Occupational Hygiene Exposure Verification: Sampling and Interpretation

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Pfizer
Introduction

• Session Scope
  – Developing Sampling Plans
  – Conducting Sampling Strategies
  – Equipment Options
  – Lab Analysis

• Session Aim
  – To provide delegates a high level awareness of the key techniques that may be used to quantify exposure potential in the workplace
  – This session is not intended to make you ‘competent’ in any of the techniques described
  – Further specific training is recommended before conducting exposure monitoring
SAMPLING STRATEGIES
Key Questions Before Monitoring:

1. Has a sampling plan/strategy been developed?
2. Is there an exposure limit for the compound being sampled?
3. Is there an analytical method for the compound being sampled?

Exposure monitoring data are required when the qualitative risk assessment indicates:

- Potential exposures (without consideration of RPE) above Action Levels (where an OEL exists); or
- The airborne concentration is within the OEB for materials with only an OEB and no data exists for similarly controlled operations considered representative of the work activity subject to assessment
- Containment verification for newly installed equipment or upgrades to existing controls
Quantitative Assessment: Exposure Monitoring

Sampling Strategy:

- A combination of personal and area samples should be taken.
- Sampling should reflect actual operating conditions.
- Determine if sampling will be done for short term exposures or full shift exposures.
- It is preferred that samples be taken for individual unit operations or tasks.
- Multiple unit operations and task samples can be combined to determine the full shift exposure.
- Consider use of wipe (surface) samples as part of the overall exposure profiling.
- Sampling frequency based on qualitative risk assessment, previous results, corrective action implementation and regulatory requirements.
Establish Similar Exposure Groups

- Can be defined:
  - By process and environmental agent
  - By process, job and environmental agent
  - By process, job, task and environmental agent
  - By process, task and environmental agent
  - By work teams
  - By non-repetitive work
Operator Variability

- Exposure pattern & concentrations are in a state of constant flux due to:
  - Changes in the process
  - Changes in ventilation rates
  - Changes in climatic conditions
  - Range of workers tasks within a day
  - Individual worker practices
The Task – Exposure Profile

- Understanding temporal relationship of workers’ exposure
  - (Fairly) uniform exposure over the work shift?
  - Short but possibly elevated exposure levels? E.g. dispensing chemicals
  - Highly irregular exposure patterns? E.g. maintenance
Sampling Strategies

• Primary Objective:
  – Provide analytical information about the workplace

• Other objectives:
  – Investigate complaints
  – Compliance to exposure limits
  – Evaluate effectiveness of controls
Sampling Strategies (cont)

- The following should be considered before developing any monitoring program
  - Qualitative risk assessment
  - Measurements other than airborne samples (bulk samples, airflow patterns)
  - Biological monitoring
  - Other health hazards
  - Any environmental or worker characteristics
Factors in a Monitoring Strategy

• Type of samples (area v personal)
• Location of sampling device (area)
• How many samples
• Length of sampling interval
• What period of the day should monitoring occur so as to be consistent with work patterns
Factors in a Monitoring Strategy (cont)

- How should the samples be taken?
- Contaminants likely to be present?
- What are the expected concentrations?
- Potential interferences with sampling or analytical method?
- Analytical method and possible constraints?
Surveys

- Initial appraisal
- Basic survey
- Detailed survey
- Routine survey
Initial Appraisal

- Commonly called a “walkthrough survey”
- Can provide answers to these questions:
  - What are the potential exposures
  - Where & when do they occur
  - Can exposures be prioritized in terms of risk
  - Is further evaluation necessary
  - If so, what is the preferred approach
- While the “walkthrough survey” gives basic information you may still need further information on:
  - Physical properties of substances
  - Physical form in the workplace
  - Potential routes of intake
  - Any skin effects
  - Any available exposure limits
Basic Survey

- Generally required when:
  - Initial appraisal indicates unacceptable exposures possible
  - New process being commenced
  - Substantial changes to a process, operations or control measures
  - Unusual events (e.g. maintenance)
  - New exposure limit declared

- Possible objectives:
  - Confirmation (or otherwise) of possible unacceptable exposures from initial appraisal
  - Information on engineering or other controls
  - To establish if a more detailed survey is necessary
Basic Survey (cont)

- Questions to be addressed before proceeding:
  - Who should be monitored?
  - When should they be monitored?
  - Where should the monitoring occur?
  - How should the sampling occur?

