GUIDELINES ON MONITORING OF AIRBORNE CONTAMINANT FOR CHEMICALS HAZARDOUS TO HEALTH

UNDER THE OCCUPATIONAL SAFETY AND HEALTH (USE AND STANDARD OF EXPOSURE OF CHEMICALS HAZARDOUS TO HEALTH) REGULATIONS 2000
(P.U. (A) 131

DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH
MINISTRY OF HUMAN RESOURCES
MALAYSIA
2002

JKKP:GP (I) 01/2002
ISBN : 983-2014-19-0

TABLE OF CONTENT

Pages

CHAPTER 1 : INTRODUCTION 1

CHAPTER 2 : SAMPLING STRATEGY 2-3

CHAPTER 3 : SAMPLER DEPLOYMENT 4-6

CHAPTER 4 : SELECTION OF WORKER 7-10

CHAPTER 5 : BLANKS 11-12

CHAPTER 6 : SAMPLING TECHNIQUE FOR AIRBORNE CONTAMINANT 13-22

CHAPTER 7 : INTERGRATED AIR SAMPLING FOR DUST OR FUMES 23-27

CHAPTER 8 : INTREGRATED AIR SAMPLING FOR GAS AND VAPOUR 28-31

CHAPTER 9 : DIRECT READING INSTRUMENTS FOR AIR SAMPLING 32-33

CHAPTER 10 : CALIBRATION OF SAMPLING INSTRUMENTS 34-35

CHAPTER 11 : CALCULATION OF DUST CONCENTRATION 36-37

CHAPTER 12 : CHAIN OF CUSTODY AND FREQUENCY OF MONITORING 38-39

APPENDICES :

APPENDIX 1 : USE OF RANDOM NUMBER TABLE FOR SELECTION OF RANDOM SAMPLING PERIODS 40

APPENDIX 2 : TABLE OF RANDOM NUMBERS FOR PARTIAL SAMPLING 41

REFERENCES 42

PREFACE

The purpose of these guidelines is to supplement the requirement of regulation 26 of the Occupational Safety and Health (Use and Standard s of Exposure of Chemicals Hazardous to Health) Regulations 2000, specifying a method of monitoring and analysis. An employer or an occupier who has an industrial process within his place of work which uses or handles chemicals hazardous to health specified in Regulation 3 of these Regulation, and in which there exists potential that any employee may be exposed to chemicals hazardous to health during work, is advised to refer to these guidelines in complying with the employee exposure monitoring requirements as stipulated in Part VIII of the above Regulations. An employer or an occupier may uses any other method of monitoring or analysis, but the method used must be proven to be on a par with or better than the method recommended in these guidelines.

The Department of Occupational Safety and Health also screens the persons who wish to conduct exposure monitoring for chemicals hazardous to health in compliance with the above Regulations and approves those found to satisfy the requirements of the Department. The approved persons are expected to be familiar with the method of monitoring and analysis recommended in these guidelines, as appropriate to their specific area of activity, and to use the method for compliance purposes.

Director General
Department of Occupational Safety and Health
Malaysia

15th November 2002

GLOSSARY

Action Level	A term used to describe the airborne concentration that triggers certain provisions of a regulation; generally, but not always, it is one-half or 50 percent of the PEL level.
Activated Charcoal	Charcoal that has its air spaces expanded by heating it to 800-900^{0}C in the presence of steam.
Aerosol	A suspension of liquid or solid particles (mist, fume, particulate, or dust) that are microscopic in size (0.5 to 10 µm), allowing them to remain airborne for an extended period.
Asbestos	A group of naturally occurring minerals containing iron, magnesium, and silica dioxide with a tendency to split into fibers. These materials are resistant to heat, chemicals, electricity and mechanical stress.
Atomic Absorption	An analytical method where the sample is converted into a vapor by passing it through a flame or other energy source. The absorbance at a particular wavelength is measured and compared with that of a reference substance. The absorbance measured is proportional to the concentration of that substance in the sample.
Blank-Corrected	Describes data that have had trace contamination amounts deducted from the total amount of contaminant detected in the sampling media.
Breakthrough	A condition that exists when the backup section of a sorbent tube is found to contain 20 – 25 percent of the total amount of contaminant captured in the front section. This is an indication that the front section of the sorbent was completely saturated during the sample collection. It also refers to detection of contaminant inside a respirator facepiece.

Breathing Zone	The region where the concentration of the airborne contaminant is the same as that entering the nostrils and it has been defined as zone infront of the face within 20 to 30 cm diameter from the nostrils.
Dust	Aerosol composed of particles typically formed by abrasion.
Fume	Aerosol produced when a material in the gases phase condenses to form a solid.
Inhalable Particles	The particles with aerodynamic diameters of 10 µm and greater.
Intergrated Sampling	Samples taken by drawing air through the sampling medium, which is then analyzed by a laboratory to determine the amount of contaminant present.
Passive Sampling	Sampling that relies on diffusion of the contaminant from the air onto a solid sorbent.
Permissible Exposure Limit (PEL)	A term used to refer to exposure levels allowed by USECHH, 2000.
Personal Samples	Samples that are obtain when a worker wears a sampling exercise for some interval during the work shift.
PTFE Filter	A chemical resistant and hydrophobic filter composed of polytetraflouroethylene (PTFE) and used for industrial hygiene sampling (e.g. aromatic hydrocarbons)
Polyvinyl Chloride (PVC) Filter	A filter that has good resistant to acids and bases and does not readily absorb water. It is lightweight and commonly used to collect dust samples
Time Weighted Average	Means an average airborne concentration over a specified period of time.

CHAPTER 1

INTRODUCTION

Under the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000, where an assessment of risk to health indicates that monitoring of exposure is required or it is requisite for ensuring the maintenance of adequate control of the exposure of employees to chemicals hazardous to health, the employers shall ensure that the exposures of chemicals hazardous to health is monitored in accordance with an approved method of monitoring and analysis.

A Hygiene Technician means an employee or any other person appointed by the employer and registered with the Director General to carry chemicals exposure monitoring or to carry out any inspection, examination or test on engineering control equipment installed in the place of work.

Chemicals hazardous to health means any chemical or preparation which –

a) is listed in Schedule I or II of the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000;

b) possess any of the properties categorised in Part B of Schedule I of the Occupational Safety and Health Classification, Packaging and Labelling of hazardous Chemicals) Regulation) 1997;

c) comes within the definition of “pesticide” under the Pesticides Act 1974; or

d) is listed in the First Schedule of the Environmental Quality (Schedule Waste) Regulations 1989.

A hygiene technician shall conduct the monitoring of exposure unless the monitoring is confined to checking the presence of toxic or flammable gases and the level of oxygen in a confined space before entry.

CHAPTER 2

SAMPLING STRATEGY

2.1 Purpose of Sampling

The objective of sampling strategy is to reduce the variation in the sampling results so that a reliable estimate can be made of the time-weighted average exposure concentration.

Work environment sampling is conducted for basally two reasons:

a) To monitor the integrity and performance of hazard control systems

- Concerned with measuring changes in ambient levels in order to follow trends of improvement or deterioration in air quality; and
- Located in fixed positions and normally in close proximity to contaminant sources.

b) To access health risk of persons at work place

- Directed towards the measurement of personal exposure to airborne toxic substances; and
- Located on breathing zone and preferably positioned on the person to be assessed.

2.2 Sampling Principles

A sampling device used to separate and collect the offending material from a measured volume of the atmosphere. The separate material may be quantified:

a) Almost instantaneously (if instrument is direct-reading); and
b) At a later stage (if instrument is not direct reading).

