CEN Draft Technical Report ‘Guide for the use of direct-reading instruments for aerosol monitoring’

Dave Mark
Member of CEN/TC137/WG3

CEN/TC137/WG3

HEALTH & SAFETY LABORATORY

- European standards committee:

  'Assessment of Workplace Exposure – Particulate Matter'.
- Produces standards and technical reports (guidelines) on measurement of exposure to aerosols in the workplace
- Currently working on standards for:
  - Revision of EN 13205: Assessment of performance of instruments for measurement of airborne particle concentrations
  - prEN ISO 28439: Characterisation of ultrafine aerosols/nanoaerosols – Determining the size distribution and number concentrations using differential electrical mobility analysing systems
  - Revision of EN 15051: Measurement of the dustiness of bulk materials – requirements and test methods
  - CEN/TR: Guide for the use of direct-reading instruments for aerosol monitoring

CEN/TC137/WG3 (cont'd)

HEALTH & SAFETY LABORATORY

- Strong liaison with:
  - ISO/TC146/SC2/WG1, Air Quality/Workplace Atmospheres - Particle Size-selective Sampling and Analysis (hold joint meetings – David Bartley ex-NIOSH, convenor)
  - ISO/TC44/SC9/WG2, Health and Safety in Welding and Allied Processes – Sampling of airborne particles and gases in the operator's breathing zone
  - ISO/TC229, Nanotechnology – WG2: Measurement and Characterisation, WG3: Health, Safety and Environment

CEN/TRxxxx: Guide for the use of direct reading instruments for aerosol monitoring

HEALTH & SAFETY LABORATORY

Currently has three parts:

Part 1: Choice of monitor for specific applications

Draft 5 – I will present here

Part 2: Evaluating airborne particle concentrations using Optical Particle Counters

Draft 4 – Peter Görner will present here

Part 3: Evaluating airborne particle concentrations using Photometers

Not yet started

Part 4: Evaluating airborne particle concentrations using other devices

May not be started – depends on availability and use of suitable instruments (TEOM, piezobalance, β attenuation, etc)

Part 1: Choice of monitor for specific applications

Contents of Part 1

1. Introduction
2. Scope and area of application
3. References
4. Principles of direct-reading aerosol monitoring methods
   - Introduction
   - Vibrational mass methods
     - *Piezoelectric mass monitors*
     - *TEOM - Tapered Element Oscillating Microbalance*
   - Beta mass monitors
   - Optical measurement of aerosols
     - *Photometers*
     - *Optical particle counters*
5. Requirements for different applications of direct-reading dust monitors
6. Bibliography

2. Scope and area of application

HEALTH & SAFETY LABORATORY

- Aim of Part 1 of TR is to produce *simple, easy-to-read* document to enable *non-specialists* to choose most appropriate monitor for their job
- The *principles* underlying the evaluation of one or more aerosol fractions using direct-reading aerosol monitors are given
- Involves only *currently available* methods for monitoring levels of aerosols in workplaces for a range of different purposes
- Details of their *limits and possibilities* in the field of occupational hygiene are given
- Does *not cover* the sampling of aerosols for compliance with occupational exposure limits or the collection of aerosol particles for subsequent analysis
- Does *not include* instruments for ultrafine and nanoparticles (they will have separate documents)

4. Principles of direct-reading aerosol monitoring methods

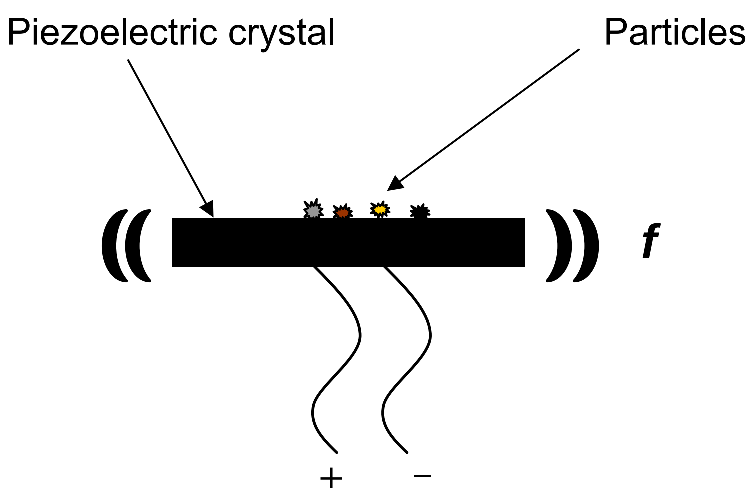
HEALTH & SAFETY LABORATORY

- Automatic methods are classified into three main groups:
  - Vibrational mass monitors
  - Beta attenuation monitors
  - Optical monitors
- Methods in first two groups involve sampling and collection of particles on substrates for analysis of mass by on-board techniques
- Optical monitors are the most numerous because of their high sensitivity and ease of use

Information given for each group

- For each group of monitors, the following information is given:
  - Operating principle
  - Determination of mass concentration of health-related fractions
  - Calibration of monitor
  - Advantages and disadvantages
  - Currently available monitors (not comprehensive)