- Other factors
  - Legislative requirements
  - Accuracy & precision required
  - Intrinsic safety requirements
  - Laboratory analysis
  - Transport of samples
  - Portability of equipment
Detailed Survey

- Usually has a clear objective
  - to obtain reliable measurements, reach conclusions regarding exposure & decide control measures

- Results need to be representative of personal exposures & appropriate method used to compare results to exposure standard
Routine Surveys

• Generally involve periodic sampling to meet defined goals, such as:
  – Checking control measures
  – Compliance
  – Corporate requirements

• No set rules on frequency, but the following should be considered when making judgments:
  – How close are exposures to exposure standard
  – How effective are the controls
  – What is the process cycle
  – Seasonal & shift variation
  – High variability in data
AIR SAMPLING THEORY & PRACTICE
Routine Monitoring

• Issues that need to be considered:
  – Frequency
  – Sampling methodology
  – Number of samples required
  – Type of data analysis

• Sampling Patterns
  – Grab samples
  – Partial period consecutive samples
  – Full period consecutive samples
  – Full period single samples
Practicalities of Sampling Programs

• Large statically based monitoring programs are expensive & rare

• What can one person reasonably do in a sampling exercise
  – Difficult to calibrate, distribute, monitor & recalibrate more than 5 sampling devices
  – Need to ensure the quality of data, the persons & situations sampled be appropriate & be able to explain abnormalities in data

• Relationship between observations & measurements is critical
  – Better to have fewer samples that can be interpreted rather than large numbers of samples which can’t

• The process may limit the sampling approach
  – Batch processes for example do not lend themselves well to statistically based random sampling exercises
Quantitative Assessment: Exposure Monitoring

Methods and Devices

- Sampling and analysis must be carried out using established protocols:
  - OSHA Analytical Methods;
- Direct readout, e.g. PID, Catalytic Ex-Sensor, IR, Electrochemical
- Colorimetric Detector Tubes
- Passive samplers
- Active Sampling
Quantitative Assessment: Exposure Monitoring

**Equipment**

- Air sampling pump
- Calibrator
- Sample media
- Detector tubes
- Passive monitors
- Associated accessories
Quantitative Assessment: Exposure Monitoring

Sample Collection:

- Determine the flow rate of the pumps based on task duration and sensitivity of the analytical method.
- Sampling pumps should be calibrated before and after sampling events.
- Sample media (filters, tubes) must be specific to the compound being sampled.
Quantitative Assessment: Exposure Monitoring

Sampling Methods Considerations

- Sampling media
- Flow rate
- Duration of Exposure
- Analytical Sensitivity
- Vol-min and -max
- Shipment
- Sample stability
- Blanks

NIOSH 2000: Methanol

<table>
<thead>
<tr>
<th>SAMPLER:</th>
<th>SOLID SORBENT TUBE (silica gel, 100/50 mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOW RATE:</td>
<td>0.02 to 0.2 L/min</td>
</tr>
<tr>
<td>VOL-MIN:</td>
<td>1 L @ 200 ppm</td>
</tr>
<tr>
<td>VOL-MAX:</td>
<td>5 L</td>
</tr>
<tr>
<td>SHIPMENT:</td>
<td>pack securely for shipment; store at 5°C.</td>
</tr>
<tr>
<td>SAMPLE STABILITY</td>
<td>at least 30 days at 5°C [1]</td>
</tr>
<tr>
<td>BLANKS:</td>
<td>2 to 10 field blanks per set</td>
</tr>
</tbody>
</table>
Quantitative Assessment: Exposure Monitoring