The contaminant level in the atmosphere is then established in terms:

a) Mass or number concentration for particulates; and
b) Mass or volume concentration for gases or vapours.

2.3 Unit of Measurement

Particulate is measured as mass concentration and is usually reported as milligram of particulate per cubic metre of air (mg/m^3). Fibre such as asbestos are counted and the fibre concentration is normally reported as the number of fibres per millilitre of air (f/ml).

Gas and vapour are usually measured as volume parts per million (ppm). One ppm means one part by volume of the gas or vapour in one million parts of the gas/air or vapour/air mixture.

2.4 Application

These guidelines had been prepared to provide guidance to conduct monitoring using prescribed techniques and methods. It is to be used by a hygiene technician for the purpose of conducting monitoring the chemicals hazardous to health in the place of work as required by the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000. A monitoring report must be made by the hygiene technician and presented to the employer.

CHAPTER 3

SAMPLER DEPLOYMENT

The deployment of samplers will depend on the purpose of sampling, whether concerning contaminant emissions or concerning contaminant exposures. For assessing emissions, the device is located at a fixed point and for assessing exposure, the sampler is placed within the breathing zone of exposed worker. Basically there is two type of sampling:

a) area sampling
located at fixed points in the vicinity of contaminant sources; and

b) personal sampling
attached to workers with the sampling head within the breathing zone.

3.1 Breathing Zone

The breathing zone is an ill-defined atmospheric region extending outwards from the face and chest within which it is assumed that the concentration of the contaminant is identical with that in which air actually enters the nose.

In order to overcome the practical difficulties associated with measurement at the entrance to the nose, it is common practice to locate the sampler at the unspecified distance in front of the face or by attaching it at the worker's shirt collar or lapel. (Although the commonest site is the lapel, studies have shown that sampler mounted at the location is capable of producing a result anywhere from, one half to twice the actual exposure concentration).

3.2 Number and Duration of Samples

Results of exposure sampling are intended for eventual comparison with some form of hygiene standard such as Occupational Exposure Limits of Threshold Limit values. These standards have been developed usually from dose-effect relationships where the dose is the estimated body burden of the contaminant accumulated over a short time for a substance producing acute effects or over a long period for a substance giving rise to chronic effects.

In order to predict the biological effects of exposure to a fast acting contaminant, it is necessary to sample for brief periods of time so as to detect the transient concentration peaks. Conversely if the airborne substance only produces its effects in the long term after a build-up of a large body burden, then a series of measurements of atmospheric concentrations carried out over an extended time period will be appropriate.

The possible sampling systems are listed below in descending order of accuracy in estimating exposure:

a) Full period consecutive samples

Obtaining several samples, whether equal or unequal time duration, obtained during the entire period appropriate to standards (e.g. 8 hours)

b) Full period single sample

Involve taking of a single sample for full period of standard. It has the advantage of less analytical cost. The system is practical in situation where the dust concentration is low.

c) Partial period consecutive samples

One or several samples, whether equal or unequal time duration are obtained for only a portion of the period appropriate to the standard. This portion of the period should cover at least 70% to 80% of the full period.

d) Grab samples

Samples taken over some number of short periods of time (less than 1 hour each-generally only minutes to seconds). These samples are taken at random intervals over the period of time for which the standard is defined.

CHAPTER 4

SELECTION OF WORKER

The purpose is to get the highest exposure from a group of workers doing a similar job at the same work area. The highest exposed worker may be determined from observation of the workplace. These factors may be considered when selecting the highest risk worker:

e) Nearest to source;
f) Duration and frequency of exposure;
g) Nature of work or work practice; and
h) Availability of control measures.

4.1 Random Sampling of a Homogeneous Risk Group of Workers

If a maximum risk worker cannot be selected for an operation with reasonable certainty, then it is necessary to resort to random sampling of the group of workers. The procedure is to randomly sample the group whose members have a similar expected exposure risk. The objective of the procedure is to select a subgroup of adequate size so that there is a high probability that the random sample will contain at least one worker with high exposure if one exists. (Note that this partial sampling procedure is not to be used once any employee exposure measurement reveals an employee exposure at or above the action level). The following procedure should be used:

Step 1 : Determine the number of employees to sample using Table 1.

Step 2 : Randomly select the required number of employees using the random numbers given in Table 1 and measure their exposures.

TABLE 1: SIZE OF PARTIAL SAMPLE
FOR TOP 10% AND CONFIDENCE 0.90

Size of group N*	Number of required samples $^{+\#}$
8	7
9	8
10	9
11-12	10
13-14	11
15-17	12
18-20	13
21-24	14
25-29	15
30-37	16
38-49	17
50	18

Notes:

*N = original equal risk group size
$^{+}$n = sample size for subgroup size
$^{\#}$n =N if N < 7

4.2 Identification of Workers To Sample

After having selected the appropriate number of workers to sample, it is necessary to actually select the workers at random and measure their exposures.

Appendix 1 contains the random numbers required for partial sampling. The appendix is used as follows:

1. Assign each individual in the risk group a number from 1 to N, where N is the number of people in the group.

2. Go to appendix 1 and arbitrarily (ideally randomly) choose a starting position in the appendix. Read down, ignoring numbers greater than N as well as the number zero, and select the numbers less than or equal to N. Continue selecting numbers in this way until a partial sample of n numbers has been chosen. It necessary proceed to the next column, and, if at the bottom of the column 25, proceed to the top of column 1.

For example, to select 15 individuals from 26 at random, the procedure of this selection yields:

1. First number individuals in group from 1 to 26.

2. Arbitrarily choose the first in column 10 of appendix 1 as a starting position and read down, selecting the following numbers: 11, 20, 8, 1, 14, 13, 25, 23, 7, 22, 18, 19, 9, 10, 3.

3. Individuals who have been assigned these numbers will now be monitored for their exposure to contaminants.

4.3 Selection of Random Sampling Periods During An 8-Hour Work Shift

To select a random, proceed as follows:

1. Divide the total period over which the standard is defined into n mutually exclusive (non-overlapping) intervals whose collective lengths equal the period for the standard. The number *n* is equal to P*/s,* where P is the period of the standard and s is the length of sampling intervals.

   For example, if 15-minute samples are taken and the standard is a time-weighted average (TWA) over an 8-hours period, there would be n=32 possible sampling intervals from which a random sample could be selected.

2. Number the possible sampling intervals consecutively: 1, 2, 3, …, n. For example, for an 8-hour standard over a work-day from 8:00 a.m. to 4:30 p.m. with 12:00 noon to 12:30 p.m. spent outside the work area for lunch, we would assign the following code numbers for 15-minute sampling intervals.

Code #	Interval
1	8: 00 – 8: 15 a.m.
2	8: 15 – 8: 30 a.m.
3	8: 30 – 8: 45 a.m.
15	11:30 – 11:45 a.m.
16	11:45 – 12:00 noon
17	12:30 – 12:45 p.m.
18	12:45 – 1. 00 p.m.
31	4: 00 – 4: 15 p.m.
32	4:15 – 4: 30 p.m.

3. If n random samples are to be taken, use Table 4 of random numbers. Select an arbitrary starting point, and from there, list the first n different integers between 1 and n.

   For example, suppose five random 15-minute sampling periods from 32 possible periods are to be selected. Arbitrarily choose the first column and eleventh row (where the integer 67 appears) as our starting point (refer to Table 4). By moving vertically downward in the table, the five periods would be 24, 6, 29, 16 and 4 since all integers greater than 32 would be ignored. We would then sample during the time periods given below.

