MDHS

Methods for the Determination of Hazardous Substances

Health and Safety Laboratory

HSE Health & Safety Executive

14/3

General methods for sampling and gravimetric analysis of respirable and inhalable dust

February 2000

INTRODUCTION

1 This MDHS aims to guide those who wish to measure the concentrations of respirable and/or inhalable dust in air, for the purpose of monitoring workplace exposure. It updates and replaces MDHS 14/2.[1] The principal change is that the recommended sampling procedures for inhalable dust have been revised to take account of new data comparing results obtained using different sampling methods for inhalable dust in a range of workplaces.[2] This revised guidance seeks to ensure the best possible method performance under real workplace conditions, and to ensure consistency with the requirements of European[3] and international[4] standards for workplace dust measurement.

Requirements of the Control of Substances Hazardous to Health (COSHH) Regulations 1999

2 Those who carry out and supervise the procedures described in this MDHS could be exposed to various hazardous substances, and therefore should be aware of the requirements of the COSHH Regulations.[5] These are designed to ensure that the exposure of people at work to substances that could cause health damage is either prevented, or where that is not reasonably practicable, adequately controlled. Employers are required to make an assessment of the health risk created by such work, and to prevent or control exposure to the substances involved. The COSHH Regulations also require that persons who could be exposed to substances hazardous to health receive suitable and sufficient information, instruction and training. Employers must ensure that their responsibilities under the COSHH Regulations are fulfilled before allowing employees to undertake any procedure described in this MDHS.

3 Guidance is given in the Approved Codes of Practices for the Control of Substances Hazardous to Health Regulations (the *General COSHH ACOP*), the Control of Carcinogenic Substances Regulations (the *Carcinogens ACOP*) and the Control of Biological Agents Regulations (the *Biological Agents ACOP*), which are included in a single publication with the COSHH Regulations.[6]

Occurrence, properties and uses

4 A number of materials hazardous to health occur in the workplace in the form of aerosols, ie suspensions of solid or liquid particles in air. Dust is generally understood to be an aerosol of solid particles, mechanically produced, with individual particle diameters of 0.1 µm upwards. Fume is an aerosol of solid particles generated by condensation from the vapour state usually following the volatilisation of molten metals. The individual particle diameters are typically less than 1 µm, though the existence of multi-particle aggregates is common. Exposure limits have been defined for many individual dusts and fumes.[7] In order to demonstrate that personal exposure is adequately controlled, it is usually necessary to determine the concentration of dust present by means of personal sampling. In some cases a direct determination of the dust concentration is all that is needed. In other cases a subsequent analytical technique is applied for the determination of a particular element or compound present in the dust.

5 This publication describes the general methods recommended for the sampling and gravimetric determination of dust concentrations; for some applications (listed in Appendix 1) modified techniques are required and the relevant guidance should be consulted. Where further analysis for specific constituents of the collected sample is required, reference should be made to the appropriate MDHS[8] method sheet. HSE Guidance Note HSG173[9] gives general guidance on workplace monitoring.

Health effects

6 Most industrial dusts contain particles of a wide range of sizes. The behaviour, deposition and fate of any particle after entry into the human respiratory system, and the response that it elicits, depends on the nature and size of the particle.[3] For the purposes of occupational hygiene, it is important to consider the concentrations of dust present in different size fractions.

Inhalable dust (also termed 'total inhalable dust')

7 Inhalable dust approximates to the fraction of airborne material that enters the nose and mouth during breathing, and is therefore available for deposition in the respiratory tract. This definition of inhalable dust appears in Regulation 2(1) of COSHH. The inhalable fraction depends on the prevailing air movement around the exposed person (wind speed and direction), and on whether breathing is by nose or mouth. It is, however, possible to define a target specification for sampling instruments that approximates to the inhalable fraction, for representative values of breathing rate, and for a person exposed equally to all wind directions. The target specification given by the European Standards Organisation (CEN)[3] and the International Standards Organisation (ISO),[4] published in the UK as part of BS EN 481:1993, has been adopted in the UK.

8 In previous revisions of this MDHS,[1] and in other key HSE publications,[7] inhalable dust has been referred to as 'total inhalable' dust, although the two terms are clearly intended to have the same meaning. It has now been established that the sampling methods previously adopted for 'total inhalable' dust, when used as recommended in this updated MDHS, have characteristics that approximate to the BS EN481 target specification (see paragraph 17). Hence, the terms 'total inhalable' and 'inhalable' may be regarded as interchangeable.

Respirable dust

9 Respirable dust approximates to the fraction of airborne material that penetrates to the gas exchange region of the lung. The respirable fraction varies for different individuals; however, it is possible to define a target specification for sampling instruments that approximates to the respirable fraction for the average person. The target specification given by ISO and CEN and published in the UK as part of BS EN 481:1993 has been adopted in the UK.

