Hazard prevention and control in the work environment: Airborne dust (WHO, 1999)

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Executive summary

Purpose

Airborne contaminants can occur in the gaseous form (gases and vapours) or as aerosols, which include airborne dusts, sprays, mists, smokes and fumes. Airborne dusts are of particular concern because they are associated with classical widespread occupational lung diseases such as the pneumoconioses, as well as with systemic intoxications such as lead poisoning, especially at higher levels of exposure. There is also increasing interest in other dust-related diseases, such as cancer, asthma, allergic alveolitis and irritation, as well as a whole range of non-respiratory illnesses, which may occur at much lower exposure levels. This document has, therefore, been produced to aid dust control and the reduction of disease.

Whenever people inhale airborne dust at work, they are at risk of occupational disease. Year after year, both in developed and in developing countries, overexposure to dusts causes disease, temporary and permanent disabilities and deaths. Dusts in the workplace may also contaminate or reduce the quality of products, be the cause of fire and explosion, and damage the environment.

As a matter of social justice, human suffering related to work is unacceptable. Moreover, appreciable financial losses result from the burden of occupational and work related diseases on national health and social security systems, as well as from their negative influence on production and quality of products. All these adverse consequences, which are economically costly to employers and to society, are preventable through measures which have been known for a long time, and which are often of low cost.

The aim of this document is to help educate and train people in the prevention and control of dust in the workplace. It also aims at motivating employers and workers to collaborate with each other, in tandem with occupational health professionals, for the prevention of the adverse effects caused by dust in the workplace. Of course, dust is only one among the many workplace hazards, which include other aerosols (such as fumes and mists), gases and vapours, physical and biological agents, as well as ergonomic factors and psychosocial stresses.

Recognizing the problem

Definitions and examples Dusts are solid particles ranging in size from below 1 μm up to around 100 μm, which may be or become airborne, depending on their origin, physical characteristics and ambient conditions. This document does not deal specifically with other aerosols (such as fumes and mists), with very fine particles resulting from chemical reactions in the air, or with air pollution outside the workplace. However, in many cases similar principles of control apply to these as to dusts.

Examples of hazardous dusts in the workplace include:

- mineral dusts from the extraction and processing of minerals (these often contain silica, which is particularly dangerous);
- metallic dusts, such as lead and cadmium and their compounds;
- other chemical dusts, such as bulk chemicals and pesticides;
- vegetable dusts, such as wood, flour, cotton and tea, and pollens;
- moulds and spores.

Asbestos is a mineral fibre, which is particularly dangerous, and is found, for example, in maintenance and demolition of buildings where it had been used as insulation material.

Size fractions

In occupational hygiene, particle size is usually described in terms of the aerodynamic diameter, which is a measure of the particle's aerodynamic properties. Whether or not an airborne particle is inhaled depends on its aerodynamic diameter, the velocity of the surrounding air, and the persons' breathing rate. How particles then proceed through the respiratory tract to the different regions of the lungs, and where they are likely to deposit, depend on the particle aerodynamic diameter, the airway dimensions and the breathing pattern. If a particle is soluble, it may dissolve wherever it deposits, and its components may then reach the blood stream and other organs and cause disease. This is the case, for example, of certain systemic poisons such as lead. There are particles which do not dissolve, but cause local reactions leading to disease; in this instance, the site of deposition makes a difference. When a relatively large particle (say 30 μm) is inhaled, it is usually deposited in the nose or upper airways. Finer particles may reach the gas-exchange region in the depths of the lungs, where removal mechanisms are less efficient. Certain substances, if deposited in this region, can cause serious disease, for example, free crystalline silica dust can cause silicosis. The smaller the aerodynamic diameter, the greater the probability that a particle will penetrate deep into the respiratory tract. Particles with an aerodynamic diameter > 10 μm are very unlikely to reach the gas-exchange region of the lung, but below that size, the proportion reaching the gas exchange region increases down to about 2 mm.

The depth of penetration of a fibre into the lung depends mainly on its diameter, not its length. As a consequence, fibres as long as 100 μm, have been found in the pulmonary spaces of the respiratory system.

Whenever exposure to airborne dust needs to be quantitatively evaluated, instruments must be used which select the right size range for the hazard concerned. There are conventions for the size ranges of particles to be measured; it is usual to collect either the inhalable fraction, i.e. everything that is likely to be inhaled, or the respirable fraction, i.e. the particles likely to reach the gas-exchange region of the lung. For example, if silica is present, it is necessary to measure the respirable fraction of the airborne dust.