Period	Interval
4	8: 45 – 9: 00 a.m.
6	9: 15 – 9: 30 a.m.
16	11: 45 – 12: 00 noon
24	2 :15 – 2: 30 p.m.
	3: 30 – 3: 45 p.m.

Small deviations in the starting times shown of up to 10 minutes (either earlier or later) would probably not significantly affect their randomness.

CHAPTER 5

BLANKS

Certain numbers of blanks are required by the analytical laboratory for each set of samples to be analysed. The specific method being used should be consulted concerning the number and type of blanks required.

Blanks are used to detect any potential contamination that could be introduced into the process monitoring as well as to detect problems with preparation and analysis of the samples. A particular analysis may involve several types of blanks measurement including reagent blanks, media blanks or field's blanks.

The recommended practice for the number of field blanks is two field blanks for each 10 samples with a maximum of 10 field blanks for each sample set. Approximately five media blanks should also be included. The number should be increased for media which are coated or impregnated with reagent.

Additional blind field blanks should be sent along with the field samples, labelled as field samples, as a further check on the analysis. Blanks are good insurance to deal with contamination, but the best approach is to avoid sample contamination by being careful.

5.1 Field Blanks

A field blank consists of sample media that are exposed to the same conditions as the media used for the actual sampling, but are not connected to a sampling pump. Field blanks measure the signal contribution from the collection media (e.g. impinger solution, filter, sorbent tube, et.). For example, during a solvent sampling activity involving fives samples, two charcoal tubes are open and immediately capped, sealed, and labelled.

These are the field blanks. The accepted number of field blanks is 10 percent of the total number of samples, or at least two regardless of the total number of samples.

The field blanks are subjected to the same chain of custody and other sample handling procedures as the rest of samples. This is the quality control step intended for detection of any potential contamination that could be introduced into the process through sample handling. Field blanks that analysis reveals to contain measurable levels of contaminant could indicate problems with sampling or handling of the media, or also a previously unsuspected source of interference or contamination.

5.2 Reagent Blanks

Reagent or Laboratory Blanks are sample media that are not sampled on, but are prepared and analyzed by the laboratory. Regeant blanks are also measure the signal contribution from solvents, acids or other regeants used by the laboratory in preparing samples for analysis.This is another quality control step that is taken to detect problems with preparation and analysis of the samples. Blank values are sometimes deducted from sample values – this procedures data that are said to be blank-corrected.

IF both field blanks prepared in the example above had contamination at a level of two micrograms, it would be assumed that all the samples contained this extra amount. The analytical data for the samples would then be blank-corrected by subtracting two micrograms from the total amount of contaminant found on each of the tubes.

CHAPTER 6

SAMPLING TECHNIQUES FOR AIRBORNE CONTAMINANT

Air contaminants can be divided into two broad groups depending on their physical characteristics. These are:

i) Particulate; and
ii) Gases, mist and vapour

Particulate is solid particles suspended in the atmosphere as dust, fumes or fibres. Dusts are of irregular shapes and sizes and are normally generated by mechanical means. Fumes are, however, generated from the condensation of materials from the gaseous state. Fibres and dusts of elongated shape with certain size criteria.

6.1 SAMPLING PRINCIPLES

Air sampling is the process of quantifying or determining the identity of a contaminant by the use of standard sampling instruments, techniques and strategy. A sampling device is used to separate and collect the offending material from a measured volume of the atmosphere.

The separate material is quantified either instantaneously (if instrument is direct reading) or at a later stage (if instrument is not direct reading). The contaminant levels in the atmosphere is then established in terms of mass or number concentration for particulate, or volume concentration for gases and vapours.

6.2 SAMPLING FOR PARTICULATE

For assessing inhalation risk, the probability of inhaling dust particles is related to the settling rate. The slower the settling rate, the longer the particles will be suspended in the air and less likely to be inhaled. For dusts of similar shape and density, the rate of settling is proportional to the aerodynamic equivalent diameter (AED) of the dust particle. The deposition in the respiratory tract is also influenced by the aerodynamic equivalent diameter.

Inhalable particulate is particulate that is inhaled either through the nostrils or the mouth. The larger diameter particulate matter (around 20 μ m can reach the respiratory bronchioles and the gas-exchange region of the lungs. These are respirable particulate. Hence, the two types of air samples, which are of concern in terms of its deposition in the respiratory systems, are:

i) Inhalable particulate
ii) Respirable particulate

6.2.1 Sampling for Inhalable Particulate

Sampling solely concern with particulates that are able to enter the respiratory system by inspiration through the nose or mouth. This sampling is carried out when the airborne particulates are soluble in tissue fluids or of an acutely toxic or irritant nature and the primary health effect of the particulate is not on the lungs.

This inspirable dust fraction (or inhalable dust fraction) is defined by the International Standard Organisation (ISO) in the form of an inspirability curve as shown in Table 2.

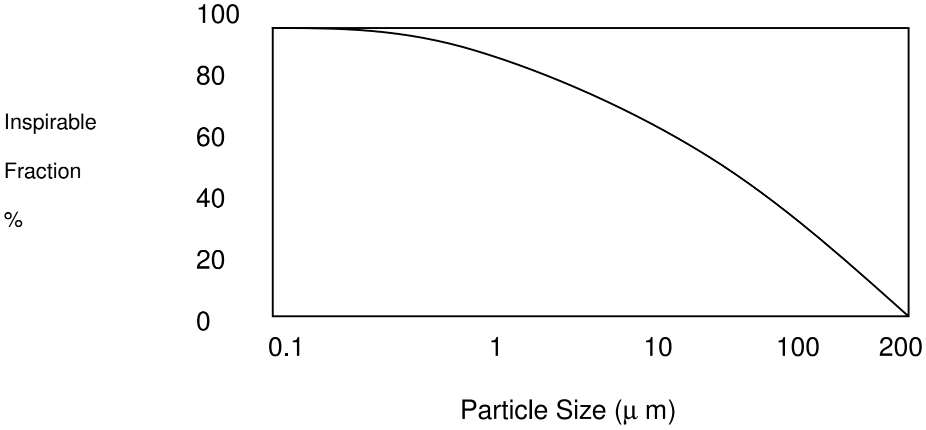

Table 2: The inspirability curve by The International Standard Organisation (ISO)

6.2.2 Sampling for Respirable Particulate

Measurement solely concerned with insoluble particles that may reach the pulmonary air spaces and potentially causing lung damage (due to the very slow rate of particle removal in the alveolar region). This type of sample is taken for exposure assessment of any particulate known to cause pneumoconiosis such as silica, talc and coal dust.

Respirable dusts are dusts particles with AED less than 7 μ m (according to British Medical Research Council) or less than 10 μ m (according to the American Conference of Industrial Hygienests).

In order to assess effectively the potential risk of lung damage, it is necessary to make use of a dust sampling instrument which is able to select and retain that portion of the use of a dust sampling instrument which is able to select and retain that portion of the dust cloud which is capable of entering, and residing for long periods within the alveolar region.

This is the form of a two-stage sampler in which an initial collector simulates the action of the respiratory tract by arresting the larger particles (elutriator or cyclone) in the airborne dust sample while passing the finer, respirable particles for subsequent collection in a second and final collector, usually in the form of a high efficiency filter.

The initial stage collector or a separator should conform to International Organisation for Standardisation/European Standardisation Committee (ISO/CEN) protocol for respirable dust.

