The future of dust monitoring technologies and its implications for dust management strategies

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MINERALS COUNCIL SOUTH AFRICA

3rd Annual

MINE DUST CONFERENCE 2026

3rd Mine Dust Conference 6 August 2026

Silverstar Casino Hotel, Muldersdrift, South Africa,

OHHRI

Occupational Hygiene and Health Research Initiative

OHHRI promotes worker health by preventing the development of occupational disease.

Disclaimer

- This presentation might 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.

Background & Aim

Background:

- I believe we have spoken enough about the background of dust monitoring technologies, limitations, opportunities, etc.
- In my view, the challenge is: How can we improve the implementation of the technology in both practice and research?

Aim:

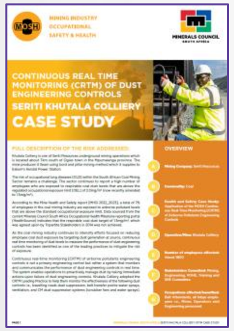
- To discuss implementation of dust monitoring technologies and to link research with practice in the field of continuous real-time particulate monitoring.

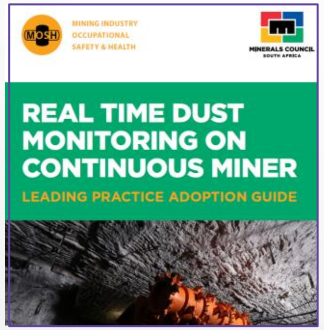
10 POINT DUST CONTROL & MANAGEMENT STRATEGY

- Multidisciplinary Approach & Leadership
- Dust Critical Control Management
- Leading Practice Adoption
- Control Performance Monitoring & Response
- Control Digitalization, Automation & Innovation
- Strengthening Qualitative Dust Measurement & Data Reporting
- Research, Development and Learning
- Risk and Critical Control Management Training
- OEM Engagement
- Quality Assurance, Review and Continuous Improvement

Khumbul'ekhaya

- Literature shows that while PM sensor technologies have great potential but it is not a simple process to implement these systems.
- Some common process elements include →





Prepare for field work
- Define Objective
- Sample Locations
- Assign Team
- Develop Sampling Plan
- Ensure infrastructure present to support sampling plan

→

Select RTPM instrument
- Ensure sensors and instrument align with sampling objective

Prepare the RTPM instrument
- Calibrate
- Charge
- Confirm data storage needs

→

Conduct field sampling

Decide if immediate action is warranted
- If "yes", take action

→

Extract data from the RTPM instrument
- Cloud-based transfer, if available
- Analyse
- Draw conclusions

Develop report
- Use data visualizations
- Make data-driven recommendations

→

Communicate findings
- Include work centers where sampling occurred

Literature

The categories of publications include:

- Legislative guidance on PM exposure in the SAMI.
- PM sensor technology.
- Side-by-side respirable PM monitoring using direct reading instruments (DRIs) and gravimetric sampling trains.
- Low-cost sensors for continuous PM monitoring in high dust areas.
- Dust chamber studies to evaluate instrument performance in controlled environments.
- Video exposure monitoring using wearable cameras.
- Particle size distribution evaluation using DRIs.
- Control measure effectiveness evaluations.
- Publications related to ethics and privacy issues.

Challenge

How do we take the next step?