Dust generation

Mineral dusts are generated from parent rocks by any breaking down process, and vegetable dusts are produced by any dry treatment. The amount, hence the airborne concentration, is likely to depend on the energy put into the process. Air movement around, into or out of granular or powdered material will disperse dust. Therefore handling methods for bulk materials, such as filling and emptying bags or transferring materials from one place to another, may constitute appreciable dust sources. Coarse materials usually have a dust-sized component as a result of attrition. If dust clouds are seen in the air, it is almost certain that dust of potentially hazardous sizes is present. However, even if no dust cloud is visible, there may still be dangerous concentrations of dust present with a particle size invisible to the naked eye under normal lighting conditions.

Unless its generation is prevented or it is removed from the air, dust may move with ambient air and reach even persons who are remote from the source and whose exposure is unsuspected.

Damp materials are less likely to release airborne dust, but of course this does not apply if they dry up later.

Sources of exposure

Work processes likely to generate dust include the following:

- mining, quarrying, tunnelling, stone masonry, construction, and any process which breaks or separates solid material;
- foundries and other metallurgical processes, especially the cleaning of casting
- and breaking of moulds;
- any process using abrasive blasting, such removal of paint and rust, cleaning of buildings and small objects, and etching of glass (N.B., use of sand for these processes is often unnecessary, and if uncontrolled can cause serious health impairment, and even fatalities, among the operators, even in a few months);
- manufacture of glass and ceramics;
- handling of powdered chemicals in the chemical, pesticide, rubber manufacturing and pharmaceutical industries;
- agricultural work involving exposure to soil, intensive animal husbandry, dry vegetable products, or agro-chemicals;
- food processing, especially where flour is used;
- any process involving weighing, bagging, bag-emptying or dry transport of powdered or friable materials.

Fire and explosion

This document is concerned with preventing disease. Nevertheless, safety hazards (which pose immediate danger of accident) cannot be overlooked. Any airborne flammable dust in sufficient concentrations can explode. Combustible dust on the ground may become airborne and increase and propagate an explosion which is started by flammable gas ignition. This can occur with vegetable and organic materials, as well as with metal and other oxidizable dusts. Static electricity can also pose hazards. Preventive measures include good housekeeping to prevent build-up of dust deposits, prevention of ignition, provision of explosion relief valves, dusting with non-flammable dusts, and confinement in low-oxygen environments.

Recognizing and evaluating the problem

If any dusty process is being carried out, an assessment should be made to establish if people are at risk from dust exposure. This requires looking systematically at the workplace to see whether there is a problem and in general terms what could be done to prevent risk. The assessment should determine which hazardous materials are in use, in what amounts, and how much dust of which fraction may become airborne and lead to exposure, among other factors. An initial “walk-through” survey of the workplace should be conducted. The controls in use should be examined to determine their effectiveness, and the eventual need for other or additional controls should be considered. Maintenance and cleaning procedures should be examined, to ensure that they are effective and do not give rise to excessive exposure. The position of workers and the organization of their tasks should be appraised in view of the location and nature of the dust sources. The level of training and information of the workforce should also be assessed. It should be ensured that management favours work practices which reduce or eliminate risks. The advice from competent professionals, preferably occupational hygienists, should be sought; this is indispensable whenever dealing with complicated situations, or with hazardous substances.

The walk-through survey will not usually include detailed measurement, although directreading instruments may be used to gain a rough picture of the risks present. Obvious and avoidable risks can be dealt with immediately, and schemes exist for using basic substance and use information to decide what controls are appropriate.

Quantitative evaluations of airborne dust may be performed for a number of reasons, for example: to assess workers’ exposure in relation to an adopted standard, to determine the need for control measures or to assess the effectiveness of control strategies.

The results of quantitative evaluations are usually compared with occupational exposure limits either of the country concerned, or of an international agency, or of some other authority. The evaluation strategy and methods should be those laid down by this authority. The determination of the dust air concentrations to which workers are exposed involves air sampling and further analysis of the collected dust sample, chemically, gravimetrically or microscopically.

Sampling for exposure assessment is usually carried out by means of a personal sampler, attached to the worker, and which consists of a pump (air mover) and a sampling head located in the worker's breathing zone. The sampling head consists of a filter holder, with a filter where the dust sample is collected, preceded by a pre-collector to separate the fraction of interest. Sampling heads should be designed to collect either the inhalable or respirable fraction of the airborne dust. The worker's average exposure during a shift or part of a shift, as laid down in the exposure limits, can then be estimated.

Other measurements may be helpful to understand where dust is coming from, or at what moment(s) of the work cycle it is being emitted. These measurements may rely on fast-response direct-reading instruments, but simpler qualitative means such as forward light scattering (dust lamp) techniques to illuminate the dust, or smoke tubes to trace air movement, may be all that is needed. Often, but not always, the workers involved may be able to say where and when dust is emitted. There are systems that combine video imaging with dust concentration measurements, thus allowing the visualization of how exposure changes as workers perform their tasks. This is useful to evaluate the effectiveness of control systems and also to compare different controls (e.g. exhaust ventilation or wet methods).