Blanks

- Reagent blanks, media blanks and field blanks
- Reagent blanks measure the signal contribution from solvents, acids or other reagents
- Media blanks measure the signal contribution from the collection media
- Field blanks measure signal contribution of the media plus any contamination which may have occurred during handling, shipping and storage before analysis.
Quantitative Assessment: Exposure Monitoring

Analytical Method Sensitivity Affects Sampling Strategy

- The limit of detection (LOD) is the lowest concentration that can be determined to be statistically different from a blank.
- The limit of quantification (LOQ) is the minimum mass of the analyte above which the precision of the reported result is better than a specified level.
- LOD in NIOSH 0500 Particulates Not Otherwise Regulated, Total is 0.03 mg/sample or 30 µg/sample.
- With a sample taken at 2 L/min for 8 hours (480 min) the total air volume sampled is 960 L or almost 1 m³, i.e. the LOD is 30 µg/m³ based on an 8-hour sampling duration!
Exposure Monitoring Strategy

- Personal or area sample?
- Short-term sampling
  - evaluation of STEL
  - Task sampling
- TWA
  - workday divided into phases based on observable changes in process or locations and average calculated
- Number of samples?
  - 1-20: 50%; 21-100: 10+5% of excess of 20; > 100: 30+5% of excess of 100
- Frequency of sampling?
Types of Sampling

Grab or Instantaneous Samples

Source: BP International
Types of Sampling

Short Term Samples

Source; BP International
Types of Sampling

Long Term Samples

LONG TERM TIME WEIGHTED AVERAGE

Source: BP International
Types of Sampling
Continuous Monitoring

- Concentration
- Time
- CONTINUOUS MONITORING

Source: BP International
Quantitative Assessment: Exposure Monitoring

- **Area sampling**
  Specific operations in the workplace.
  To evaluate the source of contamination or the degree of engineering controls needed

- **Personal sampling**
  Worker’s breathing zone
  To determine exposure throughout the work shift or in some instances for a short period
Sample Collection

- Personal samples should be located so the sampling media is within the breathing zone of the operator.
- Area samples can be used to support personal sampling information and confirm equipment containment
Sample Collection

- Multiple samples, such as sampling multiple operators, should be collected.
- Sampling events should be over multiple operating events, to allow for variation in exposures.
- At least one blank filter or tube should be submitted for each sampling period.
- It is recommended to collect a minimum of six samples over three separate sampling events.
Sub-Division Isolator in Booth -
Verification
• Personal Sample x 1
• Pass chamber door
• Glove port (LHS)
• RTP Port
• Continuous Liner Packoff
• Split butterfly valve to canister connection
• Waste/Exhaust hosing
Area – at rear of booth – 5ft from isolator

Area Sampler on tripod – product out point
Area sampler on tripod
Personal sample

Pump Location:
• 2ft from ILC Dover Pac bag – in breathing zone
  Behind the ILC Dover Pac bag

1. Personal Sample
2. <1 ft from split butterfly canister
3. Hanging 3ft from canister in breathing zone
4. Area – 10ft from canister
Sample Numbers

• Fundamental question always asked – how many samples do I need to provide representative & useful information?
  – One sample is never acceptable

• Depends on information required:
  – Compliance
  – Epidemiology
  – Corporate requirements
  – Degree of confidence
Sample Numbers

- Practical Options:
  - Point of diminishing returns
  - Reasonable approximation of exposure profile possible with about 6-10 samples (AIHA 1998 & 2006)
  - As exposure approaches exposure limit this number increases depending on level of confidence required
Personal Sampling

• Inhalation is main route of entry to the body
  – Estimate of exposure should be conducted in a location consistent with inhalation patterns

• Breathing zone
  – Personal samples
  – The shape of the head can result in significant concentration differences over short distances

• Operator variability
Breathing Zone

Personal samples MUST be taken in the Breathing Zone

300mm Hemisphere around the nose and mouth

Source: Airmet Scientific – reproduced with permission
Personal Sampling

Operator Variability:

- Exposure pattern & concentrations are in a state of constant flux due to:
  - Changes in the process
  - Changes in ventilation rates
  - Changes in climatic conditions
  - Range of workers tasks within a day
  - Individual worker practices
Area or Background Sampling

• Commonly referred to as static or area samples as they are not collected on a person but in a fixed position

• Do not correlate well with actual personal exposures but useful for:
  • Checking control devices
  • Identifying contaminant sources
  • Identifying potentially unacceptable areas of exposure
  • Continuous monitoring
  • Sampling high volumes (e.g. asbestos clearance)
Particle Size

• Distribution of an aerosol in an air stream depends on its aerodynamic properties

• Aerodynamic diameter key factor of particles in settling rates

• Particle size can influence contaminant concentration
  – Mixed dust may have one particular contaminant concentrated in one particular size range
Surface Monitoring (Wipe Tests)

- Surface Monitoring can be used to support air monitoring results as part of the overall exposure assessment.
- Surface Monitoring is also valuable in evaluating containment efficiency, contamination migration, and effectiveness of cleaning techniques.
- Surface Monitoring can identify “Red” (contaminated), “Yellow (partially contaminated), and “Green” (clean) zones.

Surface Monitoring (Wipe Tests)

- Like air monitoring, ensure that:
  - Acceptance levels are established before conducting the wipe tests.
  - Analytical methods are developed.
  - Specific test validations are completed, as removal efficiency from different surfaces will affect wipe test results.
Methods for Surface Monitoring

- Micro vacuuming
- Disposable paper towels
- Manual wipe methods
- Adhesive tape
- Colourimetric pads (acids & alkalis)
- Specific instrumentation
  - Mercury “sniffers”
Definition of Dust, Fumes & Fibers

- Solid particles can exist as:
  - Dust: solid material of varying sizes (0.1 – approx 100um)
  - Fumes: produced when a solid is heated until a gas is generated and recondenses into solid or liquid particles (typically < 1 um)
  - Fibers: solid thread like filaments with a defined length to width ratio
Typical Size Characteristics

Source: M Tranter 1999 – reproduced with permission
Health Factors of Dust, Fumes & Fibers

- Chemical composition of material
  - Toxic effect: what is the toxicology of the material & the respective target organs?

- Particle Size
  - Where it deposits in the body: is it capable of penetrating to the alveoli or only the upper respiratory tract?
Sampling Pumps

• Many commercially available pumps

• Most are small battery powered units which can be attached to a person

• Operate at flow rates between 0.5 – 5.0 L/min however most particulate sampling is carried out at flow rates of 1.0 – 2.5 L/min
Typical Sampling Pump

Source: University of Wollongong
Useful Features of Pumps

• Automatic flow control
• Pulsation dampening
• Capacity to operate at a reasonable backpressure
• Reasonable flow range
• Good battery capacity
• Intrinsically safe (ATEX)
Key Issues

• Maintenance
  – Must be performed regularly and recorded for each pump
  – Check automatic flow compensation and internal inline filters

• Battery charge
  – Nickel-Cadmium batteries prone to “memory effect”. Cycling of pumps can overcome effect in most cases
  – Use of appropriate chargers

• Internal flowmeters
  – Not accurate due to design flaw (one end must be open to atmosphere)
Filters

Particles trapped / caught on filter media by:
- Interception
- Impaction
- Diffusion

Media requirements:
- High collection efficiency
- Manageable resistance
- Low moisture pick up or loss
- Low electrostatic properties
- Compatible with analytical technique
- Low cost
Filters (cont)

Filter types:
- Mixed cellulose ester
- PVC
- Teflon
- Polycarbonate
- Silver
- Glass fibre
- Quartz
- Cellulose
Filters (cont)

- **Pore size**
  - Nominal pore size – not a sieve
  - Tortuous path – increase collection efficiencies
  - Exception polycarbonate

- **Treated / impregnated filters**
  - Particulate and gaseous contaminant
  - Glutaraldehyde – Glass Fiber/2,4-dinitrophenylhydrazine
  - Fluorides – Teflon/sodium carbonate

