation. *British journal of industrial medicine*, 44:96-100.
- REGER RB et al. (1972) The effect of film quality and other factors on roentgenographic categorization of coal workers' pneumoconiosis. *American journal of roentgenology*, 115:462-472.
- RUCKLEY VA et al. (1984) Comparison of radiographic appearances with associated pathology and lung dust content in a group of coalworkers. *British journal of industrial medicine*, 41:459-467.
- SARGENT EN (1982) *Technique for chest radiography for pneumoconiosis*. Chicago, American College of Radiology.
- WAGNER GR, ATTFIELD MD, PARKER JE (1993) Chest radiography in dust-exposed miners: promises and problems, potential and imperfections. In: Banks DE, ed. *Occupational medicine: state of the art reviews*, vol. 8, no. 1. Philadelphia, PA, Hanley & Belfus, pp. 127-141.

Annex 4

Technical considerations in the use of spirometry

This annex describes recommended procedures in the recording, performance and interpretation of spirometry in programmes of screening and surveillance of workers exposed to mineral dust.

Recommended procedures and quality control

Spirometry tests should be conducted in accordance with the American Thoracic Society's (ATS) recommended spirometry standards, as well as the recommendations of the European Respiratory Society (ERS) (Quanjer et al., 1993; ATS, 1995). These standards not only establish minimum requirements for the equipment used, but also the procedures to follow in administering tests. A quality control programme is a critical component of spirometry screening. The quality control programme should include the adoption of a procedure manual describing the proper calibration, use and maintenance of all equipment, requirements for record maintenance and the procedures of technician training and monitoring. When screening information is collected from multiple sites, centralized review of test quality is needed. If spirometry results are to be interpreted longitudinally (i.e. if several tests performed at various times on the same individuals are interpreted), the quality control centre should attempt to identify survey biases. A survey bias is an unexplained change in a group's mean FEV₁ between surveys. A record of calibration tests is particularly useful when a survey bias is suspected, so that instrumentation errors can be evaluated as a source of bias.

Interpretation

Test reproducibility

The first step in interpreting spirometry is to assess the quality of the test. The lack of a sufficient number of acceptable test trials or inconsis-

tency in results should be carefully considered during interpretation. The presence of excessive flow oscillations in the spirogram, resulting in the identification of the tracing as potentially unsatisfactory because of presumed cough, may instead indicate a functional or structural disorder. The lack of a reproducible test result may be caused by disease and has been shown to be associated with an increased risk of mortality in cohorts that are occupationally exposed to pathogens (Eisen et al., 1985; Kellie et al., 1987). In addition, shorter individuals may have more difficulty in meeting reproducibility criteria than taller individuals. Therefore, an individual's results may sometimes be safely interpreted even though the test is not considered reproducible by ATS standards (ATS, 1995).

Comparison with reference values

The recommended method of interpreting a single spirometry observation involves the comparison of an individual's observed FEV₁ values with a reference value derived from cross-sectional data that take into account subjects' height, sex and age. Both ATS and ERS have recently published statements on the interpretation of spirometry results (ATS, 1991; Quanjer et al., 1993). The cut-off values selected to separate individuals for whom no intervention is warranted (presumed "normal") from those for whom a preventive intervention is recommended or required (presumed "abnormal") should be chosen to reflect the goals of the screening programme. For purposes of screening, where the early identification of abnormality is the goal, these cut-off values may be different from those generally used in clinical practice, where the focus is on disease diagnosis and confirmation. Test sensitivity (the ability of a test to identify accurately the presence of disease), specificity (the ability of a test to identify accurately the absence of disease) and the predictive value of both positive and negative results vary depending on the cut-off values adopted and on the prevalence of disease in the screened population.

Selection of reference values

Reference values for spirometry testing should be selected on the basis of methodological, epidemiological and statistical criteria. Reference values are generally derived from regression equations generated from data on lung function gathered in healthy (often non-smoking) populations. Published reference values vary, not only for technical reasons, but also because of differences in the population mean of the groups

studied. These differences may relate to socioeconomic, psychosocial and other factors. The ATS, for example, does not recommend a universal reference value for all populations, but instead recommends that, to the extent possible, reference values be based on values obtained using comparable equipment in a population with comparable age, physical characteristics, socioeconomic background and ethnic origin (ATS, 1991). By contrast, the ERS guidelines recommend the use of one equation for males and one for females, based on pooled data collected from several countries. Almost all reference values are based on, at a minimum, an individual's age, sex and height.