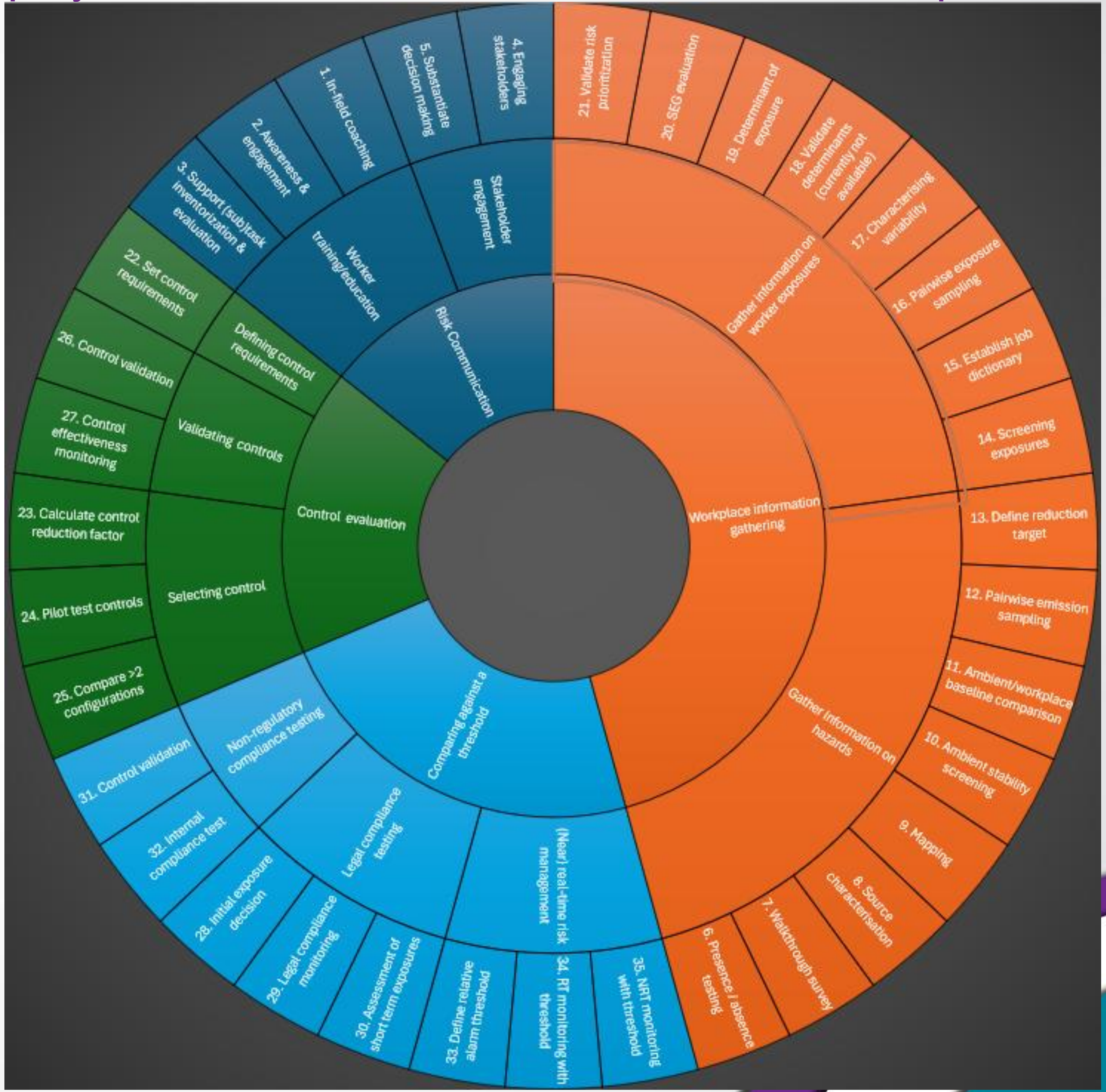
What is the logic behind CRTM implementation and research?

How do we use the information and resources available to create proactive solutions for each specific mining site?:

- Purpose of implementation.
- Value case of implementation.
- The correct team.
- Translation of data into useful/usable information.
- Practical considerations of implementation.
- Constant improvement.
- Impactful research.

Purpose

TNO (Netherlands) and GCG (Australia) has developed a "playbook" on the use of PM sensors for occupational hygiene:



Purpose

Play:	27. Control effectiveness monitoring		
Purpose:	*Control evaluation*	**Objective:**	*Validating controls*
Description:	Measurements to evaluate the performance of the control(s) over time across and/or likely variables to be experienced.		
Further considerations:	For accurate control requirements, calibrated sensors/DRIs are needed. For complex, critical and/or expensive controls are used, the program should be commensurate to the needs. If the performance requirement for the control includes the use of an OEL, the sensors/DRI must be calibrated.		