No change is recommended for the measurement of respirable particulate using a 10 mm nylon cyclone at a flow rate of 1.7 litres per minute as according to ACGIH this flow rate allows the cyclone to approximate the particulate matter concentration which would be measured by an ideal respirable particulate sampler defined by the ISO/CEN protocol. The collection efficiencies representative of several sizes of particles is given below:

Particle Aerodynamic Diameter (µ m)	Respirable Particulate Mass (%)
0	100
1	97
2	91
3	74
4	50
5	30
6	17
7	9
8	5
10	1

6.2.3 Sampling for Fibres

Respirability of fibres is principally a function of the actual diameter of the particle and is largely independent of its length up to the point where direct interception intervenes in the separation process (thickness / diameter < 3 µ m and length > 5 µ m).

There is a need to use a counting method to determine the fibre concentration since:

a) AED size selection is unable to differentiate between fibrous and non-fibrous portions of sample; and

b) AED size selection unable to exclude non-respirable fibre aggregates from the sample.

6.2.4 Sampling for Fumes

Particle sizes of a fume is generally less than 2µm, and in welding fumes up to 99% of the particles have diameters less than 0.4µm. Due to the fact that fume particles are in the sub-micron size the collector selected must be able to capture these particles efficiently. Fume is normally collected using a sampling head or filter holder loaded with a filter medium made of glass fibre or membrane with pore size up to 2µm.

6.3 SAMPLING FOR GAS AND VAPOUR

Measurement for gas or vapour can either be undertaken using the reservoir sampling or the extractive sampling methods.

6.3.1 Reservoir Sampling

In reservoir sampling, the whole of the air sample obtained is stored in a container until required for analysis, and no attempt is made to separate the gaseous contaminant at this stage. The containers for storing the gaseous contaminant is in the form of :

i) evacuated containers
ii) displacement collectors (use of pump or water-filled vessels), or
iii) gas bags (e.g. Mylar bags)

6.3.2 Evacuated Containers

It consists of a glass bulb from which the air has been removed by a vacuum pump and the neck of which has been sealed by heating and drawing to a tip during the final stage of evacuation.

This type of collection is suitable for gases such as carbon dioxide, oxygen, methane and nitrogen.

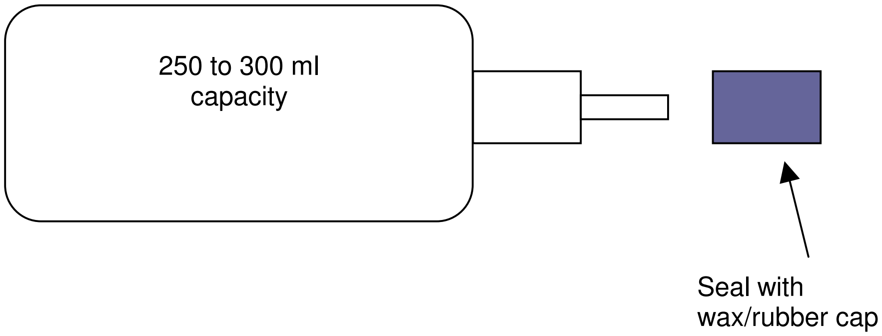

Figure 1: Evacuated Containers

It is however not suitable for collection of very reactive gases such as hydrogen sulphide, oxides of nitrogen or sulphur dioxide. This is because such gases may react with dust particles, moisture, the wax sealing compound, and to some extent even with the glass of the container, so that by the time the sample is analysed the proportion of these gases will have been altered. In such situation, an absorbing fluid for the particular gas or vapour is contained in the evacuated container.

6.3.3 Displacement Collector

These are in the form of gas tube or ordinary heavy-wall bottles. The gas sample tube may be metal or glass and may be closed with stopcocks or screw clamps and rubber tubing if the sample does not react with the rubber. Metal containers are not suitable for sampling many gases, with react with the metal, such as hydrogen sulphide, sulphur dioxide, or oxides of nitrogen.

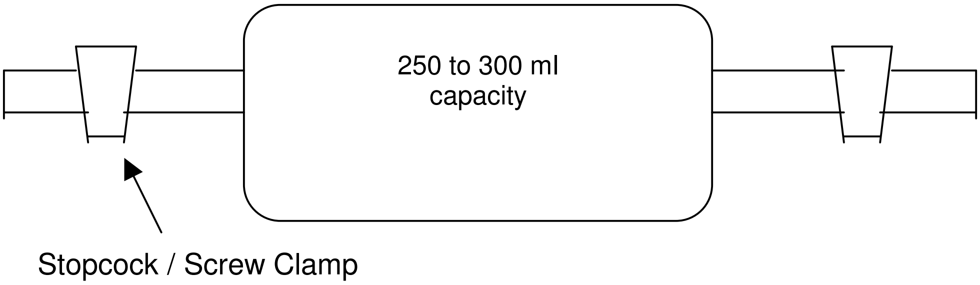

Figure 2: Displacement Collector

To fill any of the containers, it is necessary for it original air or gas content to be completely swept out and replaced by the air to be sampled. For this purpose an aspirating device is usually necessary. The most convenient devices are a double-acting rubber bulb aspirator or a double-acting foot pump.

6.3.4 Gas Bags

The typical material used is Aluminised Scotch Pak, Scotch Pak, Saran and Mylar. Entry into the bag can be accomplished with tygon, Teflon or glass tubing or an ordinary tyre valve, a sample is introduced into the bag by a hand operated pump or a squeeze bulb. Bags can be reused after purging with clean air and checking for residue components. Certain contaminants, such as styrene, cannot be sampled or stored in any plastic bag due to their reactivity with surrounding substances or themselves.

6.3.5 Extractive Sampling

The fundamental difference from reservoir sampling that is in extractive sampling, the collection and contaminant separation occur simultaneously. The principle, a continuously moving atmospheric sample is brought into inmate contact with a collection medium that separates, and at the concentrates the contaminant by the mechanism of:

a) absorption (usually liquid absorbents used);

b) adsorption (solid adsorbent such as charcoal, silica gel, porous polymer granules)
c) condensation

6.3.6 Absorption

Absorbents for collection of gases and vapours are usually liquids in which the gaseous absorbate dissolves. The process of solution is often accompanied by a chemical reaction between absorbent and absorbate.

Absorbers to be used depend on the solubility or the reactivity of the gases or vapours with the absorbents:

a) for gases and vapours readily soluble in, or react with, the absorbing solution

   - simple bubblers (or impingers)

b) for gases and vapours which are less soluble in, or reactive with, the absorbing solution

   - bubblers with diffusers
   - spiral absorbers; and
   - packed towers

The contaminant content of the absorbent liquid can be determined by standard analytical methods including visible, infrared and ultraviolet spectrophotometers, and gas, thin layer, and high performance liquid chromatography.

6.3.7 Adsorption

Any gas or vapour will, to some degree, adhere to any solid surface at ordinary or low temperatures. This phenomenon is called adsorption. This effect is particularly marked when the adsorbing material is porous and has a very large surface area for a given mass.

Gaseous substances that are highly soluble and easily liquefiable are also those that are most readily adsorbed. In the practical application of the absorption principle, the air sample is drawn through a glass or stainless steel sampling tube packed with a suitable adsorbent such as charcoal, silica gel or porous polymer granulates.

Passive sampling is another type of sampling that involves gas/vapour adsorption. It possesses a distinct advantage over the other forms of extractive sampling in that no external air mover or power source is required for it to function successfully. A passive sampler relies instead on molecular diffusion to bring gaseous contaminants into contact with an adsorbent medium. Two types of sampler are in general use:

a) badge monitor; and
b) tube monitor.