- **Moisture loss and pick up**
  - Equilibration and field blanks

- **Electrostatic charge**
  - Static eliminator (Zerostat Gun)
  - Radioactive source
Sampling Heads

- Inhalable dust
  - IOM sampling head (IOM)
  - UKAEA 7 hole sampling head
  - Conical inhalable sampler (CIS)
  - SKC button sampler
  - Pre-loaded cassettes
The IOM Sampler Components

- Cassette system
- All collected dust is measured
- Easily handled
- No contact with filter
- Multi fraction sampling with foam inserts

Source: Airmet Scientific - reproduced with permission
Pre-Loaded Cassette
Sampling Heads

- Respirable dust
  - BCIRA
  - SIMPEDS
  - Aluminium
  - 10mm Nylon (Dorr-Oliver)
Operation of Miniature Cyclone
Special Sampling Heads

- Asbestos & synthetic fibres
- Diesel particulate
- Rosin-based solder flux fume
Asbestos & Synthetic Fibres

Source: University of Wollongong
Key Points to Note

• Need to ensure sampling tubing is secure

• Need to collect appropriate information

• Need to monitor sampling system several times during sampling period

• Pre & post flow rates should be within +/- 5% as per “best practice”
Type of Information to be Recorded

- At commencement of sampling
  - Sampler identification number
  - Filter identification number
  - Pump identification number
  - Date & pump start time
  - Initial flow rate of pump
  - Workers name or description of static location
Type of Information to be Recorded (Cont)

- During sampling
  - Description of task(s) undertaken during sampling period
  - Risk control measures in place
  - Atmospheric conditions
  - Any other relevant data (e.g.- unplanned events)

- At conclusion of sampling exercise
  - Record the time
  - Re-measure flow rate prior to switching off pump
GASES AND VAPORS
Definitions

- Gas - substance which is “air like’ but neither a solid or liquid at room temperature
- Vapor - the gaseous form of a substance which is a solid or liquid at room temperature
Sampling of Gases and Vapours

• Whole of Air or Grab Sampling

• Active sampling
  – Absorption
  – Adsorption

• Diffusion or passive samplers

• Direct reading instruments

• Detector tubes
Active Sampling

• Pump
• Absorption
• Adsorption – sorbent tubes eg
  – Charcoal
  – Silica gel
  – Porous polymers – Tenax, Poropaks etc
  – TD
• Mixed phase sampling
Active Sampling (cont)

Low volume pump – 50 – 200 ml/min

Sample train

Calibration
Active Sampling (cont)

Tube Holder

Source: University of Wollongong
Active Sampling (cont)

Gas/Vapor Sampling Train

Break off both ends of a sorbent tube (2mm dia, or ½ dia of body)

Put tube in low flow adapter/tube holder

Make sure tube is in correct way around

Source: Airmet Scientific – reproduced with permission
Taking the Sample

- Place sample train on person:
  - Start pump
  - Note start time
  - At end of sample:
  - Note stop time

Source: Airmet Scientific – reproduced with permission
Active Sampling (cont)

Universal type pumps allow:
Up to 4 tubes at the same time – either running at different flow rates or with different tubes.

Multi Tube sampling

Universal type pumps allow:
Up to 4 tubes at the same time – either running at different flow rates or with different tubes.

Source: Airmet Scientific – reproduced with permission
Absorption

Absorption – gas or vapor collected by passing it through a liquid where it is collected by dissolution in the liquid

Impingers

Source: University of Wollongong
Absorption (cont)

- Collection efficiencies
  - Size and number of bubbles
  - Volume of liquid
  - Sampling rate – typically up to 1 L/min
  - Reaction rate
  - Liquid carry over or liquid loss
  - Connect in series

- Need to keep samplers upright

- Personal sampling awkward & difficult

- Absorption often used for:
  - Formaldehyde collected in water or bisulphite
  - Oxides of nitrogen – sulphanilic acid
  - Ozone – potassium iodine
Adsorption

Gas or vapor is collected by passing it over and retained on the surface of the solid sorbent media.

