Biography

Prof Stefan Linde is a registered Occupational Hygienist with SAIOH and is appointed as an Associate Professor in occupational hygiene at the North-West University where he presents lectures on toxicology, chemical stressors and noise exposure, supervises master's and PhD students and does research in the field of occupational hygiene.

His research activities focus on exposure to hazardous chemicals in the mining industry. This includes using direct reading instruments to evaluate exposure to particulates, retrospective analysis of historical exposure data, and skin and respiratory exposure to metals during refining activities.

MINERALS COUNCIL
SOUTH AFRICA

Bridging the gap: Opportunities and challenges of real-time dust/particulate monitoring systems

Prof Stefan Linde; Prof Suranie Horn; Dr Ilzé Engelbrecht
Prof Johan du Plessis; Prof Cas Badenhorst

2nd Annual Mine Dust Conference, 25 July 2025

Turning A New Leaf On Dust Risk Management Within The South African Mining Industry

Emperor's Palace

NWU® | OHHRI

Disclaimer

- This presentation will refer to various instruments available on the market and those that were used during research studies. This is not intended as a endorsement of the instruments.

- Please speak to the instrument suppliers for information regarding specific instruments.

Content

- Scope and aim
- Background
  - Legislative
  - Published resources
  - Measurement principles
- Examples of instruments / sensors and their applications
  - Personal exposure
  - Fixed sensors
- Infrastructure and costs
- International perspectives and benchmarking
- Conclusion

Scope and aim

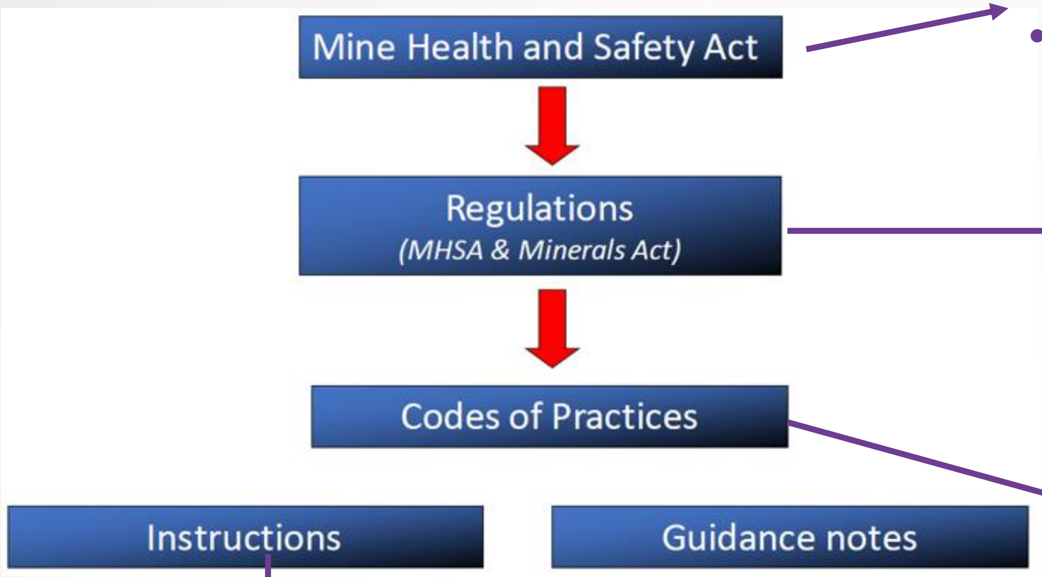
Scope

- The presentation will focus on using particulate matter (PM) sensors to manage exposure in the mining industry.
- Using sensors for gases and vapours are more widely used and accepted.

Aim

- To highlight the opportunities and challenges associated with real-time dust/particulate monitoring systems.

Background: Legislative background



- Employer to assess and respond to risk.
- Employer to conduct occupational hygiene measurements.

STAATSKOERANT, 2 JULIE 2002 No. 23583 5

CHAPTER 9

MINE ENVIRONMENTAL ENGINEERING AND OCCUPATIONAL HYGIENE

CHAPTER 22

SCHEDULES

22.9(2) OCCUPATIONAL HYGIENE

22.9(2)(a) OCCUPATIONAL EXPOSURE LIMITS FOR AIRBORNE POLLUTANTS

INSTRUCTIONS ON PREVENTION OF OCCUPATIONAL HYGIENE OVER EXPOSURES

3. Instruction(s)

The following instructions are issued as an additional measure to prevent occupational health exposures in the South African Mining Industry thereby ensuring the health and safety of persons at mines. The employer must ensure that at least the following key areas are addressed:

3.1 Implement Real-time monitoring

Occupational Health Progamme
(occupational hygiene and medical surveillance)
on
Personal Exposure to Airborne Pollutants

A QUALITY ASSURANCE PROGRAMME FOR A SYSTEM OF OCCUPATIONAL HYGIENE AND VENTILATION ENGINEERING MEASUREMENTS

2034 Milestones

- By **December 2034**, **95%** of all exposure measurement results will be below the milestone level for **respirable crystalline silica dust** of **0.03mg/m³** [these results are individual readings and not average results, and the **milestone** will be **reviewed in 2029 (after 5 years)**].

Background: Published resources

AIHA
HEALTHIER WORKPLACES | A HEALTHIER WORLD

Establishing a Process for the Setting of Real-Time Detection System Alarms

White Paper

aiha.org

Version 1 | December 30, 2022

AIHA | Real-Time Detection Systems COMMITTEE

Review of Real-time Aerosol Monitoring Standards and Recommendations for Updates
Real-time Detection Systems Committee, American Industrial Hygiene Association
Prepared by member Christin Duran, PhD, CIH and reviewed by RTDS members

Introduction:

Background

The International Council on Mining & Metals (ICMM) published a report in January 2022 encouraging the widespread application of real-time particulate monitoring (RTPM) in the mining and metals industry to reduce worker exposures to hazardous airborne particulates (ICMM, 2022). The ICMM presented the case that RTPM could be used to correlate particulate emissions with specific activities, sources and locations in real-time, which would enable the identification of risk factors leading to an increase in emissions, exposure groups at risk, requirements for new controls, and effectiveness of existing controls. The RTPM data could also be used to provide early warning of a failure in an emission source or control enabling preventative maintenance.

According to the ICMM report, particulates of concern in the mining and metals industry include dust formed during mining of materials, such as silica, coal, lead, arsenic, alumina, and asbestos fibers. Diesel particulates from mining processes that involve combustion are an additional exposure concern. The current practice is to use gravimetric analysis and reference national or local regulatory compliance standards. The limitation of this approach is that it produces data that is averaged over several hours or a full workday, and it does not capture dynamic variations in exposure over time. Further, the results take days to receive, which inhibits the ability to implement timely interventions.