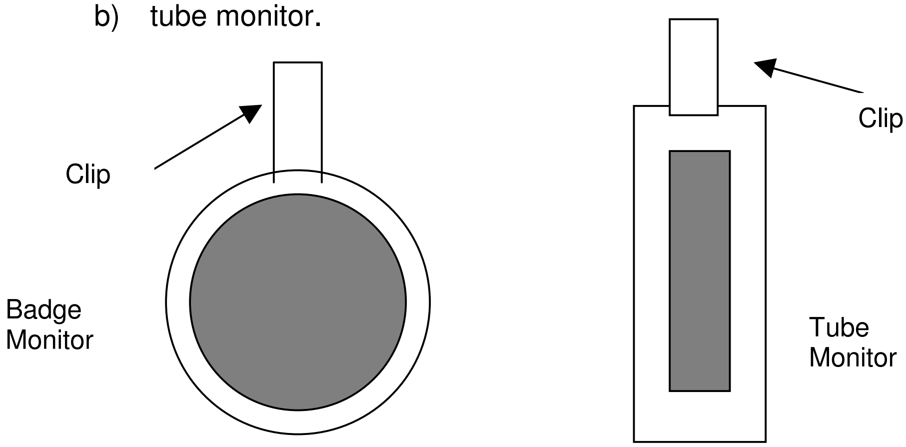

Figure 3: Badge and Tube Monitor

Due to their small size and simplicity of operation, they are favoured as personal samplers. On completion of the sampling process, gaseous contaminants collected on the adsorbent layer are usually recovered by solvent extraction and quantified by gas chromatography.

6.3.8 Condensation

This sampling involves the separation of gaseous contaminants from atmospheric samples by passing the air through a coil immersed in a cooling medium such as a mixture of dry ice and organic solvent, or liquid nitrogen.

Despite the fact that it collects the contaminant in a high concentrated form, the system can never be considered for use in personal sampling, and only in a few specialised applications is it practicable as a static sampling techniques.

CHAPTER 7

INTEGRATED AIR SAMPLING FOR DUST OR FUMES

In the integrated air sampling method, a vacuum pump is connected to the sampling head or filter holder by silicone tubing. The pre-calibrated pump provides the necessary suction, to direct contaminated air into the collector. A first stage separator, usually a cyclone, is used in addition to the second stage separator, i.e. the filter medium.

7.1 INHALABLE DUST OR FUME SAMPLING

Instruments required for inhalable dust or fume sampling:

i) personal sampling pump;
ii) filter holder: 3-pieces cassette;
iii) filter media – depends on the contaminant; and
iv) connecting tubing – usually silicone.

The pump acts as an air mover and causing the necessary suction to be created at the face of the filter holder. For personal sampling the pump must be lightweight, slim, hip-hugging style, battery operated, and capable of producing constant flow rate.

The filter holder or sometimes called the sampling head or sampler. A 3-pieces cassette consists of three plastic pieces: - the male (inlet) section, the ring section, and the female (outlet) section. For a 2-pieces cassette, the ring section is omitted.

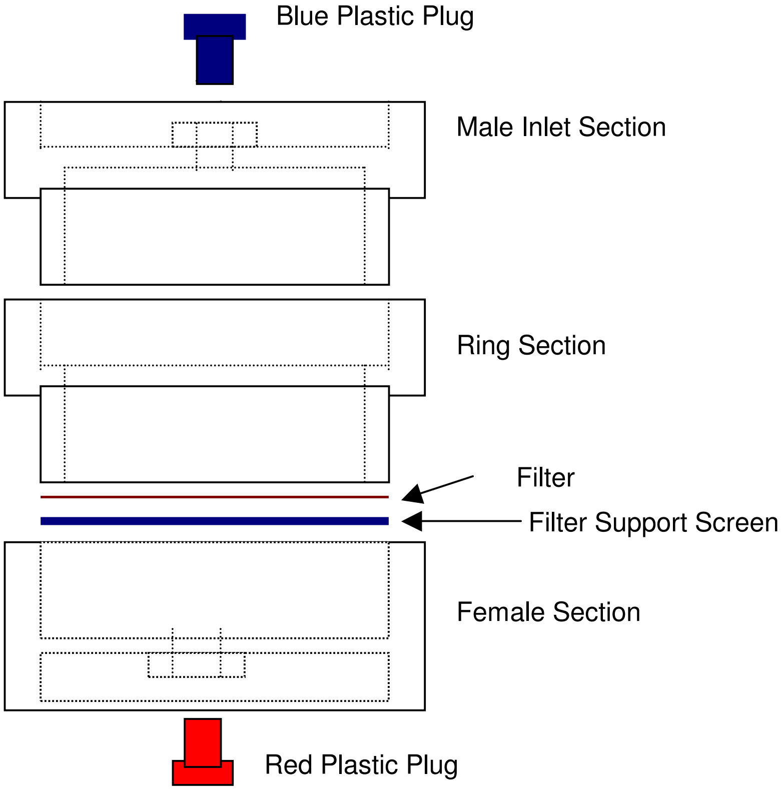

Figure 4: 3-PIECE CASSETTE ASSEMBLY

7.2 RESPIRABLE DUST SAMPLING

For sampling respirable dust the following instruments are necessary:

i) personal sampling pump;
ii) filter holder: 2 – pieces cassette;
iii) filter media;
iv) initial stage collector/respirable dust separator – usually a 10 – mm nylon cyclone; and
v) connecting tube.

Respirable dust separator is either an elutriator or a miniature cyclone connected to the sampling head to separate the non-respirable from the respirable portion of the inhalable dust.

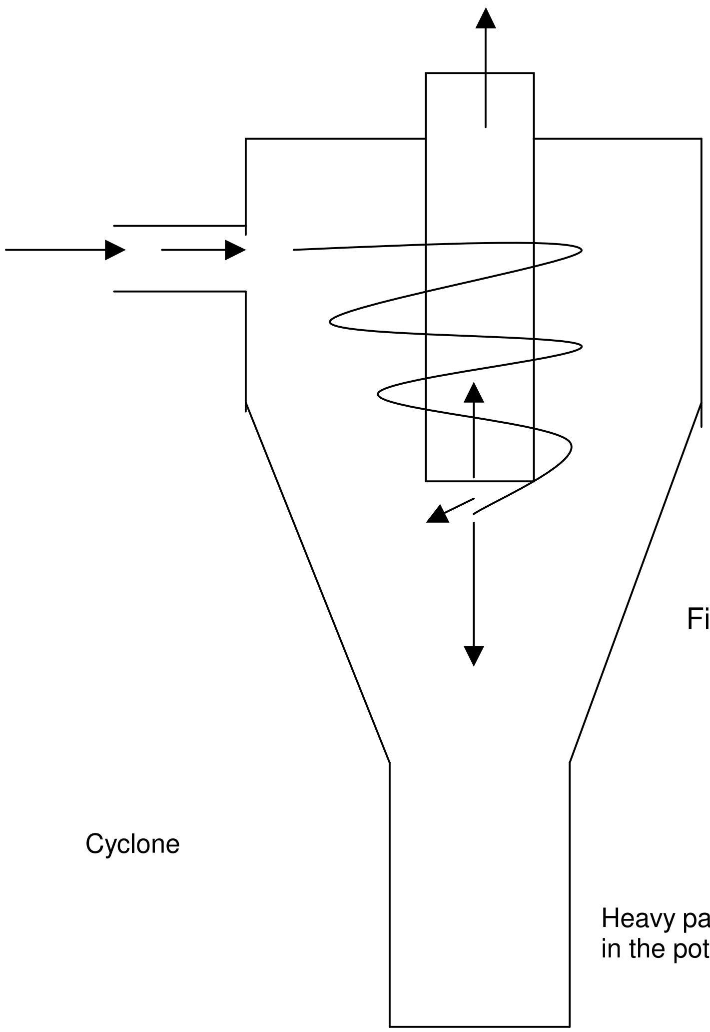

Figure 5: Respirable Dust Separator

The connecting tubes used are made up of silicone rubber. Other accessories include waist-strap to hold the pump in place; sampling head holder; and cellulose band to shrink-wrapped the cassettes.