Health and safety precautions

10 Information leaflets in HSE's MS(A) series[10] are available for several dusty compounds and processes. These summarise the risks involved in working with dusty compounds and what can be done to control them.

11 Guidance Notes in HSE's Environmental Hygiene series[11] are also available for several dusty compounds and processes. These describe measures to prevent and control exposure, emergency procedures and health surveillance.

Exposure limits

12 Regulation 7 of the Control of Substances Hazardous to Health Regulations (COSHH) 1999[5] lays down the requirements for the use of maximum exposure limits (MELs) and occupational exposure standards (OESs) for the purpose of achieving adequate control of worker exposure.

13 The Health and Safety Commission has approved OESs and MELs for a number of dusts and fumes in air. These include long-term (8-hour time-weighted average) and, in some cases, short-term (usually 15 minutes) exposure limits. UK limit values are expressed in terms of either 'total inhalable' dust or respirable dust. Unless otherwise specified (Appendix 1), the sampling methods recommended in this MDHS may be used to compare workplace dust concentrations with these limit values.

14 Maximum exposure limits and occupational exposure standards are published in Tables 1 and 2 of HSE Guidance Note EH 40.[7] That publication sets out the indicative criteria used by WATCH and ACTS in making recommendations for limits. The criteria on which some individual limits are based are documented in HSE Guidance Notes EH 64[12,13] and EH 65.[14]

15 The absence of a specific limit in HSE Guidance Note EH 40[7] does not mean that a dust or fume is not harmful. Information on the likely hazard to health of such substances can be found in a number of reference works.[15,16] Dusty compounds for which no exposure limits are specified are currently subject to the requirements of the COSHH Regulations. These state that a 'dust of any kind' is regarded as hazardous to health when present at a substantial concentration in air. A 'substantial' concentration of dust should be taken as a concentration of 10 mg m^{-3} (8-hour time-weighted average) of total inhalable dust or 4 mg m^{-3} (8-hour time-weighted average) of respirable dust, where there is no indication of the need for a lower value.

SCOPE

Applicability

16 The methods described in this MDHS are suitable for the determination of the concentrations of most dusts and fumes in the workplace. For a few materials special methods exist (see Appendix 1), and reference should be made to the specific method document. Interpretation of results is discussed in HSE Guidance Notes EH40[7] and HSG173.[9]

METHOD PERFORMANCE

17 The sampling methods for inhalable and respirable dust described in this MDHS have been evaluated in both laboratory and field-based tests to determine their performance with respect to the BS EN481 target specifications. A pan-European study of inhalable dust sampling methods was carried out to evaluate instrument performance under controlled laboratory conditions, at wind speeds ranging from 0.5 to 4 m/sec.[17] A subsequent laboratory-based study extended the performance evaluation to situations with very low external winds.[18] Finally, results obtained using different inhalable dust sampling methods have been compared in a range of workplaces.[2,19] The results from this body of research have been used to select those methods for which the bias and precision are within acceptable limits[20] (see paragraphs 20, 22 and 24).

18 The performance of the various respirable dust sampling methods recommended in this MDHS has been evaluated fully and the results published in a number of papers.[21,22,23,24,25] This body of research has enabled the sampling methods to be optimised with respect to the BS EN481 target specification for respirable dust sampling.

Detection limits

19 The lower limit of detection of gravimetric analysis is determined primarily by the length of the sampling period, the sensitivity of the balance, and the weight stability of the substrate (eg filter) used to collect and weigh the sample. These factors should be chosen to ensure whenever possible that the lower limit of detection is an order of magnitude lower than the appropriate exposure limit. Useful information on how to determine and reduce gravimetric detection limits can be found in an International Standard on gravimetric analysis, currently under preparation.[26]

Bias

Sampler bias

20 The three inhalable dust sampler types recommended in this MDHS are the Institute of Occupational Medicine (IOM) sampler, the conical inhalable sampler (CIS) and the multi-orifice (or seven-hole) sampler. See paragraph 28 for a full description with illustrations. A sampling bias of less than ±5% is typical for the IOM inhalable dust sampler, but the conical inhalable and multi-orifice samplers may exhibit larger biases (either positive or negative) under some workplace conditions.[17,18] Problematic situations often leading to negative bias are those where there are high winds, for example outdoors, and where large particles are generated by the work process. Positive bias can result from incorrect handling of the CIS and multi-orifice samplers after use, as the sampler design can allow unintended contamination of the filter. Transport procedures that minimise the potential for such contamination are recommended in paragraph 48.

21 Where workers are very close to dust sources, samplers positioned on the upper chest may in some instances be subjected to a localised high dust concentration that does not represent the air breathed by the worker. The presence of this problem can often be detected by the use of additional unpumped personal samplers as described in paragraph 42.