The ICMM report mentions two main categories of technologies for RTPM, including optical particulate counters (i.e., spectrometers which counts particles based on light-scattering) and photometers (i.e., nephelometers which count and estimate the size of particles based on light deflection). The report also describes the limitations of commercially available instruments, data handling infrastructure, and standards for practical implementation of RTPM in the workplace as follows:

1. *There is no standardisation of RTPM sensors, so comparing data across instruments is challenging.*
2. *Current RTPM technology does not support speciation of particulates and no RTPM instruments cover the entire size range germane to respiratory hazards (<0.5µm – 100µm).*
3. *Field-calibration of real-time particulate monitors is challenging.*
4. *RTPM data is not currently used for regulatory compliance.*
5. *Costs of purchase, maintenance, and required expertise to manage and discern data is high (median US$6K each, minimum US$10K per year, and US$150-250K per year, respectively).*

NMAM

Measuring respirable aerosol with real-time optical monitors

by Emanuele Cauda, Ph.D., NIOSH

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

CDC NIOSH

ICMM
International Council on Mining & Metals

CONSIDERATIONS FOR THE ADOPTION OF REAL-TIME PARTICULATE MONITORING

January 2022

This brief provides a high-level overview of the considerations for the adoption of real-time particulate monitoring (RTPM) in the mining and metals industry. Although it is not a guidance document, it includes suggested principles, implementation maturity framework and case studies from ICMM member companies highlighting the industry's journey with RTPM. It aims to encourage the operationalisation of RTPM to reduce worker exposures to hazardous airborne particulates, to improve understanding of the benefits and the limitations of RTPM and ultimately seek the improvement of RTPM through an industry call to action.

Summary

Mining companies are challenged to effectively protect workers from harmful exposures to certain airborne particles and particulates. Based on the geology of the mined materials, dusts can be formed that can contain harmful levels of microscopic particles like silica, coal, lead, arsenic, alumina, asbestos fibres, or other elements that are dangerous to inhale. Similarly, processes such as diesel combustion can lead to diesel particulate matter being released into working areas. Overexposure to these particles and particulates can lead to a spectrum of negative health outcomes, from allergic reactions to asthma, chronic diseases such as black lung disease, silicosis, chronic obstructive pulmonary disease, asbestosis, cancers, and others. Both particles and particulates will be referred to as particulates throughout the rest of the document.

Mine operators work diligently to identify high risk activities, medically monitor at-risk workers, and implement protective controls. Sampling the air to identify, and quantify, the presence of harmful particulates is the primary tool used to mitigate where and when overexposures are likely to occur and validate exposure control effectiveness.

Traditional gravimetric analysis of sampled particulates is the standard way for estimating hazardous exposures and the method that most commonly meets regulatory compliance requirements. However, these sampling methods are typically conducted over several hours to make sure enough material is captured to be analysed, and results from analysis that both quantify and characterise the particulates can take days to receive. Since conditions present at the time of sampling may have changed, this time lag can delay the implementation of timely interventions to improve worker protections and can complicate the validation of control effectiveness.

Real-time particulate monitoring (RTPM) instruments are an important tool for airborne particulate monitoring. RTPM instruments use sensor technology to quickly detect and quantify airborne particulates. Since RTPM measures quickly, it is an effective tool for identifying uncontrolled or unexpected critical releases of hazardous particulates, pinpointing specific activities within job tasks that have a high likelihood of exposure. It could also be used to improve and confirm Similar Exposure Groups (SEGs), and for validating the effectiveness of existing controls.

Therefore, ICMM members believe that RTPM is a **proactive and effective tool for preventing hazardous airborne particulate exposures, mitigating associated risks, and validating controls.**

As ICMM member companies, we encourage collaboration and innovation to accelerate the industry towards a future of RTPM, that will help us to reach the goal of zero fatalities.

AIHA

Consumer Aerosol Monitors

Fact Sheet

aiha.org

Version 1 | July 21, 2021

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Leading Practice Adoption Guide for:

Continuous Real-time Monitoring

of

Airborne Pollutant Engineering Controls

Rev 2

November 2016

Note: This guide is for use at adopter mines. The guide will be updated regularly to take account experience gained and input received during the adoption process.

Prepared by:
MOSH Adoption Team - Dust
Adoption Team Managers: G Pienaar and J van Rensburg
Adoption Specialist: Dr A V Banyini

Application of low-cost monitoring and sampling devices in occupational hygiene measurement strategies for hazardous chemicals

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e-mail: derk.brouwer@wits.ac.za

Keywords: temporal and spatial variability, data quality, workplace exposure

How to cite this paper: Brouwer D, Lavoué J. Application of low-cost monitoring and sampling devices in occupational hygiene measurement strategies for hazardous chemicals. Occup Health Southern Afr. 2020; 26(3):104-110.

ABSTRACT

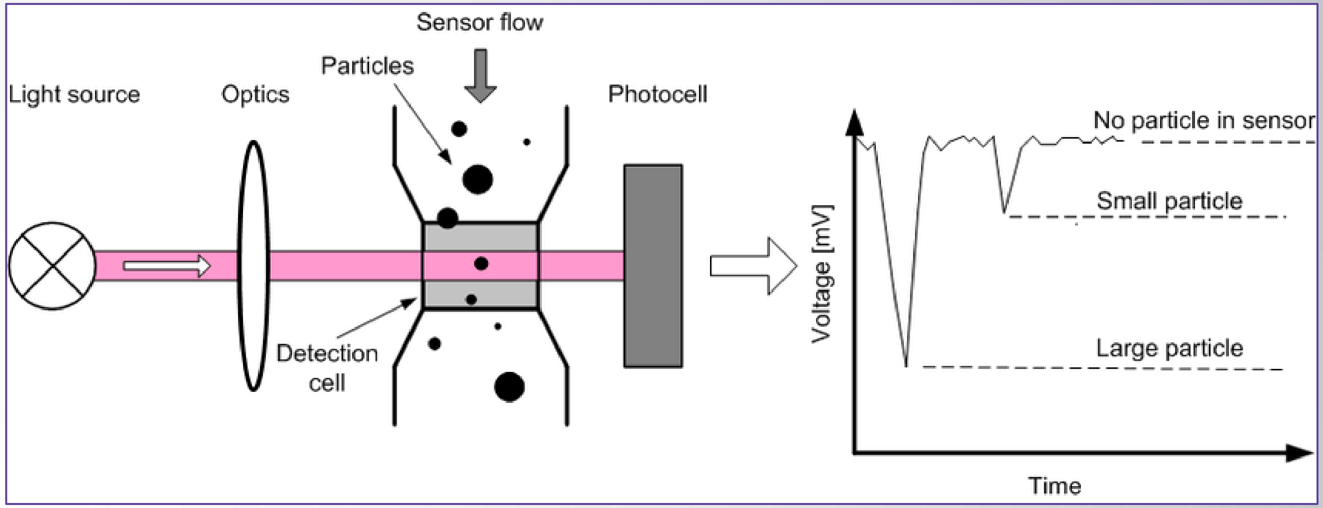
Occupational hygienists might be reluctant to deploy low-cost sensors which provide real-time concentrations of gaseous and particulate pollutants in the workplace, due to their moderate accuracy. However, depending on the objective of the measurement, low-cost sensors and low-cost samplers can be integrated into the measurement strategy and augment data to identify and process spatial and temporal variations of a stressor's intensity. In combination with high-quality data, low-cost devices can be used to refine and improve exposure and risk assessments, enriching the occupational hygienist's toolbox.

MINERALS COUNCIL SOUTH AFRICA

MANAGEMENT OF SIGNIFICANT OCCUPATIONAL HEALTH HAZARDS IN THE SOUTH AFRICAN MINING INDUSTRY

Background: Measurement principles

- Light scattering
  - Optical particle counters.
  - Condensation particle counters.
  - Photometers (nephelometers).
- Electrical mobility
  - Scanning mobility particle sizers.