For ethnic groups where specific reference values may not be available, some adjustment of the values obtained in Caucasian populations may be possible. For example, the ERS recommends that, for subjects of African descent, predicted values be multiplied by 0.87. This procedure is not recommended by the ATS, nor does it appear to be justified on the basis of a recent analysis of published data from over 30 000 men and women of sub-Saharan African descent (White et al., 1994). Some variability between ethnic groups may be due to differences in the average trunk length relative to average standing height (Quanjer et al., 1993).

Criteria for abnormal FEV₁ based on comparison of reference values

Although the 95th percentile (the value above which 95% of the population scores) is often used as the lower limit of normal (LLN) for purposes of clinical interpretation, this may not be appropriate for screening and surveillance. In some circumstances, where the purposes of cross-sectional screening would be better met by a more sensitive indication of abnormality, the 85th or 90th percentile might be selected as the level that triggers further monitoring, investigation or other action. The LLN is available, or can be calculated, from the data published for most reference values. For example, the ERS notes that a LLN approximating the 95th percentile can be estimated by subtracting 0.84 litres from the predicted FEV₁ value in men and 0.62 litres from the predicted FEV₁ value in women.

Criteria for abnormal FEV₁ based on changes over time

A comparison of an individual's current FEV₁ value with his or her own FEV₁ value from the past may be useful, particularly for workers whose FEV₁ is above the predicted value derived from a reference population. A quality control programme is, it should be reiterated, especially im-

portant if longitudinal changes are to be assessed. Because of considerable variability in FEV₁ values over the short term, a year-to-year change of less than 15% should not be considered significant. For periods of observation longer than a year, adjustment for the expected annual decline in FEV₁ is appropriate. Therefore, the LLN for a follow-up FEV₁ can be computed by taking 85% of the baseline value minus the expected decline over the period. An individual's expected decline depends on his or her age, but for practical purposes a value of 25 ml per year is often recommended. For example, an individual whose initial FEV₁ is 4.00 litres would be considered to have an accelerated decline in FEV₁ if his or her FEV₁ fell below 3.15 litres in 10 years $((0.85 \times 4.00) - (10 \times 0.025))$. This approach has been presented in more detail recently (Hankinson & Wagner, 1993).

To increase the sensitivity of spirometry for screening purposes, comparisons of an individual's FVC and FEV₁/FVC with the appropriate reference values can also be done. However, because the FVC is usually a more difficult parameter to determine accurately (being more dependent on effort than the FEV₁), the FVC and FEV₁/FVC comparisons should be used only when there is reasonable assurance of their reliability.

References

- ATS (1995) Standardization of spirometry: 1994 update. *American journal of respiratory and critical care medicine*, 152:1107–1136.
- ATS (1991) Lung function testing: selection of reference values and interpretive strategies. *American review of respiratory disease*, 144:1202–1218.
- EISEN EA et al. (1985) Effects of spirometry standards in two occupational cohorts. *American review of respiratory disease*, 132:120.
- HANKINSON JL, WAGNER GR (1993) Medical screening using periodic spirometry for detection of chronic lung disease. In: Eisen EA, ed. *Occupational medicine: state of the art reviews*, vol. 8, no. 2. Philadelphia, PA, Hanley & Belfus, pp. 353–361.
- KELLIE SE et al. (1987) The ATS spirometry variability criteria: associations with morbidity and mortality in an occupational exposed cohort of coal miners. *American journal of epidemiology*, 125:437–444.
- QUANJER PH et al. (1993) Lung volumes and forced ventilatory flows. Report Working Party, Standardization of Lung Function Tests, European Community for Steel and Coal. Official statement of the European Respiratory Society. *European respiratory journal*, 6(suppl. 16):5–40.
- WHITE NW et al. (1994) Review and analysis of variation between spirometric values reported in 29 studies of healthy African adults. *American journal of respiratory and critical care medicine* 150:348–355.

Annex 5

Questionnaire development and use

Questionnaires are often employed in evaluations of the effects of worker exposure to mineral dusts. An increased level of reported symptoms in the workplace should trigger and focus an environmental investigation. The Medical Research Council in the United Kingdom (MRC), American Thoracic Society, European Coal and Steel Community and International Union Against Tuberculosis and Lung Diseases have published respiratory symptom questionnaires for use in epidemiological studies (Ferris, 1978; MRC, 1986; Burney & Chinn, 1987). Programmes for the screening of workers exposed to mineral dust often draw their questions from these more comprehensive research tools. Critical issues in the design and use of respiratory symptom questionnaires have been reviewed in detail (Samet, 1978; Attfield, 1986). This annex summarizes the relevant guidance for questionnaire use in the screening and surveillance of workers exposed to mineral dust.