22 For respirable dust samplers, bias generally depends strongly on particle size, but should in most circumstances be within ±10%.[21, 22]

Analytical bias

23 Gravimetric analysis should be unbiased provided that the procedures described in paragraph 55 to correct for blank weight changes are followed.

Precision

24 The main source of imprecision in the measurement of workplace dust concentrations is the non-uniformity of the dust cloud surrounding the worker. Analytical and sampling imprecision is generally very small in comparison. Workplace-based studies using pairs of samplers on each worker have been used to determine the real imprecision in dust sampling results. For inhalable sampling, for example, a second contemporaneous sample on a worker was found to lie within a factor of two of the first sample, on 95% of occasions.[19] A similar study with pairs of respirable dust samplers is currently under way.

PRINCIPLE

25 A measured volume of air is drawn through a collection substrate such as a filter mounted in a sampler, and the mass of dust collected is determined by weighing the substrate before and after sampling.

DUST SAMPLING EQUIPMENT

26 Different instruments are needed according to whether respirable or inhalable dust is to be collected; paragraphs 28 to 30 give specific guidance. The essential features of all systems are a collection substrate such as a filter and a pump for pulling the air through it; the collection substrate may be held within a cassette system placed within the respirable or inhalable sampler. The pump unit must be capable of maintaining smooth flow at the specified rate throughout the sampling period.

27 In personal sampling, the sampler is attached to the wearer within his or her breathing zone, and the pump (if external to the sampler) is connected to it by a length of flexible tubing and worn on a belt, harness, or in a pocket. The breathing zone is the space around the worker's face from where the breath is taken, and is generally accepted to extend no more than 30 cm from the mouth. Personal sampling instruments are normally mounted therefore on the upper chest, close to the collar-bone.

Personal sampling for inhalable dust

28 Three examples of personal sampler for inhalable dust are the multi-orifice sampler (Figure 1), the Institute of Occupational Medicine (IOM) sampler (Figure 2) and the conical inhalable sampler (CIS, Figure 3). The multi-orifice and IOM samplers require a pump unit capable of maintaining a smooth flowrate of 2.0 ± 0.1 litre/min throughout the sampling period. The CIS operates at a higher flow rate, and requires a pump unit capable of maintaining a smooth flowrate of 3.5 ± 0.1 litre/min throughout the sampling period. For details of suppliers see Appendix 2. Other types of sampling instrument may also give satisfactory performance, although the equivalence of results for the substances of interest should be established.[26] Of the three sampler types depicted, the IOM sampler has been shown to give the best agreement with the BS EN481 target specification for the inhalable fraction, under the widest range of workplace conditions, and is therefore usually the preferred method of sampling (see paragraphs 17 to 24). Special precautions are