Source: https://www.researchgate.net/figure/Operating-principle-of-an-optical-particle-counter-21_fig38_341152720

- Considerations
  - Detection limits:
    - What size ranges can it detect?: PM10; PM4; PM 2.5; PM1; Total Suspended Particulate (TSP)
  - Can it detect changes in concentrations that are useful to you?:
    - From 50 μg/m^3 to 200 μg/m^3 or 150 μg/m^3 to 160 μg/m^3.
  - What information is needed to interpret results: E.g., dust characteristics.
  - What can influence the measurement: Humidity, fog, etc.

Note: They do not distinguish between material composition, shape, or chemical nature. They estimate mass or number concentration based on how particles scatter light and how they are calibrated.

Instruments: Personal / portable

TSI

PM4, PM2.5, PM1 and 0.8 µm DPM

PM1, PM2.5, Respirable, PM10 and TPM

0.3—10 µm

ExSens TECHNOLOGY

PM1, PM2.5, PM4, PM10

nanozen know the air you breathe

PM2.5, PM4.25, PM10

aeroqual

PM10/PM2.5

TROLEX

Silica PM1, PM2.5, PM4.25, PM10, and TSP

PM1, PM2.5, PM4.25, PM10

PM1, PM2.5, PM4.25, PM10

REMS Real-time Environmental Monitoring System

PM1, PM2.5, PM10

0.3 – 10 µm

Met One Instruments

PM1, PM2.5, PM7, PM10, and TSP

0.3—10 µm

0.3—10 µm

PM4

ThermoFisher SCIENTIFIC

PM1, PM2.5, PM4, PM10

Instruments: Fixed

VAISALA

NO_2, SO_2, CO, O_3, PM10 and PM2.5, Temperature/Humidity, Barometric Pressure, Wind speed /Direction

TSI

TSP, PM10, PM 2.5, PM1

PINSSAR

DPM specific 0—800 nm particle range

MesaLabs

TSP, PM10, PM2.5, PM1

PM10

PM2.5

aeroqual

PM1, PM2.5, PM10, or TSP

PM2.5, PM10, or TSP

PM10

PM2.5 and PM10

PM10, PM2.5 or TSP

PM10, PM4, PM2.5, and PM1

PM10, PM2.5, and PM1

Met One Instruments

PM2.5

PM2.5

SIBATA

Application

Personal exposure monitoring

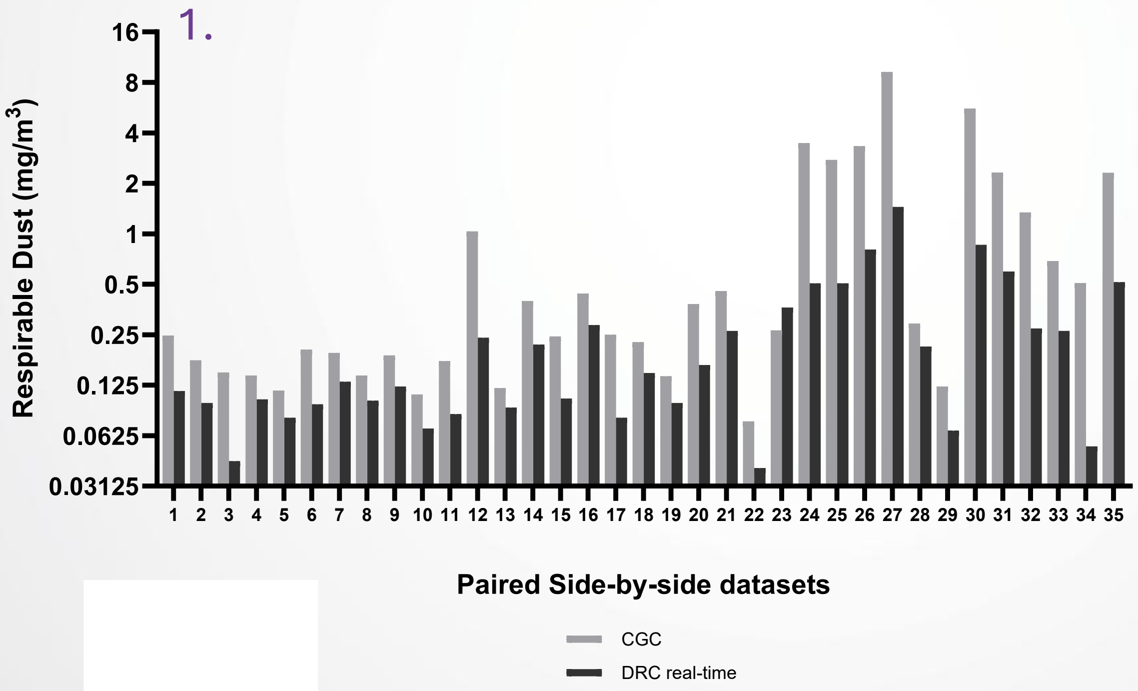
- Results from 3 studies from 3 different commodities.
- TSI Sidepak AM520 & Nanozen DustCount 9001.
- Side-by-side with conventional sampling train.