7.3 FILTER MEDIA

The filter media for particulate sampling is made up various materials such as plastic fibre, cellulose, organic membrance, silver membrane and glass fibre. The characteristics of these filters are given below:

Type of Filter	Characteristics
Plastic Fibre	Weak and friable Elestroststic charge Low moisture pick-up
Cellulose	Considerable tensile strength Rapid uptake of moisture
Organic Membrance	Brittle Very low moisture pick-up
Silver Membrance	Tough and flexible
Glass Fibre	Moderately strong Low moisture pick-up

Table 3 : The characteristics of filters

Recommended filter to be used for various type of particulate are given below:

Particulate	**Filter Used**
Asbestos Fibres	0.45 to 1.2 µm cellulose ester membrance
Elements (e.g. Arsenic)	0.8 µm cellulose ester membrance
Lead	0.8 µm cellulose ester membrance
Silica	0.8 µm or 5 µm PVC or MCE membrance
Wood Dust	5 µm PVC
Welding Fumes	Glass fibre or 0.8 µm cellulose ester membrance

Table 4 : Recommended filter to be used for various type of particulate

CHAPTER 8

INTEGRATED AIR SAMPLING FOR GAS AND VAPOUR

For the active sampling of gas and vapour, the following instruments are used:

i) personal sampling pump;

ii) adsorbent tubes or absorbing solution/reagent in impingers; and

iii) connector tubing – usually silicone tubing.

8.1 PERSONAL SAMPLING PUMP

For the active sampling of gas and vapour, the pump used should be able to deliver low flow rates so as to allow time for contact between the gas and absorbent or the vapour with the adsorbent. For gas washings in impinger bottles, the typical pump flow rates is 1 litre per minute. For sampling using charcoal tubes the recommended flow rate is less than about 200 millilitre per minute.

Different types of collection media are needed for personal sampling according to whether fumes or gases to be collected. The essential features of all systems are a collection media (on which the sample is collected) and a pump for pulling the air through it. Air flow indicating device may be provided. The pump unit must be capable of maintaining a smooth flow of the specified rate through out the sampling period. The permitted error limits of flow may be achieved either by using a flow stabilised pump or by sufficiently frequent adjustment of the flowrate.