Setup

Method overview:	Subsequent activity to once the control has been implemented. Measurements are performed to re-evaluate the performance of the control. Determine, in combination wth professional judgement if required, if the control mets or does not meet the requirements. This may be on a proactive schedule, or as needed basis. Where the control does not meet the requirements, the control may not be working as intended and followup action should be triggered.		
Typical deployment	Area	**Typical data interpretation**	Semi-quantitatively
Typical measurement resolution	Medium resolution (minutes)	**Typical data availability**	Real-time (during data collection)
Potential additional information:	Where possible, continuous monitoring would assist in ongoing evaluation of conrol performance. Observations and other information (i.e. weather / production data) may be required to support the assessment outcomes.	**Worker engagement:**	Not necessary per se. If requested by workers explain to the workers what you are going to do and why you are going to do it.
Communication with:	Management to understand if the control continues to meet the defined requirements.	**Information shared**	0

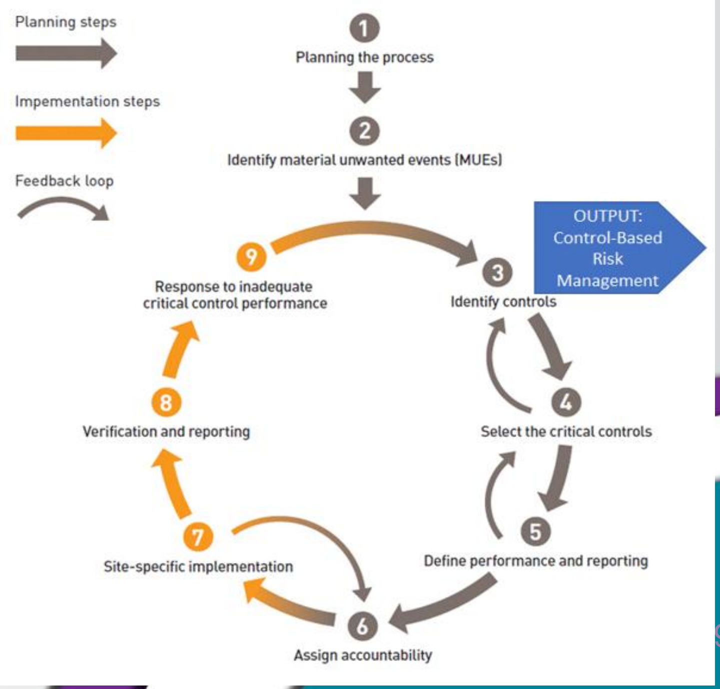
Procedures

Measurement start:	Prior to deployment routine inspections of the intruments are performed.
During measurement:	Since measurements are perfomed continuously and indefinetely, routine inspections of the intruments should be performed periodically. Data should be communicated during the measurements or the instruments needs to have an alarm function to alert when concentrations are too high.
After measurement:	Regularly screen/review data and draw conclusions to build an information base to support continual improvement.

Data interpretation and analysis

Visualisation of the data overtime against the threshold may aid interpretation. Action should be undertaken when concentrations are (prolonged) above a given threshold pr when an alarm calls for action.

Author/contact	*SR*	*Version number*	*0.1*
Date added	*29-9-2025*	*Version date*	*29-9-2025*



ICMM Critical Control Management Process

Purpose

Play:	**16. Pairwise exposure sampling**		
Purpose:	*Workplace information gathering*	**Objective:**	*Gather information on worker exposures*
Description:	High-resolution measurements in combination with time-integrated reference sampling to provide information and contextualization about evolution in time of exposure level. Alternatively to validate/calibrate previous sensor/DRI measurements.		
Further considerations:	Conventional time-integrated samples may also be used to aid in characterising the phycical-chemical properties of the aerosols. Pairwise sampling can also be used to validate sensor/DRI measurements, including generation of a calibration (K) factor. Careful consideration is required to establish a fit for purpose calibration factor.		