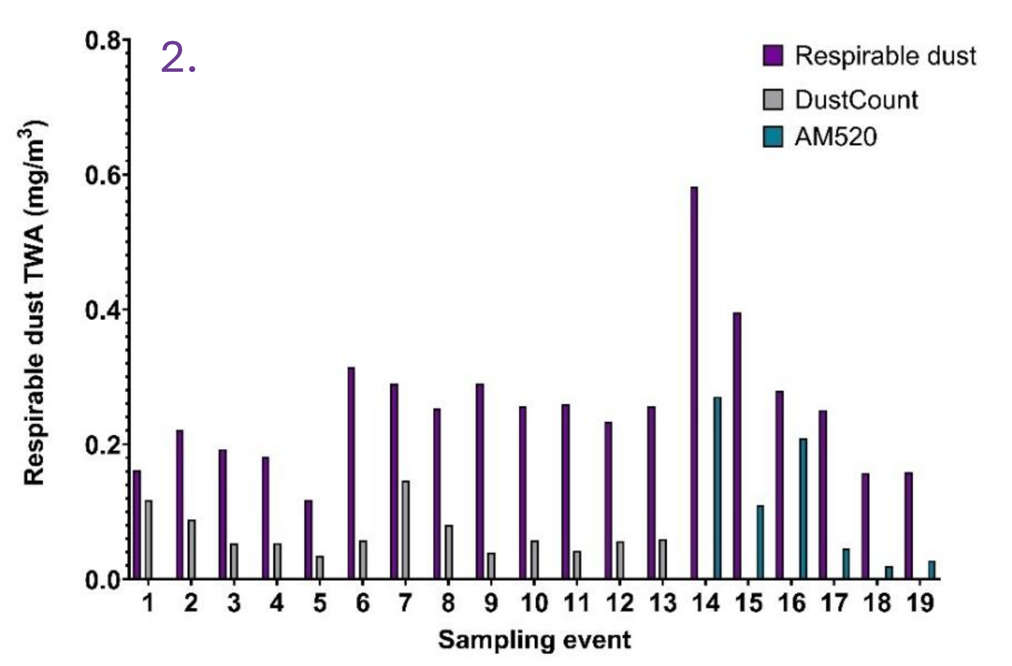
Fixed area monitoring

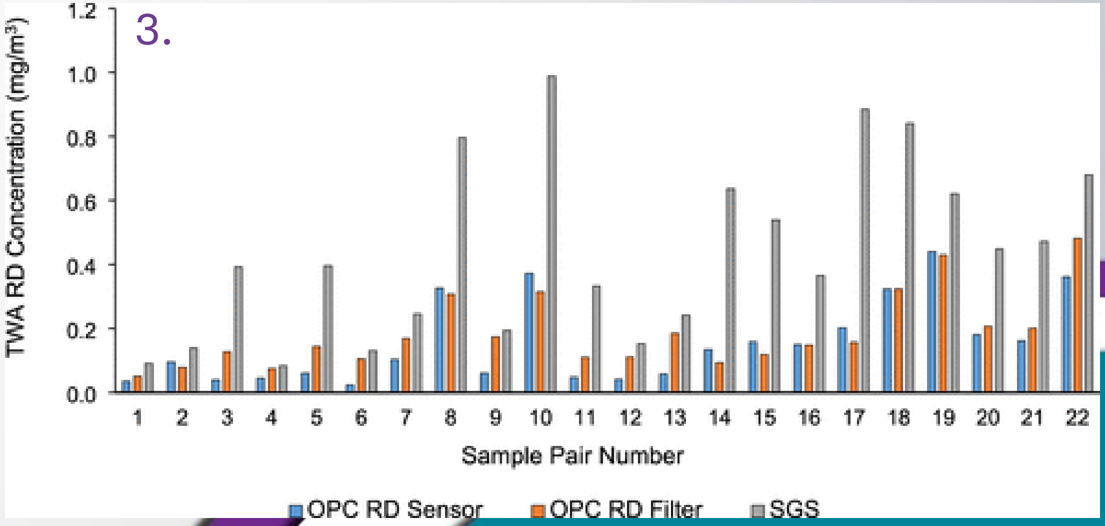
- Results from a presentation to the AIHA Mining WG.
  - Elk Valley Resources (EVR) coal mines in British Columbia, Canada.
  - Dan Sarkany (EVR) & Emanuele Cauda (NIOSH).
  - In-pit Dust Area Monitoring Proof of Concept.

Application: Personal monitoring → 3 studies

First look: Direct reading instruments under-sampled compared to conventional method.



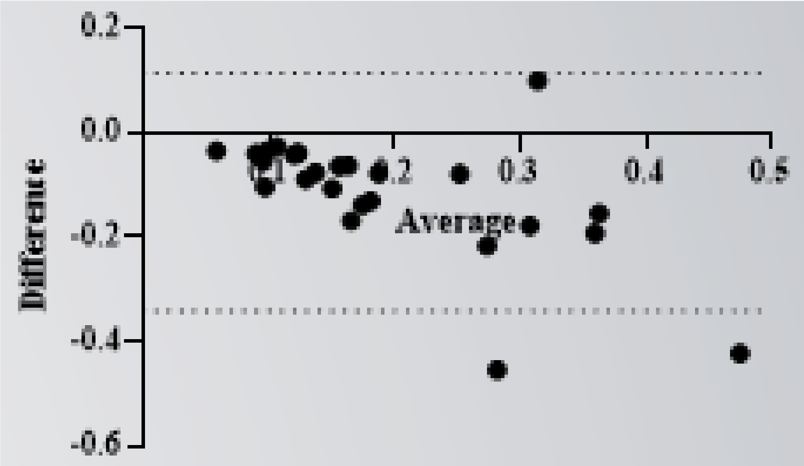




3. Nabiwa, Lubinda, et al. "Quantification of Respirable Dust Concentration at an Underground Copper Mine Using a Personal Optical Particle Counter." *ACS Chemical Health & Safety* 32.3 (2025): 326-335.

Application: Personal monitoring → Bias

1. Bias: $-0.11 mg/m^3$



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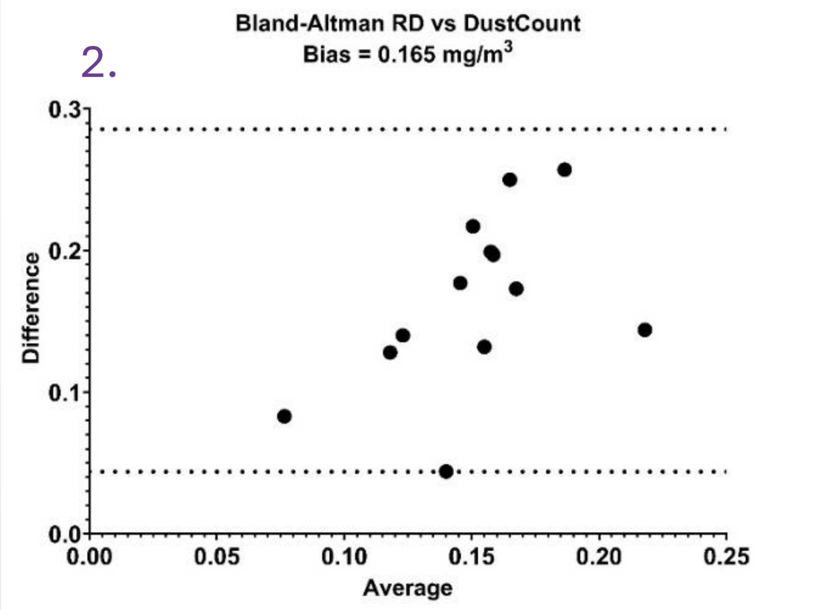


Second look: Direct reading instruments under-sampled in a uniform way enabling the calculation of a correction factor. → lead to estimation of exposure based on results.

3.