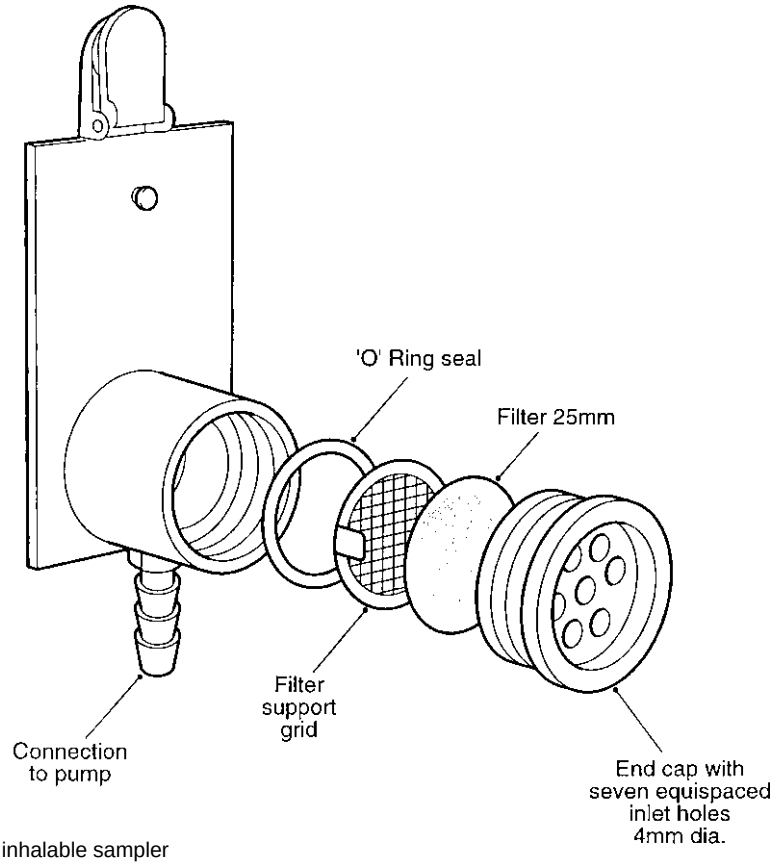

Figure 1 Multi-orifice total inhalable sampler

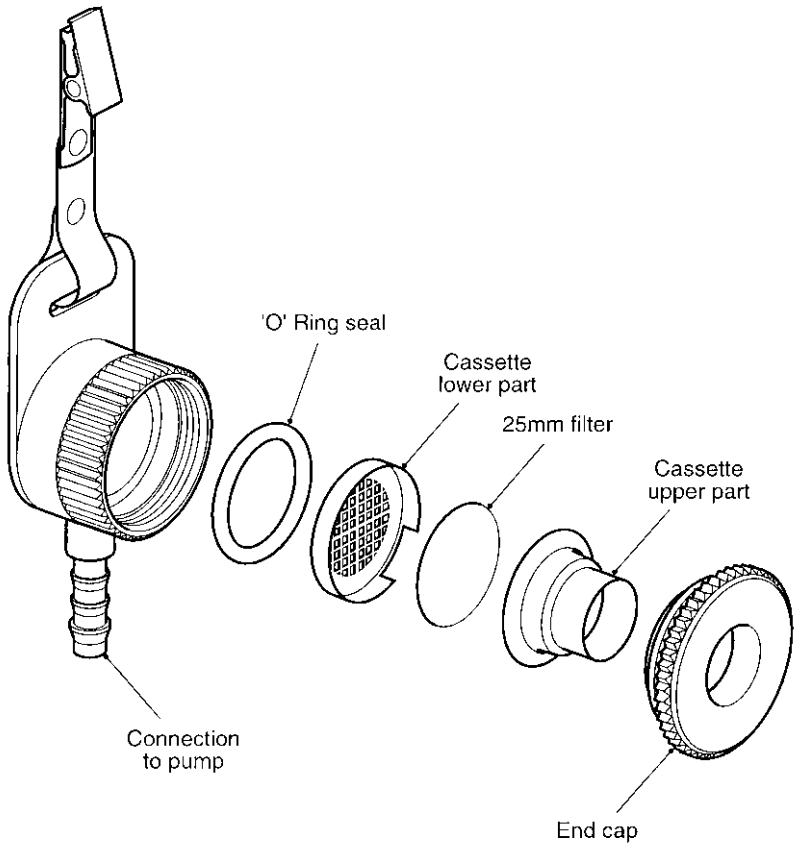

Figure 2 IOM inhalable sampler

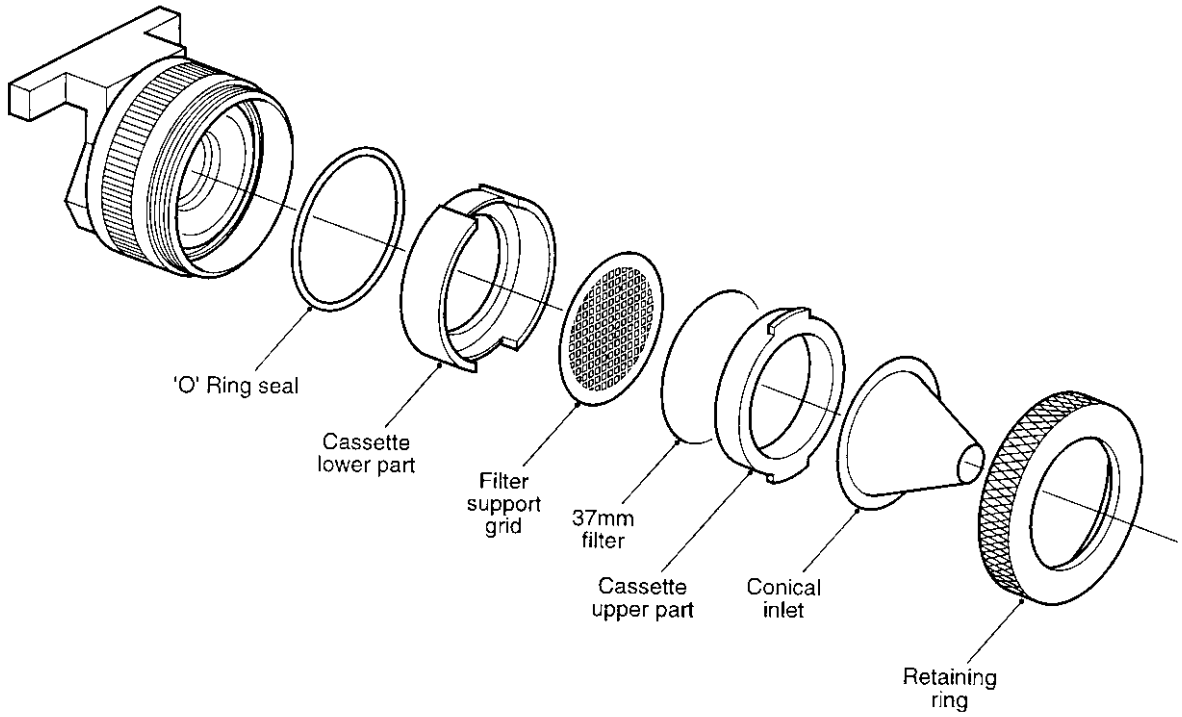

Figure 3 Conical inhalable sampler

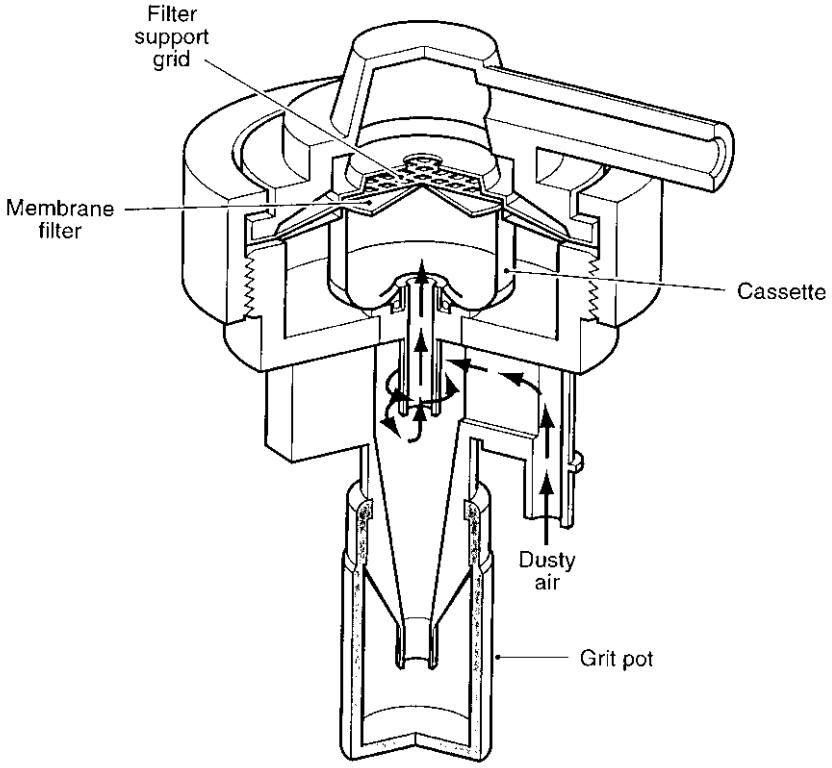

Figure 4 Cyclone respirable sampler

required if one of the other two sampler types is used, in order to prevent significant underestimation or overestimation of personal exposures (see paragraph 19). In most circumstances, and with correct handling, the bias introduced by choosing a sampler type other than the IOM sampler will be small compared with the imprecision of the exposure estimate (paragraph 24).

Background sampling for inhalable dust

29 Fixed point sampling may be used to determine background levels of dust in the workplace, although it is not appropriate to compare fixed point (background) samples with the exposure limit, because the distribution of dust in the workplace is not uniform. In addition to this discrepancy, because of aerodynamic effects, background samplers will not exhibit the same characteristics as when mounted on the body, and will usually underestimate the inhalable dust concentration. If used for background sampling, personal samplers should be positioned at approximately head height, away from obstructions, fresh air inlets or strong winds. The sampling procedures are otherwise the same as for personal sampling.

Personal sampling for respirable dust

30 The respirable fraction is generally collected using a cyclone preselector (see, for example, Figure 4). The cyclone type typically used in the UK is of the generic Higgins-Dewell design, which should be operated at a flow rate of 2.2 ± 0.1 litre/min for optimal agreement with the BS EN481 respirable convention. Alternative cyclone types that also agree with the respirable convention at specified flow rates can also be used. Some examples are the 10-mm Dorr-Oliver cyclone (used at 1.7 ± 0.1 litre/min) and the GK2.69 cyclone (used at 4.2 ± 0.1 litre/min). Other types of personal sampler that give equivalent results are the CIP10-R respirable sampler with integral pump, operated at 10 litres/min, and the IOM dual-fraction respirable sampler (used at 2 litre/min). For details of suppliers see Appendix 2. Other types of sampling instrument may also give satisfactory performance, although the equivalence of results for the substances of interest should be established.[27]

Background sampling for respirable dust

31 In use, the personal samplers should be mounted at approximately head height, away from obstructions, fresh air inlets or strong winds. The sampling procedures are otherwise the same as for personal sampling. Again it is not appropriate to compare fixed point (background) samples with the exposure limit.