Setup

Method overview:	Time-integrated measurements are performed with conventional methods as usual, with the addition of a high-resolution sensor/DRI. The traditional measurements are used quantitatively (e.g. to compare with limit values) and the high-resolution data is used to try and explain exposure results. Alternatively, these measurements can be used to generate a calibration factor or judge how accurate previous sensor/DRI measurements in the same environment were.		
Typical deployment	Personal (on worker)	Typical data interpretation	Semi-quantitatively
Typical measurement resolution	High resolution (seconds)	Typical data availability	Retrospectively (>1 day after data collection)
Potential additional information:	To explain exposure patterns over time in the measurement results (e.g., peaks), detailed information on tasks and locations of the workers throughout the measurement may be needed. Make sure that the traditional method and sensor/DRI sample as closely as possible the same air.	Worker engagement:	Explain to the worker what you are going to do and why you are going to do it.
Communication with:	Communication with the worker directly after the measurement may help explain observed the exposure pattern. E.g., discuss the moments of peak exposures and if the worker can recall what he was doing at that time.	Information shared	High-resolution exposure profiles.

Procedures

Measurement start:	Prior to deployment routine inspections of the intruments are performed. Conventional and high-resolution sampling equipment are placed on the same worker.
During measurement:	During the measurement, collect contextual information to explain exposure profiles. During the measurement, collect contextual information to identify parameters that affect exposure levels.
After measurement:	Stop the measurement and complete sampling record sheets. Retrieve and store the data and label the data with the correct situation. Save all relevant information on file. Perform cleaning and maintenance on sensor/DRI as recommended by supplier.

Data interpretation and analysis

Data is visualized to identify patterns (peaks, consistent increases in concentrations, the time it takes after an exposure peak to 'recover' to background concentrations) in exposure to add information to the conventional measurement.

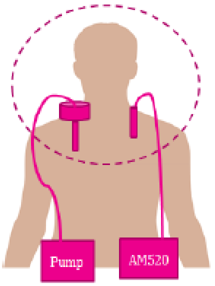
Author/contact	*SR*	*Version number*	*0.1*
Date added	*26-9-2025*	*Version date*	*26-9-2025*

Initial Assessment with 'co-location' method:

Co-located sampling uses both the SidePak AM520 Monitor and a traditional gravimetric sampling pump with both instruments using a PM4 Dorr-Oliver Cyclone within the breathing zone of the worker.

This will provide the information needed to calculate a calibration factor for the **Total Respirable Dust** using the following formula:

$$PCF = \frac{Reference\ Concentration}{Data\ Log\ Concentration} \times ECF$$



Co-located sampling

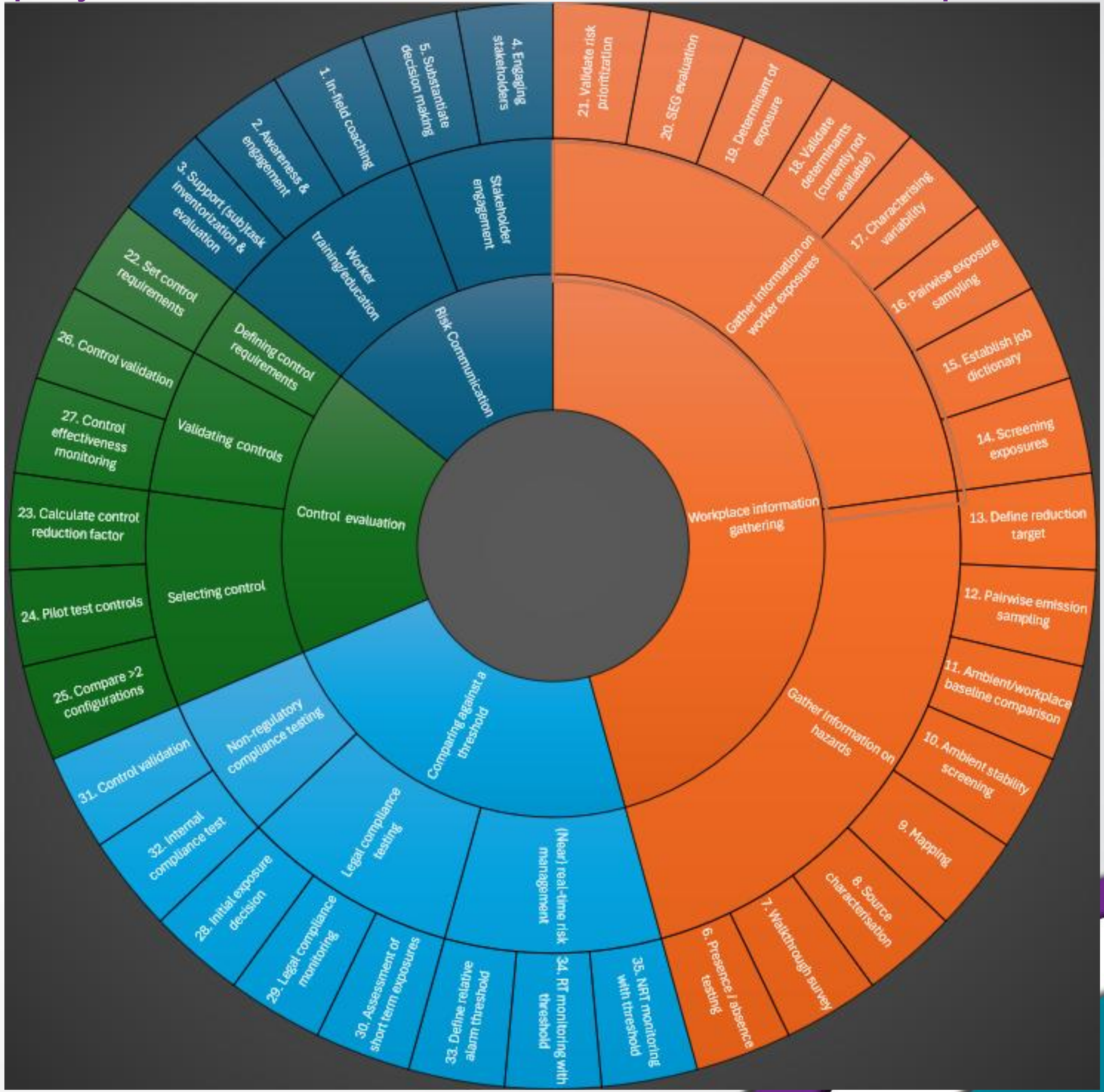
PCF = Photometric Calibration Factor
Reference = Gravimetric Average Concentration
Data Log = AM520 Average Concentration
ECF = Existing Calibration Factor of Real-Time Instrument (factory default calibration is 1.0)

Initial worker co-located breathing zone assessment with SidePak AM520 Monitor and gravimetric sample pump.

Source: TSI

Purpose

TNO (Netherlands) and GCG (Australia) has developed a "playbook" on the use of PM sensors for occupational hygiene:



Value case

GENERIC VALUE CASE

Table 1 outlines the guide for determining the value case to enhance the decision making for adoption of real time dust monitoring on CM Leading Practice.

Table 1: A guideline for establishing a value case for adoption of real time dust monitoring on continuous miner leading practice.

Risk management	**Early warning systems**	Empowerment of the CM and shuttle car operators to minimise exposure to coal dust, but also to proactively protect the health and safety of others downstream.
	Critical control management	Performance, availability and failure of critical controls can be monitored and attended to by the CM Operator or the engineering department immediately, to ensure that the CM operate within permissible dust limits.
	Incident investigation	Investigation of coal dust exceedances can be conducted immediately by line supervision, and findings actioned (maintenance) and communicated to the next shift.
Health and Safety	**OHS benefit**	Risk of occupational lung diseases to underground employees will be significantly reduced. This is of real value to both the employees and employer.
	Progress towards Zero Harm	Death from Coal Workers Pneumoconiosis (CWP) and other occupational lung diseases caused by excessive exposure to coal dust. Reducing this risk to underground employees most at risk will constitute a significant step towards achieving the goal of Zero Harm.
Governance	**Legal compliance**	The installation and use of continuous real time dust monitor on board CM units will assist in monitoring and ensuring that the regulated permissible coal dust exposure levels are achieved. It will also be a good case of management doing what is reasonably practicable to provide and maintain a working environment that is safe and without risk to the health of all underground employees.
	Reduced compensation	In the longer term, the mining industry, including the source mine, stand to benefit from a reduction in compensation and other costs associated with occupational lung diseases.
Stakeholder relations	**Improved working relationships**	Implementation of the behavioral communication and leadership behavior plans has the potential to significantly improve the operational working relationship between supervisors and their staff.
	Buy-in and support	The mine-wide intervention in the interest of protecting the health of those most at risk will help engender buy-in and support for the intervention, from employees and relevant stakeholders.
	Improved investor relations	A positive outlook on the mine's commitment towards elimination of OLD.