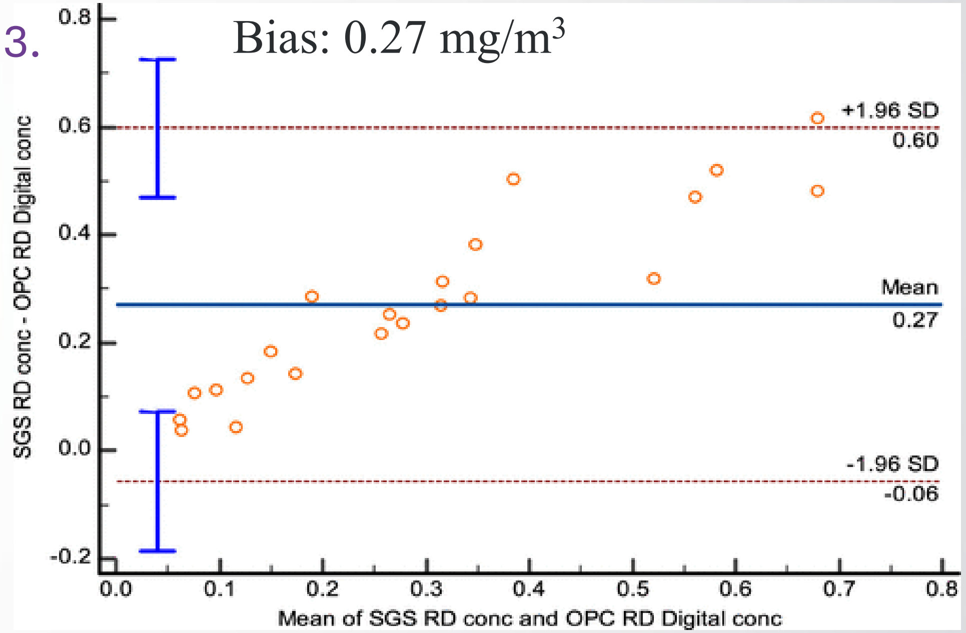


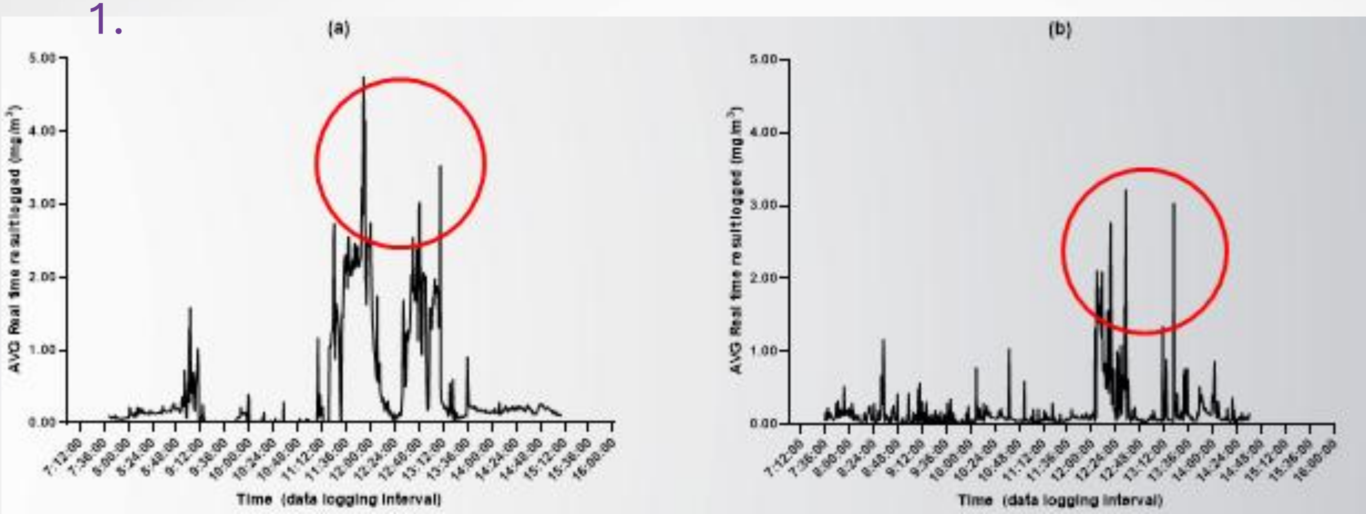
Table 2. Relationship between the Three Methods of RD Quantification a

parameters (n = 22)	r-value	P-values	equations	
SGS RD vs OPC RD sensor	0.93	<0.001	$f(x) = 2.078x + 0.093$	(3)

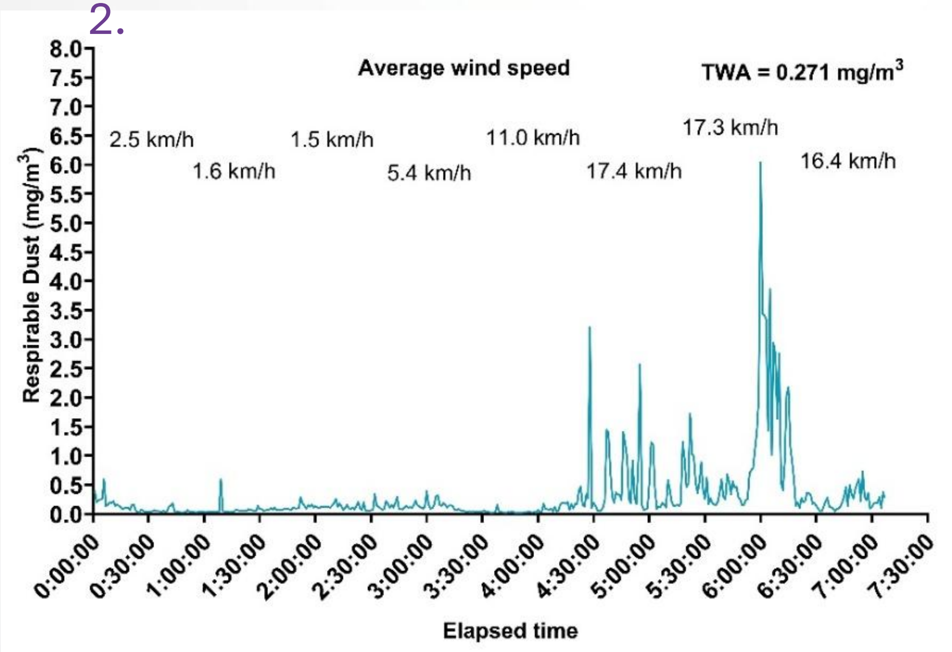
Application: Personal monitoring → Time series data

- Time-series data linked to activities and environmental conditions; e.g. plant shutdown, wind, etc.
- Particle size data: Substantial amount < 1µm.

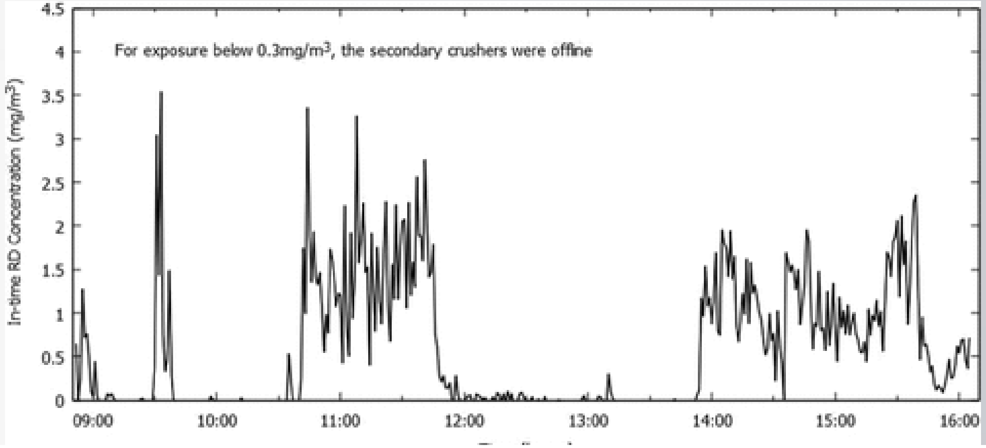
1.

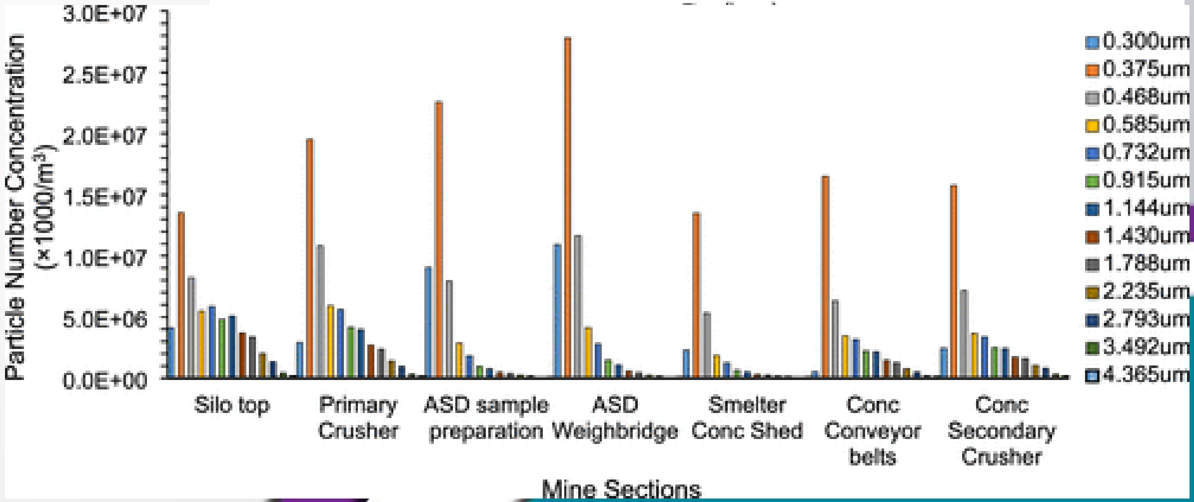


2.