8.2 ABSORBERS – IMPINGER BOTTLE

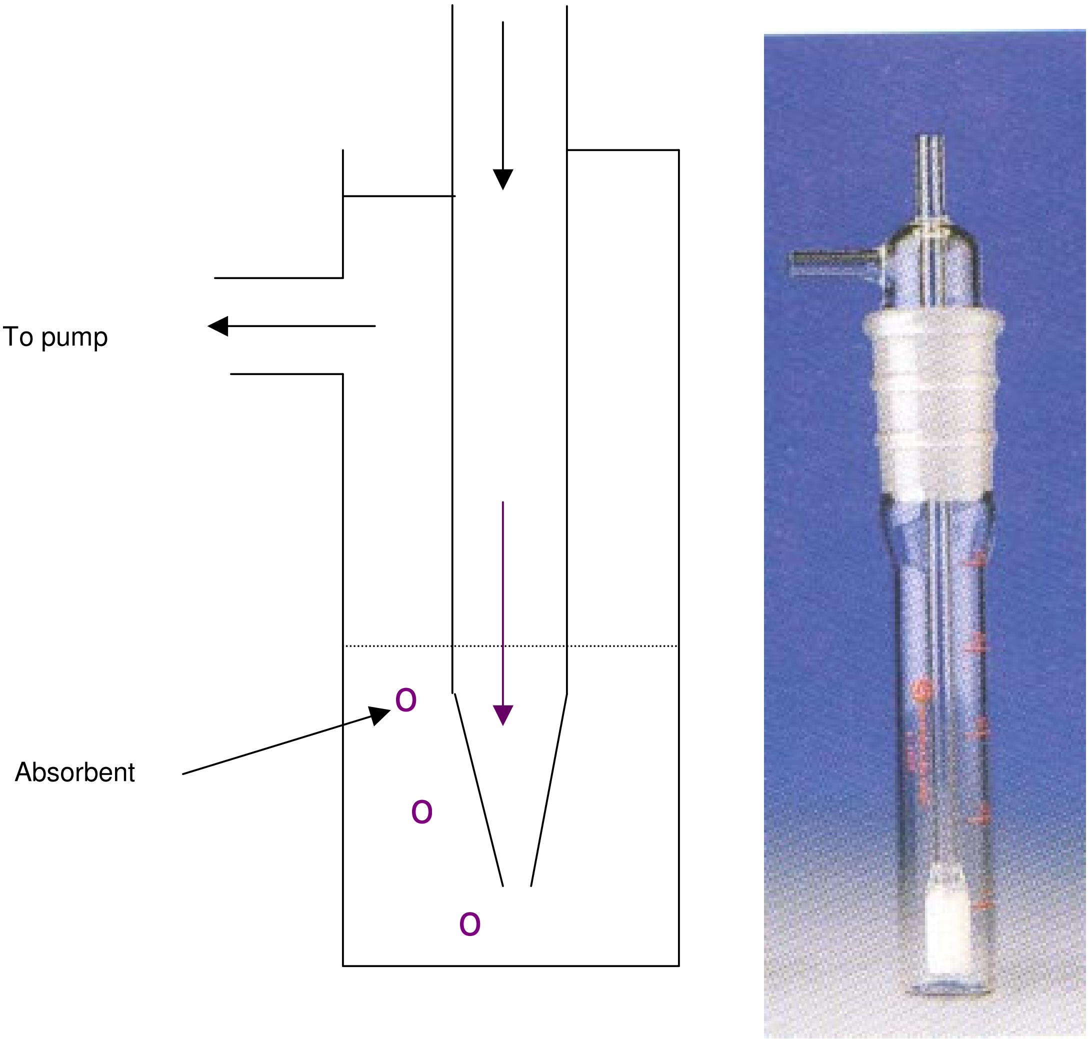

Figure 6: Impinger Bottle

8.3 ABSORBERS – SORBENT TUBE

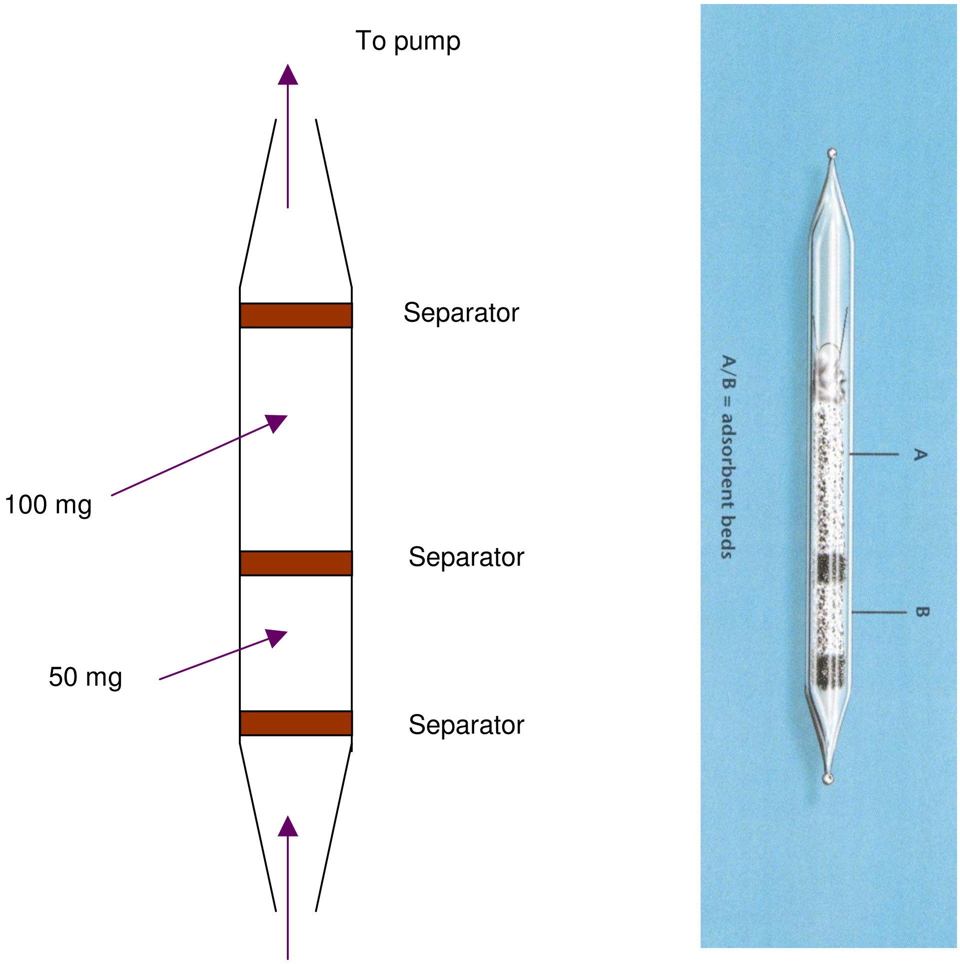

Figure 7: Sorbent Tube

8.4 ADSORBENT AND ABSORBENT MEDIA

Some common adsorbent and absorbent media are listed below:

Analyte	**Absorbent / Adsorbent**	**Collector**
Acids, inorganic	Washed silica gel (400/200) mg	Solid sorbent tube
Ammonia	Sulphuric Acid-treated silica gel	Solid sorbent tube
Formaldehyde	**20ml + 20ml 1% sodium bisulphite solution**	2 impingers + 1µm PTFE filter
Hydrocarbon – boiling point (36-126)^{0}C (e.g. benzene, toluene)	**Coconut shell charcoal** **(100mg/50mg)**	Solid sorbent tube
Hydrogen Cyanide	Soda lime (600/mg200mg)	Solid sorbent tube
Isocyanates	Trytamine/DMSO; 20ml	Impinger
Methanol	Silica gel (100mg/50mg)	Solid sorbent tube

CHAPTER 9

DIRECT READING INSTRUMENTS FOR AIR SAMPLING

Instruments used for sampling of airborne contaminants can be categorised as direct reading instruments and integrated air sampling instruments. Direct reading instruments are also known as real time instruments because they give instantaneous read-out of the measurements made. Integrated air sampling instruments are non-real time instruments because the results of the measurements made are not known immediately as the samples have to be sent for analysis to a laboratory.

9.1 DIRECT READING INSTRUMENTS FOR PARTICULATES

Direct reading instruments are compact, portable devices that combine sampling and analytical functions designed to measure respirable particle mass concentrations.

The physical principles employed for gravimetric analysis of particulate samples are most usually the attenuation of β-radiation, the change in the resonant frequency of a crystal oscillator, or the scattering of light.

9.2 DIRECT READING INSTRUMENTS FOR GAS OR VAPOUR SAMPLING

Direct reading instruments for measuring gases and vapours are devices that sample the atmosphere either continuously or intermittently, quantitatively analyse the sample, and display the results in the form that gives an immediate indication of the atmosphere concentration of the analyte (the substance that is analysed).

Some of these instruments may be used as personal samplers. These direct reading instruments are also useful in tracing sources of contaminant emission, the immediate detection of unacceptable conditions, and the rapid assessment of the efficacy of hazard control procedures.

Some of the commons direct-reading instruments are:

i) MIRAN

Based on the photometric principle, i.e. solutions of air mixtures of gaseous contaminants absorb specific wavelength of light in the infrared regions of the electromagnetic spectrum;

ii) Portable GC

Mixtures of chemical compounds are separated from one another by selective partition between a stationary liquid phase and a mobile phase; and

iii) Gas Detector Tubes

Make use of the chemical properties of the gaseous contaminant to promote a reaction between the gas or vapour and a specific reagent which results in the formation of a coloured product.

9.3 MEASURING ATMOSPHERIC CONDITIONS

Whirling Hygrometer is used to determine the relative humidity of the work environment by measuring the wet and dry bulb temperatures and the relative humidity chart is used to read-off the relative humidity.

CHAPTER 10

CALIBRATION OF SAMPLING INSTRUMENTS

The purpose of calibrating sampling instrument is to set the pump to the recommended flow rate so as to get an accurately measured volume of air over the sampling duration. There are two type of calibrator, i.e. the primary calibrator and the secondary calibrator. The most commonly used primary calibrator is the bubble meter that uses the principle of 'frictionless cylinder'. The accuracy of a primary calibrator should be less than ± 5 %. The secondary calibrator is less accurate and it is used to check the flow rate of the pump during sampling.

The pumps need to be calibrated before every air monitoring. When carrying out pump calibration, the sample collector needs to be connected between the pump and the calibrator. The pump flow adjustment is adjusted so that the desired flow rate is obtained. When the desired flow is achieved, the pump flow meter or rotameter is marked, to indicate the set value.

10.1 CALIBRATION SET-UP FOR INHALABLE PARTICULATE SAMPLING

Before calibration, make sure that the pump is fully charged and in good order. Set up the apparatus according to the arrangement as shown in Fig. 8. The bubble meter uses the principle of cylindrical air displacement meter with nearly 'frictionless' piston. The interior surface is wetted with detergent solution to make it 'frictionless'. A soap-film bubble is placed and suction is provided from the pump to be calibrated. The bubble will be drawn up the cylinder. The column displacement per unit time can be determined by measuring the time required for the bubble to pass between the two scale marking which enclose a known volume.

By adjusting the flow rate of the pump, the required flow rate as derived from the bubble meter can be found. The temperature of the room and the barometric pressure must be recorded during the calibration. After sampling, the pump has to be recalibrated to check the flow rate and to calculate the error. If the error is more than 10%, the sample must be rejected.

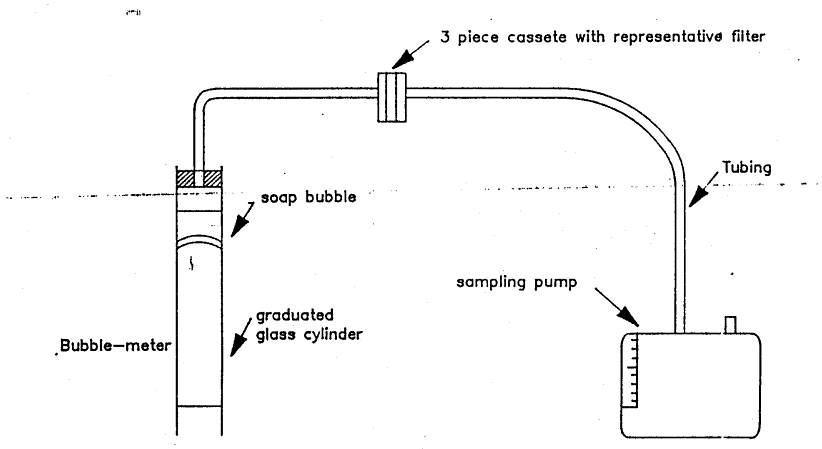

Fig. 8 Calibration Set-Up For Inhalable Particulate Sampling

10.2 CALIBRATION SET-UP FOR RESPIRABLE PARTICULATE SAMPLING WITH A 10 MM NYLON CYCLONE

Calibration set-up for the respirable particulate will be similar to the inhalable particulate and the arrangement is shown in the Fig. 9.