Collection substrates

32 The choice of collection substrates (eg filters, foams) will normally be dictated by the choice of sampling instrument and by analytical considerations. Factors affecting substrate choice for gravimetric analysis are discussed in paragraphs 49 to 51. In some types of sampler the collection substrate is held within a cassette that is intended to be weighed along with the filter, ie dust collected on the inner walls of the cassette forms part of the sample. In other instruments the collection substrate is held within a holder that is *not* intended to be weighed along with the filter. The operating instructions supplied by the manufacturer should be consulted to find out exactly what parts of the sampler should be included in the analytical procedure.

Sampling pumps

33 Sampling pumps used for dust sampling should have as a minimum the following features:

- an automatic flow control which keeps the volumetric flow rate constant to within ±0.1 litre/min in the case of changing back pressure;
- either a malfunction indicator, which following the completion of sampling indicates that the air flow has been reduced or interrupted during sampling; or an automatic cut-out, which stops if the pump flow is reduced or interrupted;
- a facility for adjustment of the flow rate such that it can only be actuated with the aid of a tool (eg a screw driver) or requires special knowledge for operation (eg software), so as to prevent inadvertent adjustment of the flow rate during use;
- for cyclone samplers, pulsation damped flow is particularly important and an external pulsation damper must be used if the pump does not contain an integral damper.

In addition, compliance with the requirements of BS EN1232 is recommended.[28]

Ancillary equipment

34 A portable flow meter, capable of measuring the desired volumetric flow rate to within 0.1 litre/min, and calibrated against a primary standard (ie a flow meter whose accuracy is traceable to national standards). Bubble flow meters are preferred for measuring the volumetric flow rate because the readings they give are independent of temperature and pressure. For other flow meters, it may be necessary to measure the temperature and pressure at the time of use and apply corrections if these differ from the conditions under which the flow meter was calibrated.

35 For personal sampling, belts or harnesses to which the sampling pumps can conveniently be fixed, unless they are small enough to fit inside workers' pockets.

36 A means to transport the samples from the workplace to the laboratory, which minimises the possibility of accidental transfers of collected dust to or from the collection substrate; flat-tipped forceps for handling filters where used.

DUST SAMPLING PROCEDURE

Preparation of personal sampling equipment

37 Clean the samplers before use. Disassemble parts that come into contact with dust, soak in detergent solution, rinse thoroughly with water and allow to dry before reassembly. Refer to the manufacturer's instructions before disassembly.

38 In a clean, dust-free environment, load the samplers with pre-weighed collection substrates or cassettes, label each sampler so that it can be uniquely identified, and seal with its protective cover or plug to prevent contamination.

39 Set the volumetric flow rate in a clean area. Connect each loaded sampler to a sampling pump, ensuring that no leaks can occur. Remove the protective cover from the sampler, switch on the sampling pump, and attach the calibrated flow meter so that it measures the flow through the sampler's inlet orifice(s). Note that for the CIP10 sampler a different procedure is required; refer to the manufacturer's instructions. Allow the pump to stabilise before measuring and adjusting the flow (for older pumps this may require several minutes. In this situation it is advisable to stabilise the flow rate through a 'warm-up' sampler, which is not otherwise used, to reduce the risk of contamination.) Set the flow rate to the required value (±0.1 litre/min). Switch off the pump and replace the protective cover on the sampler. Note that if the temperature and pressure in the environment where the samplers are used differ from where the flow rate was set, the volumetric flow rate may change and need to be re-adjusted before sampling.

40 Retain as blanks one unused loaded sampler (or loaded cassette) from each batch of ten prepared; a minimum of three blanks should always be kept. Treat these as far as possible in the same manner as those actually used for sampling, in respect of transport to and from the sampling site, but do not draw air through them.

41 Attach the sampling instrument to the worker on his or her upper chest, not more than 30 cm away from the nose-mouth region. Cyclone samplers are not generally sensitive to orientation, but should if possible be attached with the grit-pot at the base as shown in Figure 4. Attach the pump to a belt or harness so that it causes minimum inconvenience to the worker, and safely secure any tubing used to connect the sampler and pump.

42 When deciding where to position samplers, give consideration to the nature of the processes being undertaken by the worker and whether these may cause differences in the dust concentration within the breathing zone. This is particularly important where the sources of dust are close to the breathing zone, where large particles are generated by the process, and where the inhalable dust concentration is to be measured. Ensure that, as far as possible, the position at which the sampler is mounted will reflect the exposure of the worker. Where there are dust sources very close to the worker, it may be useful to employ a second unpumped sampler, identical in all respects to the pumped sampler except with no pump connected, mounted close to the pumped sampler and exposed to dust over the same time period. Procedures for comparing and interpreting the results from the pumped-unpumped sampler pair are given in paragraph 57.

43 When ready to begin sampling, remove the protective cover from the sampler and switch on the pump. Record the time and volumetric flow rate at the beginning of the sampling period. If the pump is fitted with an integral timer, ensure that this is reset to zero. Check the sampler and pump periodically during sampling to see that the equipment is still working, and if necessary re-measure and adjust the flow rate.