If the situation is unsatisfactory, control strategies should be designed and implemented, as will be discussed in later chapters. Afterwards, the situation should be re-assessed, and a programme of periodic re-assessment should be planned and carried out.

Control approaches and strategies

The prevention of occupational hazards is much more effective and usually cheaper if it is considered at the planning stage of any work process and workplace, rather than as control solutions of already existing hazardous situations. This applies first to the planning of new processes or factories, to ensure that hazardous substances are only used if necessary. If they are necessary, then emissions inside and outside the workplace, as well as waste generation, should be minimized, considering the whole life of the process and the products. The workplace and the job should be planned so that hazardous exposure is either avoided or kept to an acceptable minimum. Incentives should reward work practices which minimize exposure. The same considerations should apply to the introduction of new or modified processes and procedures. The order of priority should be to:

"Plan out" the exposure, by not using hazardous substances, or using them in such a way that no one is exposed;
If (1) does not completely prevent exposure, then prevent or minimize emission of the substances to the air;
If it is not possible to prevent exposure by any other method, then give personal protective equipment, including respiratory protective equipment (RPE), to the workers and other persons, as needed.

It is essential to adequately plan for supervision and maintenance, in order to ensure that controls are used and continue to be effective. Workplace control of exposure must be integrated with other measures, such as control of emissions to the atmosphere and waterways, and waste disposal, so that all these measures work together. (Of course, elimination of the hazardous substances prevents all these problems.) Similarly, the control of any hazardous substance in the workplace should be part of an integrated control system encompassing other hazards, such as noise and heat, as well as the ergonomic design of tasks and workplaces.

Control of exposure to dusts, alongside other health and safety measures and environmental protection, should be a key priority of the top level management, and workers should continually be made aware that this is a management priority. Incentive systems for supervisors and workers should be designed to encourage safe procedures and not just productivity.

Prevention and control measures should not be applied in an ad hoc manner, but integrated into comprehensive, well-managed and sustainable programmes at the workplace level, involving management, workers, production and occupational health professionals.

Elimination at the source

Elimination at the source can involve three different items: the production process, the hazardous substance and the work practices. A production process can be changed by applying a production method which generates less dust. This is a sensible approach at the design stage of a production process or when production lines are changed due to the introduction of new product lines.

A hazardous substance may be eliminated by changing the process so that the substance is no longer needed, or by using a less hazardous substance as a substitute. It is, of course, necessary to assess all of the effects of the change, taking into account other hazards such as noise, and any effects on the performance of the product, particularly effects on its safety. If substances are changed, it will be necessary to assess and control any eventual new risks.

If substitution is not feasible, ways should be sought of reducing dust generation. For example, substances might be used as pellets or in liquid suspension, rather than as powders, or, brought in as pre-formed blocks, rather than being cut in the workplace. Any wet method is likely to cause less dust exposure than a dry one. In breaking and drilling, it is much more effective to keep the substance wet at the point of dust generation than to try to capture already airborne dust by spraying it. Moreover, it is necessary to prevent subsequent drying out of dusty material, eventual slipping hazards due to wet surfaces, electrical hazards, and heat stress from the increased humidity. It is also necessary to plan for the adequate disposal of any contaminated liquid effluent.

Containment and ventilation

Containment consists in placing a physical barrier between the substance and people, for example putting a process inside a box. It is usually necessary to have a ventilation system that keeps the enclosure under negative pressure, so that there is no emission at cracks or at points where material moves in or out of the enclosure. The design should be such that maintenance and cleaning can be performed without causing high exposure; unplanned breakdowns, which may tempt workers to open the enclosure, should be foreseen.

It may be satisfactory to partially enclose a process, for example, by having an opening at the front of an enclosure for the operator to reach in (however, the worker’s breathing zone should never be between the contaminant source and the hood). Effective design is difficult, because the flow of air into the opening must be sufficient to prevent escape of the airborne material, including when people move across the opening.

Local exhaust ventilation is the removal of airborne contaminants, close to their source of generation or release, before they can spread and reach the worker’s breathing zone. For this, it is necessary to ensure that the airflow is sufficient and its direction appropriate, particularly where the process generates air movement, such as a grinding wheel, or a hot process. For the same exhaust volume, the velocity of air being drawn towards the hood opening rapidly decreases with the distance (from the opening); considering that a minimum air velocity is required to ensure the capture of an airborne contaminant, it follows that the hood must be as close as possible to the point of dust generation.