3.





Application: Personal monitoring: Take away

Opportunities:

- Quicker results
- Time-series data can be linked to activities, tasks, processes, location or environmental factors.
- Excellent for investigations of individual over-exposure.
- Can be used in remote areas far away from analytical laboratories.
- More data:
  - Peak exposure data.
  - Particle size data.

Challenges:

- Initial work to setup operating procedure is a big job.
- Needs calibration based on side-by-side conventional monitoring.
- Expensive instruments.
- Not yet accepted by legislation (TWA).
- Instrument interference from non-particulate aerosols, like water mist and vapor is common.
- Instruments may not be suitable for harsh environments.
- Instrument failure may be a problem.
- Repairs:
  - Europe.
  - USA.

Application: Fixed sensors

Applied Particle Technology

National Institute for Occupational Safety and Health NIOSH

EVR A GLENCORE COMPANY

24/7 Real-Time Dust Monitoring in Open Pit Mining: From Concept to Operation

Driving Action with Timely Exposure Risk Communication to Protect Worker Health

With permission from Dan Sarkany (EVR) & Emanuele Cauda (NIOSH)

Application: Fixed sensors

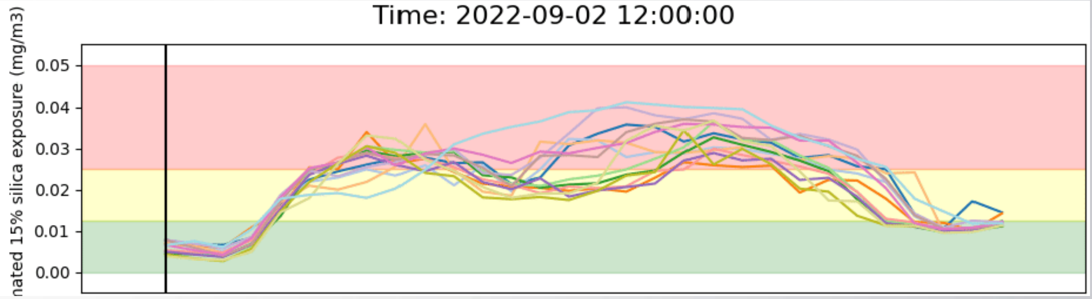
Perimeter and in-pit sensors.

⬇

24h monitoring of PM10 concentrations.

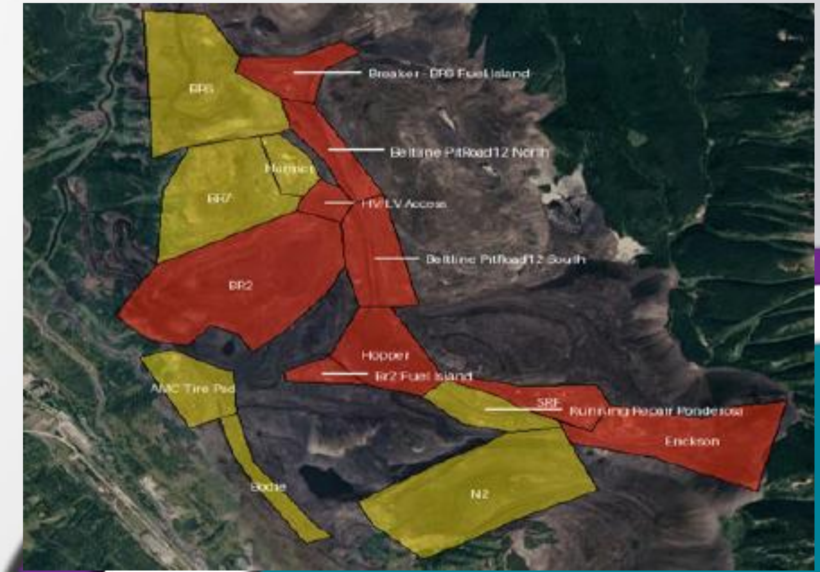
⬇

Use modelling to apply dust concentration to estimate silica exposure risk.



⬇

Pit divided into zones.



⬇

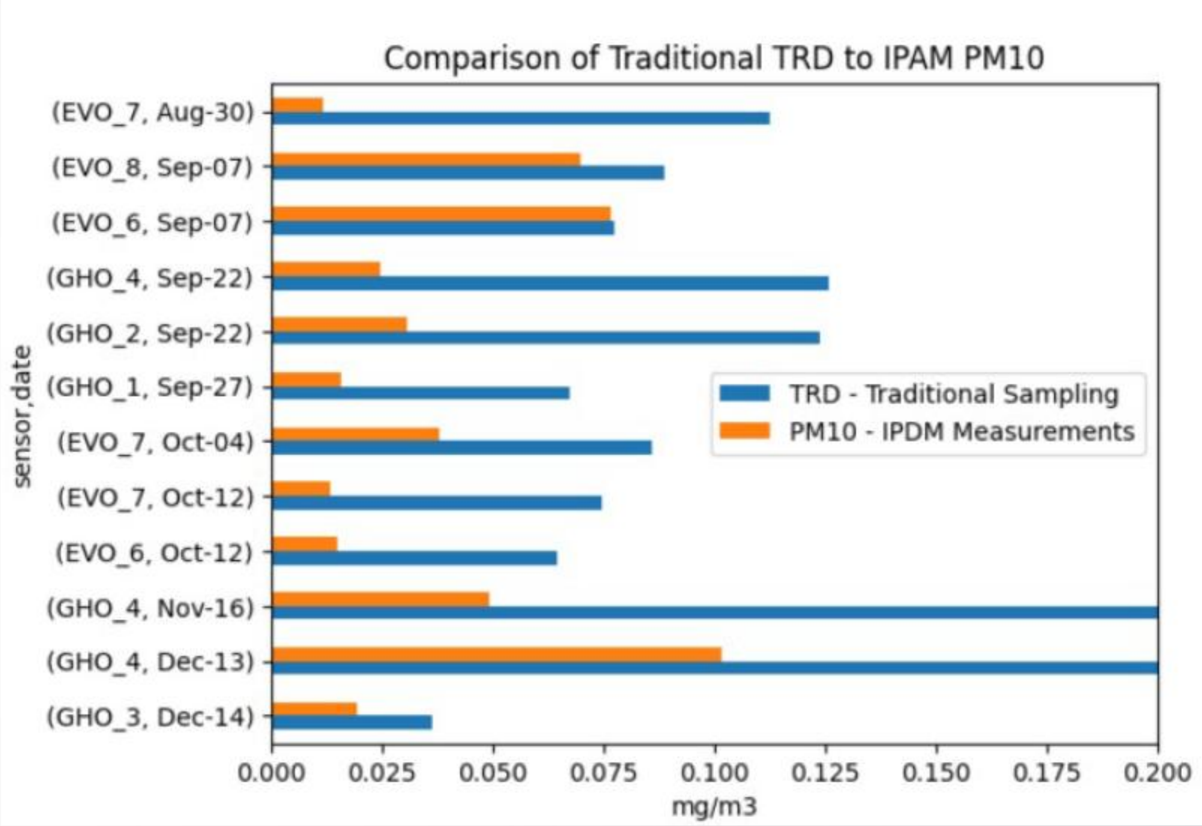
Periodic notifications to teams in pit to communicate current conditions (email but they are moving toward light system).