Source mine benefits

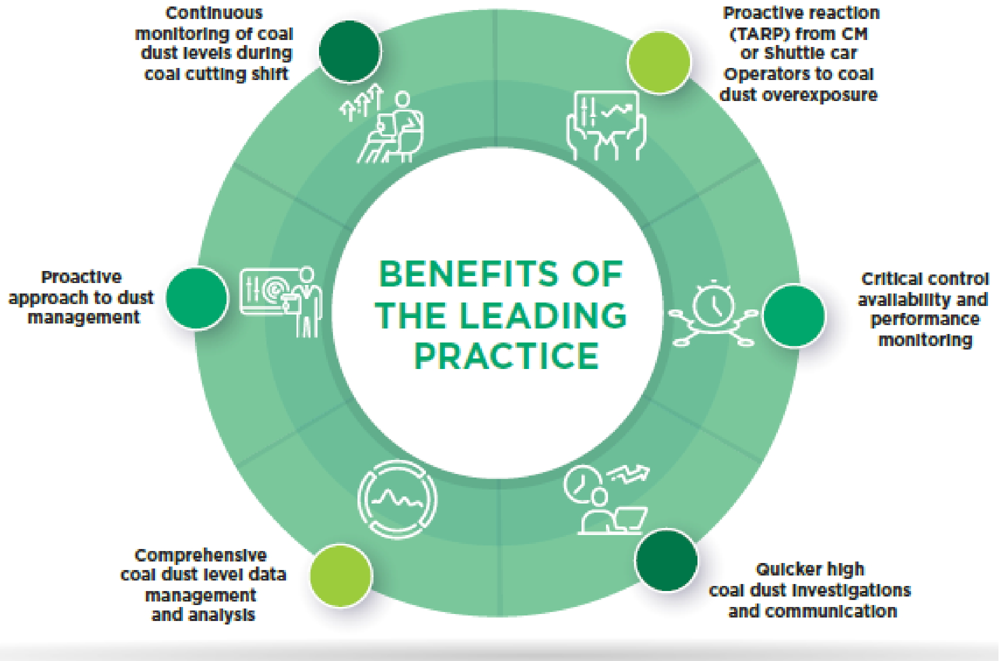


Figure 6: Documented benefits of real time dust monitoring on CM leading practice

Value case

Guideline **Particulate Matter Sensors in the Workplace** 6 What to Consider When Selecting a Sensor?

6 What to Consider When Selecting a Sensor?

Different sensors are characterized by different properties. Whether certain properties are important depends on how the sensor will be used. For example, if you want to continuously measure dust concentrations, it is important that the measurement data is automatically processed and stored, while this is much less important if the sensor is used incidentally.

When purchasing a sensor, it is therefore important to first determine the purpose for which the sensor will be used. Based on this, you can list the specifications the sensor must have. These specifications can be divided into essential specifications (must-haves) and specifications that are only desirable (nice-to-haves) (Figure 6.1).

Figure 6.1: The purpose for which the sensor is used determines the specifications the sensor must have.

Set Goal > Divide Specifications into Must Haves and Nice to Haves > Selection Sensor

Generally Relevant Specifications >	Application-Dependent Specifications >
Measured Particle Size >	Alarm Functions >
Concentration Range >	Data Storage Capacity >
Measurement Frequency >	Battery Life >
Environmental Factors >	Feedback on Sensor Status >
Connectivity >	Size and Weight >
	Attachment Method and Material >
	Supplied Data Processing and Analysis Software >
	Additional (Context) Sensors >