44 At the end of the sampling period, carefully dismount the sampling equipment from the worker without subjecting it to mechanical shocks. Carefully move the used sampling equipment to a clean, dust-free area such as that used for sampler preparation. Cyclones and CIP10s must be retained upright when switched off, until the filter has been removed. Measure the volumetric flow rate to an accuracy of 0.1 litre/min using the calibrated flow meter. Record the flow rate and the sampling time, and calculate the duration of the sampling period. If the pump is fitted with an integral timer, check that the indicated period agrees with the calculated period. Consider the sample to be invalid if the two sampling times differ by more than 5%, since this indicates that the pump did not operate for the entire period.

45 Carefully record the sample identity and all relevant sampling data. For inhalable sampling, calculate the mean volumetric flow rate by averaging the flow measurements made at the beginning and end of the sampling period. For respirable sampling, consider the sample to be invalid if the two measured flow rates differ by more 0.1 litre/min or 5% (whichever is larger). Where the sample is valid, assume that the mean volumetric flow rate is exactly equal to the recommended flow rate (eg 2.2 litre/min for the Higgins-Dewell cyclone).

46 For samplers that collect the dust on a filter alone, remove the filter from each sampler using flat-tipped forceps, place in a labelled filter transport container and close with a lid. Take particular care to prevent dust being dislodged from heavily-loaded filters. Note that when using the CIS or multi-orifice sampler types, it is essential to handle the loaded samplers with great care before the filters are removed. Ideally, filters should be removed before transport to a remote laboratory in order to prevent movements of loose material within the sampling heads. If this is not done, additional material can fall from the insides of the sampler onto the filter, causing positive sampling bias.

47 For samplers that use an internal cassette (eg the IOM sampler), remove the cassette from each sampler and fasten with the transport clip supplied by the manufacturer. Alternatively seal the samples within the sampler and return them to the laboratory for disassembly.

48 Transport the samples to the laboratory in a container designed to prevent damage in transit, and labelled to ensure proper handling. Carefully inspect the transport containers, clips etc for signs of loose material lost from the filters. In cases where losses are suspected, it may be necessary to develop and document special transport procedures for the used samplers. Special precautions to recover lost material, for example the use of weighable cassette covers and filter containers, are likely to be needed where samples are sent by post.

GRAVIMETRIC ANALYSIS EQUIPMENT

Filters

49 If sampling is carried out solely for the measurement of the gravimetric concentration, without analysis, glass fibre filters may be used. Fibre loss from such filters may occur during handling and may be significant if less than 1 mg of dust is collected. At such concentrations, silver, teflon or membrane filters should be used. Some types of filter (eg cellulose nitrate) can show excessive weight change due to moisture absorption, and other types (eg PVC, teflon) can show excessive static build-up. Filters made of mixed esters of cellulose do not have these drawbacks to the same degree. If analysis of the collected material is required, this is likely to determine the choice of filter, and the appropriate MDHS or other method sheet should be consulted.

50 The diameter of the filter needed will, in general, be dictated by the sampling apparatus used. For the instruments described in this MDHS, filter sizes of either 25 mm or 37 mm are required. Smaller filters have lower tare weights, but larger filters have lower resistance, and this may assist in maintenance of the correct flowrate.

Other substrate and cassette materials

51 The CIP10 sampler utilises a porous polyurethane foam substrate to collect particles, held in a small plastic cup that is weighed together with the foam. The IOM sampler utilises an internal cassette made of either plastic or metal that is weighed together with the filter it contains, as dust is collected on the inner walls of the cassette as well as on the filter. The IOM dual-fraction respirable sampler collects inhalable dust in the whole cassette, and respirable dust on the filter only. Consult the manufacturer's instructions when weighing samples taken with these instruments. Foams and plastic materials used for filter holders and cassettes may show large weight variations due to moisture absorption, unless the temperature and humidity of the conditioning and weighing environment is carefully controlled (or naturally stable).

Balance

52 The balance should have a range that easily accommodates the tare weights of the substrates, cassettes etc, and has readability (ie the finest division on the scale) of 0.01 mg or better. The pan should be large enough to accommodate the substrates used.

53 It should be noted that the reproducibility of weighing on a balance is usually substantially worse than might be expected from the finest division of the scale. Repeat weighing of unexposed substrates over several days is a better guide to true performance. The detection limit of the gravimetric analysis for a particular application can be estimated as approximately three times the standard deviation of weight changes of the group of three blank substrates included in each batch of samples, weighed before and after sampling.[29] The magnitude of the blank weight changes can be minimised by choosing less moisture-retentive substrate materials, or by better control of the temperature and humidity of the weighing environment.