Example: Piezoelectric mass monitors



Schematic of piezoelectric mass monitor

- Operating principle
  - Particles drawn into the instrument are collected the surface of a piezoelectric crystal, forming part of a quartz crystal-based oscillating circuit
  - The mass of deposited particles causes a reduction in the oscillation frequency *f*.
  - Frequency reduction is directly proportional to the particle mass

Aerosol concentration, $C = \frac{\Delta f}{Qtk_f}$

Δf = *reduction in frequency*

Q = *sampling flowrate*

t = *sampling time*

k_f = *proportionality constant*

Determination of mass concentration of health-related fractions

HEALTH & SAFETY LABORATORY

- Change in frequency Δf ❝ *mass* of particles deposited and largely *independent* of the physical and chemical properties of the particles
- No need therefore to use on site calibration factors, providing that the crystal is not overloaded
- Only *respirable* fraction is measurable, because of particle size limitations on particle/sensor coupling
- Respirable size selection can be achieved using any suitable size selector; one instrument uses a single stage impactor with the respirable particles deposited on the crystal by electrostatic precipitation.

Calibration of piezoelectric instruments

- Each crystal sensor has its own frequency response and so the instrument incorporating the crystal will be calibrated in the factory to give the required mass response.
- Provided that the crystal is not damaged, no further calibration is required.

Advantages/disadvantages of piezoelectric instruments

HEALTH & SAFETY LABORATORY

Advantages	**Disadvantages**
❖ Direct measurement of dust mass	❖ Usage limited by dust loading on crystal
❖ No on-site calibration required	❖ Regular cleaning of crystal required
❖ Response independent of chemical composition and particle size (below 10 µm)	❖ Only suitable for respirable particles
❖ Relatively easy to use	❖ Moisture can condense onto deposited particles and effect mass measurement

Currently available piezobalance instruments (manufacturer's information)

HEALTH & SAFETY LABORATORY

Name	**Portable/ personal**	**Size (mm) /weight**	**Size selection**	**Flowrate (l min^{-1})**	**Response time**	**Accuracy**	**Measurement range (mg m^{-3})**
Kanomax Piezobalance dust monitor Model 3511	Portable	311x170x130 2 kg	Respirable fraction by impactor	1	*0 – 1 mg m^{-3}*: 24 s *1 – 10 mg m^{-3}*: 120 s	± 10 % of reading	0.02 – 10

NOTE: "Accuracy" is defined by the manufacturers

Advantages/disadvantages of photometers

HEALTH & SAFETY LABORATORY

Advantages	**Disadvantages**
❖ Very fast response	❖ Response not directly proportional to mass, but is dependent upon particle size, shape and refractive index
❖ Very wide concentration range	❖ Need factory and on-site calibration for mixed or varying aerosols
❖ Portable and personal models available	❖ Response drops off for particles > 10 µm, so only suitable for respirable fraction
❖ Passive models require very little power	❖ Oversensitive to fine aerosols (e.g. water mist, fume and cigarette smoke)
❖ Pumped models may have filter collection that can be used for analysis	
❖ Very simple use (most simple of all types of monitor described)	

Currently available photometers (not comprehensive, manufacturers information)

HEALTH & SAFETY LABORATORY

Instrument name	Pumped (flowrate l min^{-1}), passive	Personal or portable	Size (mm) and weight (kg)	Particle size range (µm)	Measurement range (mg m^{-3})	Precision (mg m^{-3})	Accuracy	Resolution	Calibration	Display and data logging
Casella Microdust Pro	Passive	Portable	245x95x50 Probe 290x35ø 1.0	NM	0 - 2500	NM	NM	0.001 mg m^{-3}	Factory calibrated to ISO 12103-1 using A2 fine test dust and can be calibrated on-site using add-on pump/filter system	128x64 pixel screen gives rolling averages of concentration, 15,700 points data logger
SKC Haz-dust 1	Passive	Portable	229 x 70 x 63 0.5	0.1 - 50	0.01 - 200	± 0.02	± 10% to NIOSH 0600	NM	Factory calibrated to NIOSH 0600 with SAE fine dust	1 line LCD, Optional data logger
SKC Split2	Pumped (2) or passive	Personal	180 x 80 x 45 0.8	0.1 – 10 (R) 0.1 – 50 (T)* 0.1 – 100 (I)*	0.01 – 200	± 0.02	± 10% to NIOSH 0600	NM	Factory calibrated to NIOSH 0600 with ARD. Has inhalable entry and back up filter as standard and calibration post for on site	4 line LCD, 21,500 points data logger
TSI Sidepak	Pumped (0.7 - 1.8)	Personal	130x92x70 0.5	0.1 – 10 Built-in impactors to choose “none”, 1.0, 2.5 or 10	0.001 – 20	NM	NM	0.001 mg m^{-3} (min)	Factory calibrated to respirable fraction of ISO 12103-1 with A1 test dust	2 line LCD, 31,000 points data logger
TSI Dustrak	Pumped (1.4 - 2.4)	Portable	221x150x87 1.5	0.1 – 10 (approx)	0.001 – 100	NM	NM	0.1% of reading or 0.001 mg m^{-3}	Factory calibrated to ISO 12103-1 with A1 test dust	1 line LCD, 31,000 points data logger
Thermo DataRAM 4	Pumped (1 to 3	Portable	134x184x346 5.3	0.08 - 10	0.0001 – 400	± 0.01	± 2% of reading ± precision	0.1% of reading or 0.0001 mg m^{-3}	Factory calibrated with SAE fine test dust and has in-built optical scattering element	8 line LCD, 50,000 points data logger
Thermo personal DataRAM	Passive or pumped (1 – 5) with add-on pump/filter system	Personal	153x92x63 0.5 (passive)	0.1 – 10 (max response)	0.001 – 400	± 0.005	± 5% of reading ± precision	0.1% of reading or 0.001 mg m^{-3}	Factory calibrated with SAE fine test dust and can be calibrated on-site using add-on pump/filter system	2 line LCD, 13,000 points data logger
Sibata PDS 2	Pumped (2)	Personal	Sensor 100x36x95 0.3 Control unit 98x43x106 0.5	NM	0.001 - 100	NM	± 10% to Calibrated latex particles	0.001 mg m^{-3}	Factory calibrated with 0.6 µm latex spheres	1 line LCD, 60,000 points data logger
Hund TM-µP	Passive	Portable	200x110x40 1.0	Respirable	0 - 100	0.01 (LOD)	NM		Factory calibrated with respirable coal dust –can be calibrated with other dusts	4 digit display in mass concentration
TSI Respicon	Pumped (3 – 11)	Personal	Sensor 110x63x69 0.48 Datalogger 210x100x55 0.58	Three fractions via virtual impactors	0-250 for each of the 3 stages	0.05 (LOD)	?30% following EN 13205 procedures	0.01 %		