Questionnaire screening in isolation from other screening methods lacks utility. Questionnaires should also be a part of a wider prevention programme. They aid in the identification of respiratory symptoms, trigger further medical investigation and treatment or support workplace interventions to decrease exposure for workers. Conditions caused by mineral dust exposure are reviewed briefly in Chapter 5 of the text. Of the conditions listed, chronic bronchitis alone is defined by responses to questions. Other conditions commonly have symptoms that can be detected by questionnaires, but for most, more definitive diagnostic methods are available. At the other extreme, there is currently no direct medical benefit from using questionnaires to screen for work-related malignancies, because of the short period between the onset of symptoms and the time that medical care is sought, as well as the lack of effective interventions. Nevertheless, the documentation of malignancies can be important in surveillance programmes.

Unlike other medical tests, questionnaires gather information that the worker already knows. The information derived from question-

naires can be very useful in permitting observation of patterns of symptoms in the workplace, but workers will generally require an explanation of the importance of both individual and group results. To ensure comprehensive and successful screening, it is essential to include workers and their representatives in all phases of the development and administration of questionnaires and in the interpretation and reporting of their results, as well as in the design of plans based on these results.

The questionnaire may be self-administered or administered by a trained interviewer, depending on local conditions. The use of interviewers provides the benefit of consistent questionnaire administration and may be necessary in dealing with workforces comprising several language groups or including illiterate workers. The possible disadvantages of using interviewers include the time needed to train the interviewers and potential interviewer bias. A self-administered questionnaire has the benefit of reducing training requirements and personnel time but has the potential drawback of introducing a non-response bias if workers ignore some questions. To avoid a non-response bias, self-administered questionnaires may be checked for accuracy and completeness while the respondent is waiting. The advantages and

Table 1. Comparison of the methods of questionnaire administration

Interviewer-administered questionnaires

Advantages

- Structured administration
- Reliability
- Adaptable to several language groups or to illiterate workers

Disadvantages

- Time and cost of training interviewers
- Possible observer bias
- Inconvenience (i.e. need to schedule appointments, etc.)

Self-administered questionnaires

Advantages

- Minimal cost and personnel requirements
- Convenience (i.e. can be mailed, etc.)
- Less stressful for workers (i.e. can be completed when desired and without real or implied pressure)

Disadvantages

- Possible non-response bias
 - Person other than the designated respondent may complete the questionnaire
 - Must be simpler than an interviewer-administered questionnaire
 - Requires literate respondent or surrogate
 - Multiple versions necessary for workforces comprising several language groups
-

disadvantages of interviewer-administered questionnaires and self-administered questionnaires are summarized in Table 1.

Steps in questionnaire design and development

Clarify the goals of the programme

- Will the questionnaire be used for screening, surveillance or both?
- What are the diseases or conditions of concern?
- What kind of information would trigger a response or intervention?

Identify existing resources

- Is there already a questionnaire or section of a questionnaire reported to be useful in screening for the conditions of interest?
- Can existing questions be translated into the relevant languages and format?

Determine notification and reporting requirements

- What information will be needed for efficient notification of workers?
- What, if any, information will be aggregated, analysed and reported outside the worksite (either voluntarily or compulsorily)?

Plan for data analysis

- Have the personnel who will be analysing data been involved in the process of questionnaire design?
- Will a particular format facilitate data analysis?
- Will data entry or analysis be technologically aided (e.g. by use of optical scanning technology)?

Select question form and wording

- Clear, specific, short questions often stimulate the most reproducible results and are easiest to analyse and track over time.
- “Skip patterns” are used in most standard questionnaires to elicit more information about a positive answer. If the answer is negative, the respondent “skips” to the next topic.
- Will the questions be understood by the respondents? Is the

language used appropriate for their educational and cultural background?

- The word-for-word translation of questions from an existing questionnaire may lead to misunderstanding, and it is usual to translate and reverse-translate questionnaires several times before they are considered ready for use in the target language. If comparability of results with other workforces elsewhere is an objective, questions should, if possible, be identical to those used in the other workplaces.
- Worker representatives and others familiar with the local language should assist in the translation and design of questionnaires. The ATS questionnaire has produced useful, valid, and comparable results in English- and French-speaking workforces in Quebec (Osterman et al., 1991), as have the IUATLD questionnaires in English-, French- and German-speaking populations in Europe (Burney et al., 1989).
- In many developing countries, which typically have experienced the pressures of rapid urbanization, workforces are made up of several different language groups, and the practice of translation and back-translation in three or more languages is not practical. Even though the reproducibility of responses may be adversely affected if workers are not interviewed in their mother tongue, free translation by multilingual interviewers from a standard questionnaire (e.g. the ATS questionnaire) can give answers to certain questions that are comparable to those obtained in more homogeneous workforces (Becklake et al., 1987).