⬇

Respirators to be used.

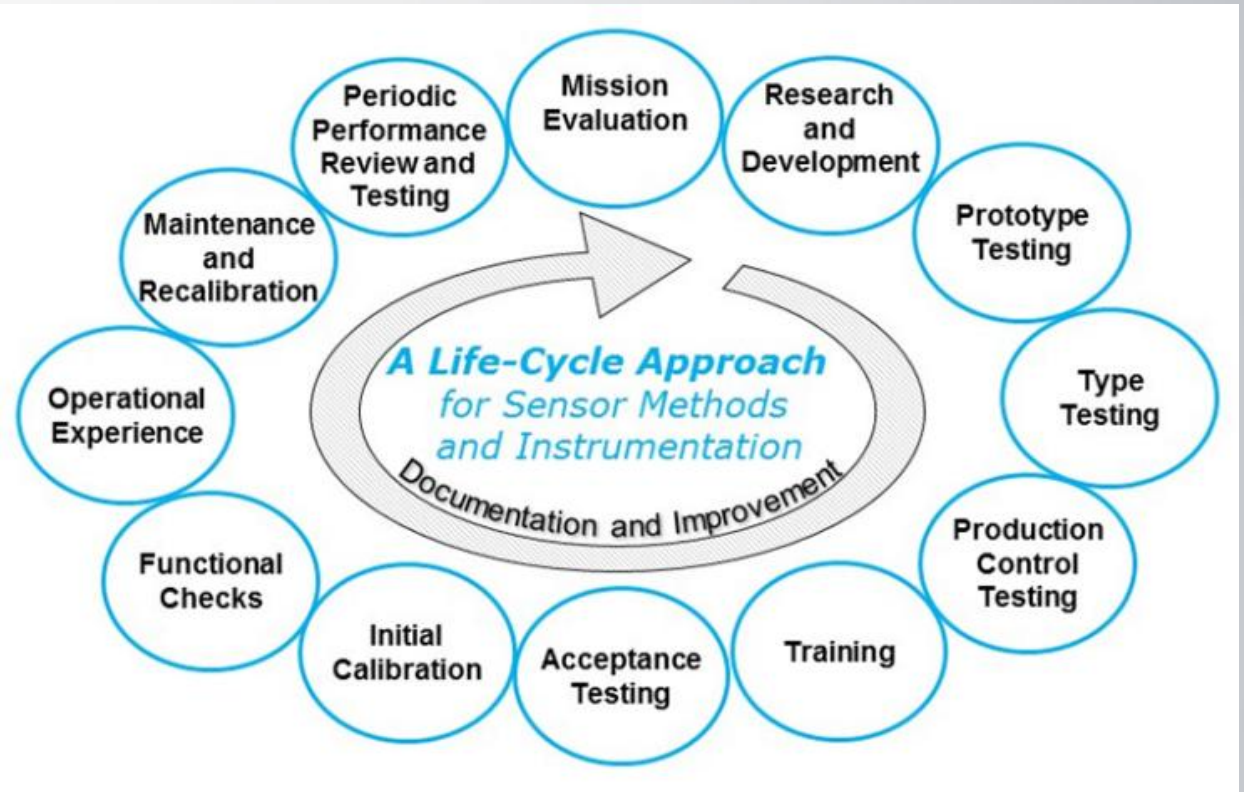
Application: Fixed sensors: Findings

- PM10 sensors under-sampled compared to conventional method.
    - Concentration correction factor applied to data.
    - Humidity correction applied to data.
- Spacing of sensors ≈450m apart.
- One higher accuracy monitor was also incorporated as reference.
- Main use was risk category communication:
    - Repeatability more important than precision.
- Power supply (solar and battery) was challenging → sample; charge; transmit data.



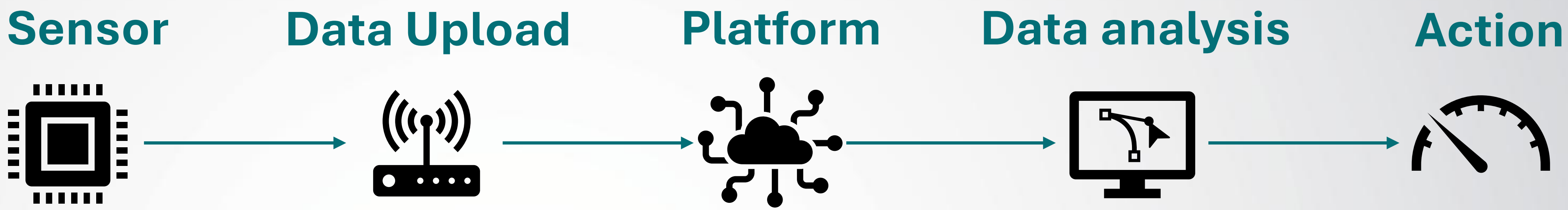
Application: Fixed sensors: Learnings

- Support from management & a lot of stakeholder engagement.
- Good relationship with service provider → Initial and continuous development work is essential.
- Link environmental monitoring with in-pit area monitoring is advantageous.
- Team effort: Occupational Health and Hygiene (lead); data scientist; IT; management; production; workers, etc.
- Need to be linked with other higher-level controls; this remains an admin control.
- Main barrier: Transfer of knowledge to end user.



Life-cycle decision-making framework and process for the effective selection and use of sensor methods and data.
Source: https://blogs.cdc.gov/niosh-science-blog/2019/05/16/right-sensors-used-right/

Infrastructure and costs



- Higher initial investment but unlimited amount of samples.
  - Long term exposure analysis.
- Software:
  - Can it be integrated into the organization’s system? Bandwidth?
  - WIFI vs cellular network?
- Initial setup and optimalisation can take time and effort.
- Data volumes & big data sets.
- Training of users.
- Intrinsically safe / durable instruments.
- Calibration / maintenance considerations.