General ventilation is usually desirable to control the temperature and humidity of the environment, and a properly designed system can act as a back-up control of exposure to airborne substances, by providing continual dilution of any accidental emissions. In certain cases, general ventilation can be used to control widely disseminated low toxicity contaminants.

Ventilation must be so designed that movements of personnel and vehicles, or the opening of doors and windows, cannot jeopardize its effectiveness. The design of ventilation systems should always be the responsibility of specially trained professionals. The task is particularly difficult where one fan exhausts from a set of ducts and hoods (multi-hood systems). It is easy to accidentally arrange a system so that very little air is exhausted from one or more of the openings, or to badly design a ductwork system so that it has an unnecessarily high resistance to flow. The design of the ductwork must take into account the need for cleaning (which may involve exposure of the cleaning staff) and the abrasive effect of dust.

It is essential that managers ensure a continued and effective inspection and maintenance programme, so that ventilation systems continue to work as designed, and that workers are properly informed and trained about their use.

It is necessary to ensure that ventilation does not move contaminated air to unsuspecting workers downstream, and that hazardous substances are not exhausted to the general environment in an unplanned and undesirable way. When dealing with toxic contaminants, air cleaning devices must be incorporated in ventilation systems, in order to prevent their discharge to the outside environment, and also to prevent re-circulation to the workplace. The disposal of collected toxic dusts must be controlled so as to minimize exposure of the responsible workers and avoid environmental effects.

Work practices

The manner in which a worker performs a task can appreciably affect exposure, so it is important to train workers in good work practices. Video recording of tasks, with simultaneous measurement of airborne concentrations, can be a useful tool for designing and training in adequate work practices. In the case of dusts, it may be effective (and cheaper) to use a dust lamp to make the dust visible, and to use this in conjunction with video filming. Work practices which affect exposure include:

- the manner in which containers are handled and lids removed;
- the care taken in transferring dusty materials;
- work speed; and
- the way in which empty containers are handled.

If the material is likely to offer an ingestion hazard, smoking, eating and drinking in the workplace should be forbidden; such activities should be restricted to designated areas, with adequate washing facilities. Personal care, including teeth brushing, washing hands and cleaning nails, showering and washing hair, before eating and after the work are important measures whenever there is the possibility of dust contamination. Workers must be properly trained about the hazards and risks from the substances used, the control measures, and any exposure monitoring. The workers are often the people who have the fullest knowledge of what happens during work, and their views should be sought on what leads to exposure and the effectiveness of control.

Personal measures

Every attempt should be made to avoid or minimize exposure by other methods before resorting to personal protective equipment (PPE), especially respiratory protective equipment (RPE). A respirator, particularly of the mask type, is not easy to wear for long periods; it can be very uncomfortable, especially in hot or cramped conditions, and workers may be tempted to remove it. Moreover, uncontrolled airborne dust may spread and affect people who are distant from the task, so it is better to prevent the occurrence of dust exposure in the first place. Another problem is that PPE is fallible, and may not give the protection assumed; moreover, it offers no environmental protection. Finally, PPE and especially RPE must be conscientiously cleaned and maintained to remain effective, which often makes them a costly option; poor maintenance makes any PPE ineffective.

Nevertheless, there may be some operations, such as cleaning and maintenance, where RPE is the only practical control method. It is very important that such equipment be selected by trained personnel, taking into account the type of hazardous materials it should protect from, the nature of the work, the expected exposure, and the facial characteristics of the wearers; proper fit is of paramount importance. Workers, supervisors and maintenance staff must be properly trained in the use, maintenance and limitations of the equipment.

The tasks for which PPE is prescribed should be periodically re-assessed to see if other control measures have become applicable. Gloves and other skin protection are necessary if the dust may pose a hazard through skin absorption or ingestion, or can have a direct effect on the skin.

Substances should only be purchased from suppliers who adequately label containers and who supply adequate material safety data sheets. A management system should ensure that the necessary information is passed on to all who may be potentially exposed. Areas where there is a need for the use of PPE or other precautions should be clearly indicated by warning signs.

Work clothing should not allow the collection of dust; problems such as gathering dust in pockets and shoes should be foreseen. Laundering of clothing contaminated with toxic materials should be done safely, under controlled conditions, never in the homes of workers.

Environmental protection

Prevention and control systems should be designed to protect both workers' health and the general environment. Environmental consequences include the effect of fine particles on atmospheric visibility, damage to buildings, effects on vegetation and animals, and health effects on people outside the plant. As in the workplace, the first priority is to prevent the generation of airborne dust, and, if generation cannot be prevented, then secondly, its removal. Measures that minimize waste generation should be given priority, and any inevitable waste disposal should be so planned as to avoid environmental damage.