WEIGHING PROCEDURE

Weighing the samples

54 The weight of dust collected is determined by weighing the substrates (in cassettes, where used) both before and after sampling. As a minimum, the accuracy of the balance should be checked with a calibrated standard weight at the intervals recommended by the balance manufacturer. For accurate determination of sample weights, the substrates should be conditioned by being placed in individual, labelled, clean tins (or other suitable containers), and left with the lids slightly ajar in the weighing environment overnight before each weighing. This time period is usually sufficient to allow moisture in the substrates to come into equilibrium with the weighing room atmosphere, although it should be noted that some types of substrate or cassettes may take longer to equilibrate.[26] In such cases the use of blanks to correct for weight changes due to moisture absorption is particularly important. The substrates should also be passed over the static eliminator before weighing to dissipate any electrostatic charge. After sampling, the conditioning procedure should be repeated before re-weighing.

55 Weight changes in the used sample substrates caused by variations in atmospheric conditions are corrected by weighing the blank substrates at the same time as the sample substrates, both before and after sampling. The average weight change of the blank substrates is subtracted from the weight change of each sample substrate, in order to calculate the net weight gain.

Calculation of dust concentration

56 The volume of air passing through the sampler is calculated by multiplying the mean volumetric flow rate in cubic metres per minute by the sampling time in minutes. (Note: flowrate in litre/min = 1000 x flowrate in m^3/min.) The net weight gain (mg) of the sample substrate is divided by the volume of air sampled (m^3) to give the average dust concentration in milligrams per cubic metre of air (mg/m^3).

57 Where an unpumped sampler has been used alongside a pumped sampler on the same worker, the mass of material collected on the unpumped sampler would normally be expected to be between 5 and 20% of the mass collected on the pumped sampler over the same

period.[2,28] In those instances where the dust concentrations are unusually high and variable, the unpumped sampler may collect an abnormally large mass of material. In these circumstances it is reasonable to assume that the pumped sampler positioned on the chest is not necessarily representative of the dust actually inhaled by the worker, and to either disregard the result, or treat it as a 'worst-case' estimate of personal exposure.

Sampling time

58 A long sampling time ensures a heavier deposit and therefore reduces the weighing inaccuracies. Sampling times should therefore be as long as is reasonably practical (preferably not less than four hours, unless short-term concentrations are being evaluated) and should be representative of the working periods of individuals exposed. Further guidance on this is given in Guidance Note EH42.[7] If the dust concentration is so high that a single sample would be overloaded, several substrates should be used consecutively.

ADVICE

59 Advice on this method and the equipment used may be obtained from the Health and Safety Laboratory, Broad Lane, Sheffield S3 7HQ (tel: 0114 2892000, e-mail: hslinfo@hsl.gov.uk).

The Health and Safety Executive wishes, wherever possible, to improve the methods described in this series. Any comments that might lead to improvements would, therefore, be welcomed and should be sent to the above address.

APPENDIX 1

Applications requiring modified techniques

1 Cotton dust and wool process dust sampling: the measurement of exposures for comparison with the new maximum exposure limits set by the 1996 amendments to the Control of Substances Hazardous to Health (COSHH) Regulations (1994) should be carried out using only the IOM personal inhalable sampler unless the equivalence of other methods for these substances has been established. The reason for this restriction is due to the presence of long fibres ('fly') in the dust; these cannot enter the multi-orifice sampler and so form a fibrous mat on the exterior, preventing more compact particles from being sampled as well. The 'fly' enters the orifice of the IOM sampler and is included in the sample weight. The maximum exposure limits have been set on the assumption that 'fly' will be sampled.

2 Coal tar pitch volatiles: measurement of particulates and cyclohexane-soluble material in air. For laboratory method using filters and gravimetric estimation, see MDHS 68 (latest revision).

3 Respirable dust in coal mines: the Coal Mines (Respirable Dust) Regulations 1975 and the Coal Mines (Respirable Dust) (Amendment) Regulations 1978 require background sampling using an instrument with horizontal elutriator to select the respirable fraction (MRE 113a sampler). These regulations are currently under review and the sampling and analysis of coal mine dust is likely to be the subject of a separate MDHS.

APPENDIX 2

Major UK suppliers of dust sampling instruments

Note: suppliers of pumps, balances, filters and other ancillary equipment are not listed.

Instrument	*Supplier*				
	Casella	*JS Holdings*	*Labtech*	*MSA*	*SKC*
IOM sampler					✔
Multi-orifice sampler	✔	✔			✔
Conical inhalable sampler	✔	✔			
Higgins-Dewell cyclone	✔	✔			✔
GK2.69 cyclone		✔			✔
10 mm cyclone				✔	✔
CIP10					✔
IOM dual-fraction					✔
Contact points					
Telephone	01234 841441	01438 316994	0161 4773004	01236 42466	01258 480188
Fax	01234 841490	01438 316994		01236 44081	01258 480184

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