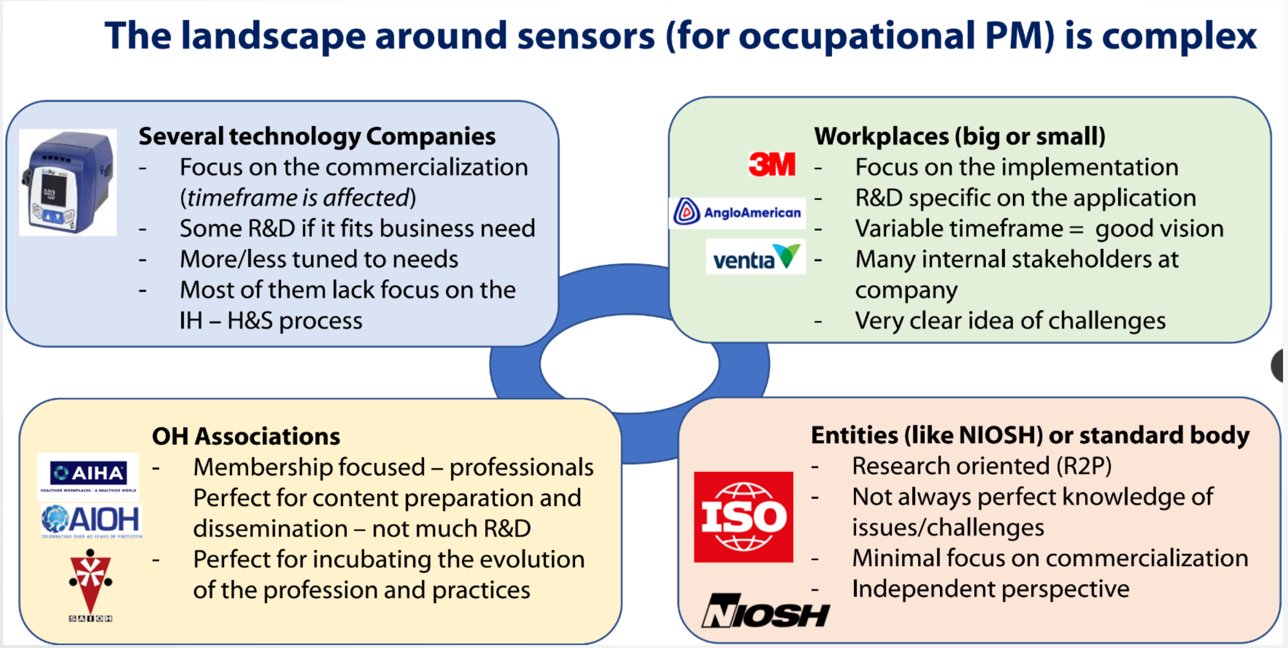
International perspectives and benchmarking

IOHA's Community of Practice on Particulate Matter Sensor Technologies

BY SAMANTHA CONNELL AND EMANUELE CAUDA

The International Occupational Hygiene Association (IOHA) was established in 1987 as a non-governmental organization for the purposes of improving, promoting, and developing occupational hygiene (OH) worldwide. Its 43 member organizations now represent over 20,000 practicing OH professionals globally. IOHA aims to enhance the worldwide network of OH organizations that promote, develop, and improve occupational hygiene around the world to provide a safe and healthy working environment for all. AIHA is a member of IOHA and therefore of the global network.

Source: https://publications.aiha.org/202503-particulate-matter-sensor-technologies



- 23 Countries (3 African).
- To provide the international occupational hygiene community a common place for everything associated with sensor technologies for PM or aerosols in general from a technical perspective.
- RSA is one of the first to include RTM in legislative instructions.

Conclusion

- Real-time dust monitoring systems allow for evidence-based action.
  - More data→ better decisions.
  - Real-time data → quicker decisions.
  - Can the data mean something and lead to action to reduce risk?
- No one size fits all solution → Each site has their own needs and solution.
- Correct implementation requires:
  - Understanding of the work environment (e.g., dust composition, the layout of the workplace, the nature and sequence of tasks, the duration and intensity of specific activities, and even behavioural patterns of workers).
  - Knowledge about the sensor and overall system.
  - Integration with company procedures.
- Challenges remain:
  - Time and cost involved with calibration, maintenance and repairs.
  - Infrastructure.
  - More data → Data intelligence required (ability to extract, analyse and interpret 'big data')
  - Continuous development.

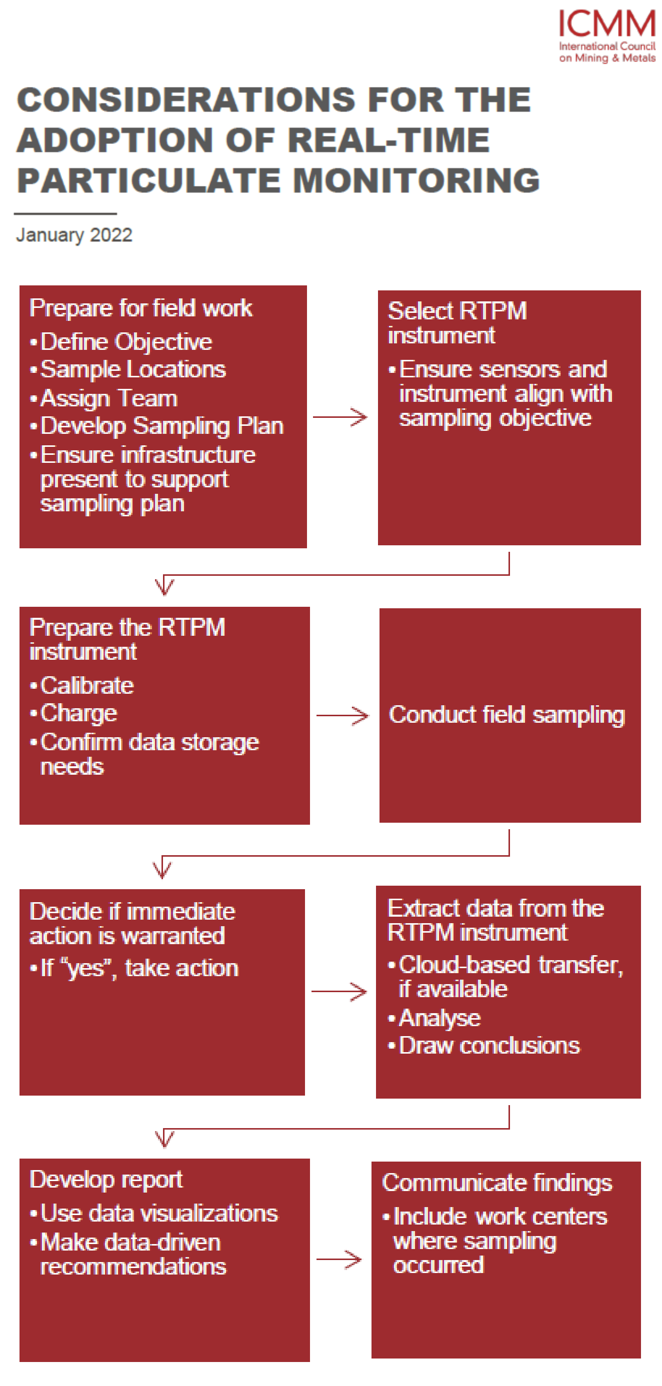


Figure 1. RTPM framework diagram

Thank you

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Acknowledgements

Dan Sarkany (EVR) & Emanuele Cauda (NIOSH)

Useful resources

https://publications.aiha.org/202401-improving-monitoring-practices?

https://blogs.cdc.gov/niosh-science-blog/2019/05/16/right-sensors-used-right/

https://www.tno.nl/en/healthy/work-health/occupational-exposome/using-sensors-create-healthy-environment/

https://blogs.cdc.gov/niosh-science-blog/2021/10/28/sensors-data/

https://www.cdc.gov/niosh/research-programs/portfolio/mining.html

https://www.aiha.org/get-involved/volunteer-groups/technical-committees/mining-working-group