Source: Airmet Scientific – reproduced with permission
Adsorption (cont)

Breakthrough:

Source: Airmet Scientific – reproduced with permission
After sampling:
- remove tube
- cap the tube
- store, submit for analysis with details of sample
- Don’t forget to send a blank with samples to laboratory

Source: Airmet Scientific – reproduced with permission
Activated Charcoal

- Extensive network of internal pores with very large surface area
- Is non polar and preferentially absorbs organics rather than polar compounds
- Typically CS\textsubscript{2} for desorption
- Limitations:
  - Poor recovery for reactive compounds, polar compounds such as amines & phenols, aldehydes, low molecular weight alcohols & low boiling point compounds such as ammonia, ethylene and methylene chloride
Silica Gel

Used for polar substances such as
- Glutaraldehyde
- Amines
- Inorganics which are hard to desorb from charcoal

Disadvantage
- Affinity for water

Desorption
- Polar solvent such as water and methanol
Collection Efficiencies of Adsorption Tubes

- **Temperature**
  - Adsorption reduced at higher temperatures
  - Some compounds can migrate through bed
  - Store cool box, fridge or freezer

- **Humidity**
  - Charcoal has great affinity for water vapor

- **Sampling flow rate**
  - If too high insufficient residence time

- **Channeling**
  - If incorrectly packed

- **Overloading**
  - If concentrations / sampling times too long or other contaminants inc water vapor are present
Treated Filters

Chemical impregnation including use for:

- Mercury
- Sulphur dioxide
- Isocyanates
- MOCA
- Fluorides
- Hydrazine
Every contaminant on every brand of monitor has its own unique, fixed sampling rate

Source: 3M Australia – reproduced with permission
Diffusion or Passive Sampling (cont)

Advantages

- Easy to use
- No pump, batteries or tubing & no calibration
- Light weight
- Less expensive
- TWA & STEL
- Accuracy ± 25% @ 95% confidence
Diffusion or Passive Sampling (cont)

Limitations

– Need air movement 25 ft/min or 0.13 m/sec
– Cannot be used for
  • Low vapor pressure organics eg glutaraldehyde
  • Reactive compounds such as phenols & amines
– Humidity
– “Sampling rate” needs to be supplied by manufacturer
Diffusion or Passive Sampling (cont)

• After sampling diffusion badges or tubes must be sealed and stored correctly prior to analysis.

• For example with the 3M Organic Vapor Monitors:

  • Single charcoal layer: Fig 1 - remove white film & retaining ring. Fig 2 - Snap elution cap with plugs closed onto main body & store prior to analysis.

Source: 3M Australia – reproduced with permission.
Those with the additional back up charcoal layer remove white film & snap on elution cap as above (Fig 3)

Separate top & bottom sections & snap bottom cup into base of primary section (Fig 4) and snap the second elution cap with plugs closed onto the back up section.

Source: 3M Australia – reproduced with permission
Diffusion or Passive Sampling (cont)

What can be typically sampled?

- Extensive range of organics
  - Monitors with back up sections also available

- Chemically impregnated sorbents allows
  - Formaldehyde
  - Ethylene oxide
  - TDI
  - Phosphine
  - Phosgene
  - Inorganic mercury
  - Amines
Detector Tubes - Colorimetric Tubes

Change in color of a specific reactant when in contact with a particular gas or vapor

Source: Dräger Safety – Reproduced with permission
Detector Tubes - Colorimetric Tubes

Advantages:

- Relatively inexpensive & cheap
- Wide range of gases and vapours – approx 300
- Immediate results
- No expensive laboratory costs
- Can be used for spot checks
- No need for calibration
- No need for power or charging
Detector Tubes - Colorimetric Tubes

Limitations:

- Interferences from other contaminants
- Accuracy of results
- Need to select correct tube & correct range
- Results should NOT be compared to TWA
- Correct storage
- Limited shelf life
COMMON SAMPLING ERRORS
Common Sampling Errors

• Misuse of “self-calibrating” pumps

  – Some sampling pumps available today have internal flow sensors that measure and display the flow rate