NOTE: “Precision”, “accuracy” and “resolution” are defined by the manufacturers themselves and may be different

NM = Not mentioned

5. Requirements for different applications of direct-reading aerosol monitors

HEALTH & SAFETY LABORATORY

- Presented here are the requirements that a suitable direct reading aerosol monitor must have for different applications.
- The reader can then compare these requirements with the characteristics of the available instruments given in Section 4 to enable the *most suitable choice* of direct reading aerosol monitor to be made for his/her *specific application*.
- Six different potential uses of direct reading aerosol monitors are discussed:
  - *Walk through surveys*
  - *Identification of main process or source emitting aerosols*
  - *Use with video visual techniques*
  - *Assessing efficiency of control systems*
  - *Watchdogs to monitor levels in workplaces and ensure controls are working*
  - *Surrogate personal exposure assessment*

Example 1 : *Walk through surveys*

HEALTH & SAFETY LABORATORY

- For walk through surveys, the direct-reading aerosol monitor should have the following attributes:
  - *Portable (battery-powered)*
  - *Response preferably independent of particle characteristics (particle size and composition)*
  - *Fast response time*
  - *Concentration displayed on an in-built screen*
  - *Particle size selection not important*

- Walk through surveys could provide additional information for inclusion in the Basic Survey outlined in EN 689 (1995) –Sampling strategy document

Example 2: *Watchdogs to ensure controls are working*

HEALTH & SAFETY LABORATORY

- For use as watchdogs to monitor levels in workplaces to ensure that deployed controls are working, the direct-reading aerosol monitor should have the following attributes:
  - *Simple, cheap (passive) monitors for multiple use around workplaces*
  - *Can be battery or mains powered*
  - *Response calibrated against reference monitors, possibly personal monitors for specific processes, so response does not have to be independent of particle characteristics*
  - *Information tele-metered to central hub system*
  - *Alarm function set to go off when agreed level exceeded*
  - *Fast response not necessary*

Example 3: Surrogate personal exposure assessment

HEALTH & SAFETY LABORATORY

- Direct reading aerosol monitors cannot currently be used to measure exposure to determine compliance with occupational exposure limits (OELs).
- However, there are a number of situations where an indication of exposure is important:
  - a) use with video visual techniques to demonstrate changes in techniques to minimise exposure for worker training,
  - b) for situations where there is no OEL and relative changes in exposure as measured with direct reading aerosol monitors can be used to demonstrate improvements in control.
- For this purpose, the direct reading aerosol monitor should have the following attributes:

Example 3: Surrogate personal exposure assessment - attributes

HEALTH & SAFETY LABORATORY

- *Personal and unobtrusive*
- *Particle size selectivity related to the potential health effects from the process being monitored*
- *Response calibrated on-site against in-built filter or suitable compliance sampler worn alongside direct reading aerosol monitor*
- *Fast response time for video visual work, but not necessary for demonstrating overall reduction in exposure*

Progress with guidance documents

- Currently Parts 1 and 2 have been accepted as new work items by CEN/TC 137
- Both have been under discussion for about 2 years, but still not final versions
- Any comments you may have will be very welcome!
- TIMELINE:

1 March 2009:	Circulation of first draft
1 September 2009:	Dispatch of draft for Technical Committee approval