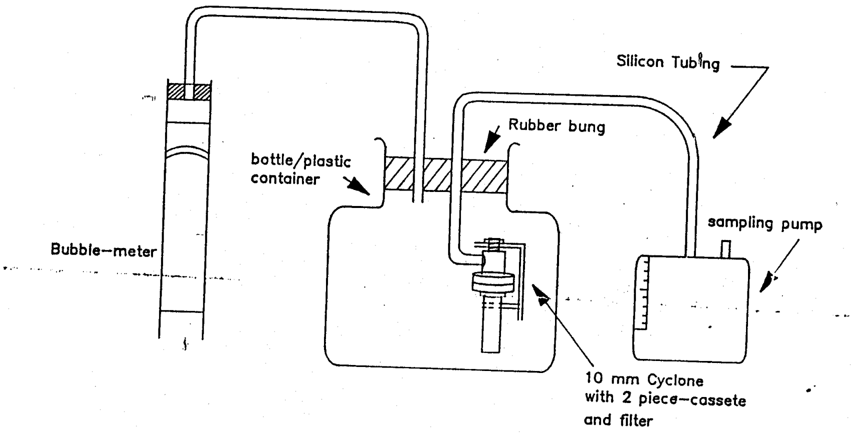

Fig. 9 Calibration Set-Up For Respirable Particulate sampling

CHAPTER 11

CALCULATION OF DUST CONCENTRATION

The difference between the weight of the conditioned filter after sampling and the weight of the conditioned filter before sampling represents the weight found in the filter. The difference in the weight of the blank filter after and before sampling represent the weight found in the blank filter.

Corrections for the blank must be made for each sample.

Corrected sample weight, M

M = weight found in the sample filter – average weight in the blank (s)

11.1 CORRECTION OF VOLUME AIR SAMPLED

It is necessary to correct the volume of air sampled for barometric pressure, where the difference in altitude is more than 1000 ft or the temperature difference more than 14^0C.

Actual volume of air sampled (cubic metre) for pumps with linear scale

$$V = \frac{fc \ x \ t}{1000} \left[\frac{Pc \ x \ T}{P \ x \ Tc} \right]^{½}$$

Where,

fc = Calibrated flow rate (litre per minute)

t = Sample duration (minutes)

Pc = Barometric pressure at calibration location (mm Hg)

P = Barometric pressure at the sampling location (mm Hg)

T = Absolute average ambient air temperature during sampling (Kelvin)

Tc = Absolute ambient temperature during calibration (Kelvin)

Note: for pumps without rotameter, the above correction should not apply.

11.2 CONVERTION VOLUME OF AIR SAMPLED TO STANDARD CONDITION

The formula used to convert the volume of air sampled to standard condition of 25^0C (298 Kelvin) and 760 mm Hg:

$$Vs = V \frac{P}{760} \times \frac{298}{T}$$

Where, Vs = Volume of air sampled at standard condition

V = Actual volume of air sampled

P = Volumetric pressure at sampling location (mm Hg)

T = Absolute average ambient air temperature during sampling (Kelvin)

11.3 THE CONCENTRATION OF DUST

The concentration of dust in the air sampled can be expressed in milligram (mg) per cubic metre:

$$\text{Concentration} = \frac{\text{corrected sample weight (mg)}}{\text{corrected volume of air sampled } (m^3)}$$

CHAPTER 12

CHAIN OF CUSTODY AND FREQUENCY OF MONITORING

12.1 CHAIN OF CUSTODY

Hygiene Technicians rely on support from laboratories whose are capable of analysing samples collected in the field. In selecting a lab, they should be convinced that the laboratory has the technical expertise to support the problems most likely encountered in the field and can demonstrate competence. Labs may have available a sampling protocols manual, which assures that the techniques used to collect samples are compatible with their established analytical procedures. They may also provide a collecting media.

The selected laboratory should demonstrate general competence by participating in appropriate external quality assurance, proficiency Test and certification programs initialised by The Department Standard of Malaysia. They should be capable of producing a set of standard operating procedures, chain of custody practices, sample handling and control procedures, instrument calibration and maintenance records, internal and external testing programs, and quality control of individual methods.

The selected laboratory should also review the methodology used to verify the accuracy, precision, sensitivity, temperature, humidity, and storage effects of the procedure. Both the hygiene technician and the laboratory management should be concerned with maintaining the integrity of the sample through a chain of custody procedure.

This practice assures that the analysed samples are not confused with each other and that the sample was not damaged or in some way altered as it passes through various individuals or organisation's areas of responsibility. In the field, samples should be dated, labelled, and, if necessary, stored to remain fresh as soon as possible after collection.

Sampling data sheets should be updated continuously with pre-and post sampling flow rates, date and duration of sampling, type of sample, individual collecting the sample, and critical information such as the individual location or operation being investigated as well as pertinent field notes. A common identification number should link sample and data sheets. The laboratory and field personnel should maintain sample logs.

12.2 FREQUENCY OF MONITORING

Monitoring has to be repeated at interval of not more than 6 months for employee exposed to chemical hazardous to health listed in The Schedule II of The Occupational Safety and Health (Use And Standards Of Exposure Of Chemicals Hazardous To Health) Regulations 2000.

In general, the re-evaluation frequency for monitoring should be based on the risk rating (RR) as determined from the assessment. The frequency should be as follows:-

i) Very High (RR=5) : Continuos monitoring
ii) High Risk (RR=4) : Monthly to quarterly
iii) Moderate (RR=3) : Quarterly to annually
iv) Low Risk (RR=2) : 1 – 3 years
v) Very Low (RR=1) : 3 – 5 years

APPENDIX 1: USE OF A RANDOM NUMBER TABLE FOR SELECTION OF RANDOM SAMPLING PERIODS

APPENDIX 2 : TABLE OF RANDOM NUMBERS FOR PARTIAL SAMPLING

REFERENCES

i) Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000;

ii) Threshold Limit Values for Chemical Substances and Physical Agents; and Biological Exposure Indices 2000 By ACGIH

iii) NIOSH Occupational Exposure Sampling Strategy Manual By Nelson A. Leidel, Kenneth A. Busch & Jeremiah R. Lynch

iv) NIOSH Manual of Analytical Methods (NMAM), Fourth Edition

v) Sampling Strategy for Airborne Contaminants By Tuan Haji Anuar Mohd Mokhtar (Division Head of the Chemical Section, DOSH)

vi) Basic of Industrial Hygiene Debra Nims

vii) Encyclopaedia of of Occupational Safety and Health, Volume 1
Third (Revised Edition), by Dr. Luigi Parmeggiani

viii) Occupational Safety and Health (Classification,Packaging and Labelling) Regulations 1997;

ix) Approved Method of Monitoring and Analysis
Made under Factories and Machinery (Mineral dust) Regulations, 1989
Published by Factories and Machinery Department, 31st Mac 1993

x) Patty Industrial Hygiene and Toxicology, General Principles
Volume 1, Part B, 4th Edition,
By George D.Clayton & Florence E. Clayton