  – These devices are secondary standards that should be verified with an external calibrator
Common Sampling Errors

• Failure to calibrate with recommended sampling media in-line
  – Various types of sampling media (and the build up of dust) produce differing resistances to air flow (pressure drops) for which the pump must compensate.
  – Standard methods require that pumps be calibrated within ±5% of the recommended flowrate with the sampling media in-line.
Common Sampling Errors

• Failure to sample at the design flow rate when using a cyclone sampler

  – Each type of cyclone respirable dust sampler has a specific design flow rate that achieves the 50% cut-point
  – Using a different flow rate will alter the collection efficiency curve including the 50% cut-point
Common Sampling Errors

• Failure to calibrate a pump properly

  – Calibration, in air sampling, means to set and verify the flow rate
  – Typically, this is done before and after every sample using a primary standard calibrator or using a secondary standard that has been calibrated to a primary standard
Common Sampling Errors

• Failure to use a constant flow pump

  – Constant flow pumps automatically compensate for flow restrictions ensuring the flow rate is held constant
  – Without this feature, users need to constantly monitor and manually adjust the flow rate to accurately measure air volume
Common Sampling Errors

• Use of area samples to assess personal exposures

  The best estimation of a person’s exposure to a contaminant is obtained by placing the sampling equipment on the exposed individual. Area samples will be more difficult to defend as a reliable estimate of personal exposure.
Common Sampling Errors

• Failure to insert filter or sorbent tube properly
  – Inserting the filter or tube backwards in the airflow will result in lack of contaminant collection on media
  – Ensure filter, and not the filter backing, or the primary sorbent tube section is facing outward
Common Sampling Errors

• Failure to clean cyclones before use
  
  – To achieve the desired particle size separation, the internal parts of a cyclone must be clean
  – Deposits of particulate matter adhering to the sides of the cyclone can alter the size-selection characteristics of the particulate penetrating the cyclone and collected on the filter
Common Sampling Errors

• Inverting a cyclone during or after sampling

  – The cyclone separator permits collection of smaller particles on the filter and removal of larger particles into the grit pot.
  – Inversion of the cyclone causes larger particles to erroneously fall from the grit pot onto the filter material.
Common Sampling Errors

• Use of a pulsating pump for collecting respirable dust samples
  – Size-selective devices such as cyclones are affected by changes in flow rate.
  – It is important to maintain a constant and non-pulsating flow rate to ensure correct size selection
CALIBRATION
Calibration

• Primary standards
  – Traceable to a national standard
    • Soap film meters
    • Wet-test gas meters
    • Bell spirometer

• Secondary standards
  – Requires calibration at regular intervals against a primary standard
    • Electronic meters (some types considered primary standard in some countries)
    • Rotameters
    • Magnehelic gauges
Electronic Flow Meter

Source: University of Wollongong
Calibration with an Electronic Meter
Points to be Considered in Calibration

- Use identical sampling head & filter to that used in field
- Allow sample pump to stabilize
- Measure flowrate of pump (3 consecutive readings within +/- 1 % of mean)
- Take account of changes in environmental conditions such as altitude (if > 500m) & temperature (if >15°C)
Suggested Calibration Schedules

• All pumps: on use

• Flow compensation
  – Direct: 6 months if +/- 5% after 2 tests then 3 years
  – Indirect Flow: 4 months if +/- 5% after 3 tests then 12 months
Suggested Calibration Schedules

- **Rotameters**
  - Monthly for 3 months (+/- 3%) then 1 or 2 years depending on bore size

- **Soap Film Meter**
  - On commissioning

- **Electronic flow meters**
  - Monthly for 3 months (+/- 3%) then 6 monthly
Suggested Calibration Schedules

• Stopwatch
  – 6 Monthly

• Balances
  – 1 point check monthly, 6 month repeatability check,
  36 months full range calibration by external authority
Direct Reading Instrumentation
Direct Reading Instruments

