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;

Radiographs may be insensitive to early changes resulting from expo-
sure 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 abnormali-
ties (Kipen, 1987). Physicians untrained or inexperienced in the recog-
nition of occupational lung disease may miss certain abnormalities,
which are often quite subtle. Nevertheless, particularly at higher profu-
sions of coal- and silica-induced lesions, there is a reasonable correla-
tion 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 de-

Chest radiographs are not an adequate tool for surveillance or recog-
nition 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 expo-
sure to disease-inducing dusts. Periodic radiographs, alone or in combi-
nation 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 (Fukuhsisa 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 (FEV₁) and the total volume exhaled without a time limit (Forced Vital Capacity (FVC)). These values, and their ratio (FEV₁/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 FEV₁ 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 FEV₁ and the FVC. The FEV₁/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., 1995). 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
monitoring systems are already in place. In arriving at these recommenda-
tions, 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 screen-
ing. Hence, it is strongly recommended that well thought-out surveil-
lance 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 partici-
pation should be identified and removed, and incentives for participa-
tion 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.