Determine frequency of questionnaire administration

Depending on the characteristics of the target disease and the conditions of exposure, parts of questionnaires may be usefully administered with different frequencies. In many instances, a comprehensive baseline questionnaire is useful on entry into the workforce. Subsequently, only periodic information on work exposure, medical history and symptoms need be recorded. Since questionnaires are not recommended as an exclusive means of screening workers exposed to mineral dust, the frequency of questionnaire administration is generally determined by the periodicity of other programme components.

Organize the questionnaire logically

Group together questions that elicit demographic information, symptoms of concern, relevant medical history, the history of past work

exposure, current work and exposures, use of protective equipment and other exposure history (e.g. at home or during leisure time).

Edit the questionnaire

- Assess the relevance and importance of each question.
- Ensure that the minimum data needed to fulfil the goals of the programme will be collected.

Write instructions for questionnaire administration and coding

Develop a coding system that is consistent with data analysis. If a computer will be used for data entry, allot areas on the questionnaire for a coding system that meets the requirements of the software.

Pre-test the questionnaire

- Administer the questionnaire to a limited number of workers and involve them in determining whether the questionnaire functions as intended. Assess the clarity, validity and reproducibility of the questionnaire and identify any sources of bias.
- Revise the questionnaire as necessary.

Questionnaire analysis

The use and analysis of the questionnaire results should be planned when questions are selected and intervention strategies are developed. Actions to be recommended on the basis of questionnaire results should also be defined. When data will be grouped and reported, or analysed over time for an individual, the following steps should be included in data analysis:

- Checking questionnaires for completeness.
- Maintaining a logging or tracking system for each questionnaire.
- Coding questionnaires for data entry.
- Entering data on paper forms or into a computer.
- Verifying the accuracy of data entry.
- “Cleaning” data by checking for outliers and inconsistencies. (A computer can print out the distribution of every variable. Values that fall outside an acceptable range should be checked.)
- Creating computer files for statistical analysis (when appropriate).

- Reporting results to participants.
- Conducting and reporting analysis of aggregate data.

Intervention

Interventions resulting from questionnaires may include referral for testing (e.g. spirometry or chest X-ray), referral for medical examination or more comprehensive environmental monitoring and exposure control. Upon completion of the aggregate analysis, exposure and risk groups can be identified. When risk groups are recognized, controls should be implemented to limit further exposure and unfavourable health effects.

Assessment, review and revision

The contribution of the questionnaire to achieving the goals of the screening programme should be periodically assessed. The questionnaire should be revised when needed, with the understanding that changes in the wording, ordering and length of the questionnaire may produce results that are not comparable over time. Nevertheless, the non-comparability of results is of less concern in screening than in the conduct of surveillance programmes or longitudinal epidemiological research. However, unclear questions and questions producing no useful information should always be revised or eliminated. If possible, new questions should first be used along with the original questions in order to check their comparability before the original questions are dropped. If new information about health risks becomes available, more questions should be added.

References

- ATTFIELD MD (1986) Respiratory questionnaires. In: Merchant JA, ed. *Occupational respiratory diseases*. Cincinnati, OH, National Institute for Occupational Safety and Health (Publication No. 86-102), pp. 171–179.
- BECKLAKE MR et al. (1987) Respiratory questionnaires in occupational studies: their use in multilingual workforces on the Witwatersrand. *International journal of epidemiology*, 16(4):606–611.
- BURNEY MB, CHINN S (1987) Developing a new questionnaire for measuring the prevalence and distribution of asthma. *Chest*, 91(6):79S–83S.
- BURNEY PGJ et al. (1989) Validity and repeatability of the IUATLD (1984) bronchial symptoms questionnaire: an international comparison. *European respiratory journal*, 2(10):940–945.

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- FERRIS BG (1978) Epidemiology Standardization Project (American Thoracic Society). *American review of respiratory disease*, 118(6 Pt 2):1–20.
- MRC (1986) *Questionnaire on respiratory symptoms*. London, Medical Research Council.
- OSTERMAN JW et al. (1991) Comparison of French and English revisions of the American Thoracic Society respiratory questionnaire in a bilingual working population. *International journal of epidemiology*, 20:138–143.
- SAMET JM (1978) A historical and epidemiologic perspective on respiratory symptom questionnaires. *American journal of epidemiology*, 108(6):435–446.