- Where immediate data is needed
- Personal exposure monitoring
- Help develop comprehensive evaluation programs
- Evaluate effectiveness of controls
- Emergency response
- Confined spaces
- For difficult to sample chemicals
- Multiple sensors; multiple alarms
- Stationary installations
- Fit testing of respirators
- Video monitoring
Direct Reading Instruments

Advantages:
- Direct reading
- Continuous operation
- Multi alarms
- Multi sensors
- TWA, STEL & Peaks
- Data logging

Limitations
- Often costly to purchase
- Need for frequent and regular calibration
- Lack of specificity
- Effect of interferences
- Cross sensitivity
- Need for intrinsically safe instruments in many places
- Battery life
- Sensors- finite life, poisoning, lack of range
Direct Reading Instrumentation

Dust and Powder:

- Numerous instruments available on market
- Most based on light scattering
- Most optical based instruments over-respond in areas of high moisture
- Emerging technologies addressing this problem
- Very useful for
  - Finding emission sources
  - Measuring effectiveness of control technologies
  - Highlighting dust issues to workers
Direct Reading Instruments

Gas and Vapor

• Many different instruments
• Many different operating principles including:
  – Electrochemical
  – Photoionisation
  – Flame ionisation
  – Chemiluminescence
  – Colorimetric
  – Heat of combustion
  – Gas chromatography
• Many different gases & vapors
• From relatively simple to complex
SAMPLE ANALYSIS
Sample Analysis

• Samples should be stored in refrigerators prior to shipment to laboratory
• Samples should be sent to an approved laboratory capable of conducting the specific analysis using validated methods.
• Sampling reports should be sent with the collected samples, identifying pump flow rates and sampling times.
• Need to consult with laboratory
Analytical Techniques

- Spectroscopy
- Chromatography
- X-Ray diffraction / fluorescence
- Mass Spectroscopy
- Gravimetric
- Microscopy
Detection Limits - Example

Sampling rate 2 L/min
Limit of Detection 10 µg

If the TLV is 0.1 mg/m$^3$

Minimum sampling time = $10 \times \text{analytical limit of detection}$
Exp standard x flow rate

= $10 \times 10 \, \mu g$

= $100 \, \mu g/m^3 \times 2 \times 10^{-3} \, m^3/\text{min}$

= 500 mins

ie full shift sample required
Sources of Analytical Methods

- NIOSH Manual of Analytical Methods (NMAM)
  - Over 1,700 methods in air & blood
  - On line

- UK HSE MDHS Series
  - More than 100
  - On line

- OSHA Standard Methods for sampling
  - On line
Sources of Analytical Methods (cont)

• ISO – Standard Methods for Sampling & Analysis
• National Standards in many countries
• SKC Inc Comprehensive Catalog & Sampling Guide
  – Over 2,500 specific compounds – on line
Quality Assurance of Analysis

Internal quality control

- Method validation (use of validated methods)
  - Check for accuracy – adding known amounts
  - Check for precision – analyse replicate samples
  - Measurement range
  - Interferences
  - Capacity of collection media
  - Sample stability
  - Critical steps in the analytical process
Quality Assurance of Analysis (cont)

- Standards
  - Standard reagents of known purity & composition
  - Calibration standards, calibration curves
- Blanks
  - Field blanks should be submitted with field samples
  - Checks for contamination
  - Laboratory reagent blanks
- Control Materials
  - Previously analyzed and run against field samples to compare actual with expected result
Summary

• Determine OEL/OEB for the substances

• Conduct qualitative risk assessment to determine “high, medium and low risk” work activities
  – High risk: potential exposure above OEL or above OEB
  – Medium risk: potential exposure above Action Level (AL) or within OEB
  – Low risk: potential exposure below AL or below OEB

• Develop a comprehensive sampling plan, consider:
  – STEL or TWA sampling
  – Area or Personal sampling
  – Number of samples
  – Location or SEG to sample

• Select sampling and analytical methods for the substances; select suitable laboratory for analysis

• Collect, preserve, ship and analyze samples in accordance with recognized protocols

• Collate and analyze results, pursue control strategies as appropriate
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