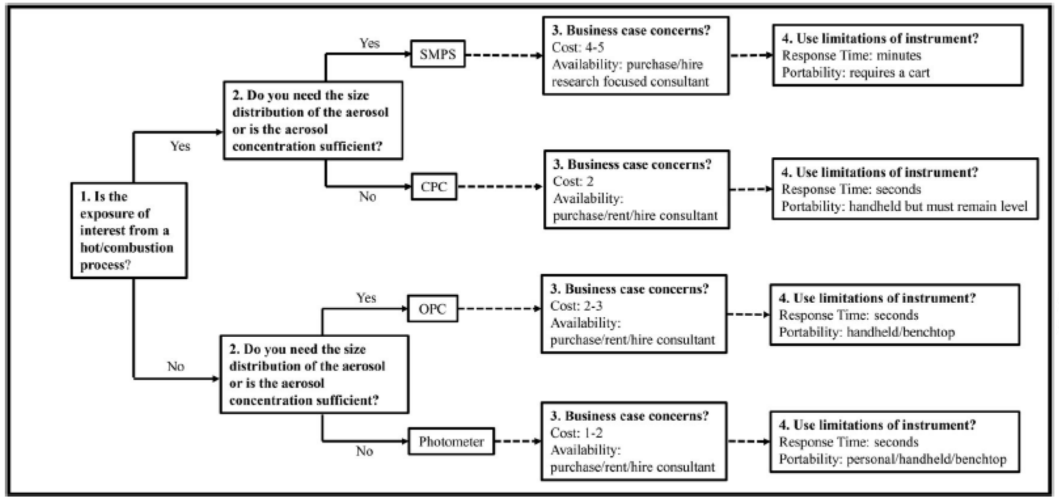


Figure 1. Considerations for choosing the appropriate aerosol DRI. For cost values 1 represents under \$5,000, 2 represents \$5,001–\$10,000. 3 represents \$10,001–\$20,000, 4 represents \$20,001–\$30,000, 5 represents greater than \$30,000.

Source: Vosburgh, et al. (2022)

The correct team

Buy-in from everyone involved.

MOSH DUST NEWSLETTER

JANUARY 2026

MINERALS COUNCIL SOUTH AFRICA

MINING INDUSTRY OCCUPATIONAL SAFETY & HEALTH

CONTENTS

Multidisciplinary Approach & Leadership

SASOL Thubelisha Shaft

Adopt a Multidisciplinary approach to address exposures, risks and controls. Assign ownership and reporting accountabilities to Risk Owners (Mining), Risk Control Owners (Engineering), Control Verification Activity Owners (Ventilation & Occupational Hygiene), and all other relevant disciplines (i.e., HR, Training Department, Procurement, etc) to **continuously and actively engage** in the identification & management of the dust risk. This can be achieved through **a Dust Management Committee** within a mining operation to frequently review dust exposure results, dust control performance and remedial actions where necessary.

Research, Development and Learning

Ledjadja Coa - Boikarabelo

Participate in the continuous **identification, facilitation and dissemination** of dust and airborne pollutant related research. **Adopt and apply research outcomes** to optimize dust control. Promote a **culture of learning** from others through facilitation and participation in industry forums, workshops, Leading Practice community of practice adoption (COPA) meetings and MOSH Dust Days of Learning.

Risk and Critical Control Management Training

Seriti - Kriel Colliery

Training the relevant mining personnel in the principles of Risk Management and the Critical Control Management Process, will enhance their understanding of **risk concepts** (ICMM, ISO 31 000, etc.), equip them to develop **strong dust risk strategies** and alternatives, and document these as strong business cases. It will further enhance their understanding of the various processes and steps that make up the critical control management process.

ICMM International Council on Mining & Metals

CONSIDERATIONS FOR THE ADOPTION OF REAL-TIME PARTICULATE MONITORING

January 2022

Prepare for field work
- Define Objective
- Sample Locations
- Assign Team
- Develop Sampling Plan
- Ensure infrastructure present to support sampling plan

→ **Select RTPM instrument**
- Ensure sensors and instrument align with sampling objective

Prepare the RTPM instrument
- Calibrate
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- Confirm data storage needs

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Decide if immediate action is warranted
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← **Extract data from the RTPM instrument**
- Cloud-based transfer, if available
- Analyse
- Draw conclusions

Develop report
- Use data visualizations
- Make data-driven recommendations

→ **Communicate findings**
- Include work centers where sampling occurred

Practical considerations

- Type of data generated.
- Reporting procedures.
- Connectivity.
- Power supply.
- Durability & maintenance.
- Calibration requirements.
- Security.
- Acceptance by workers.

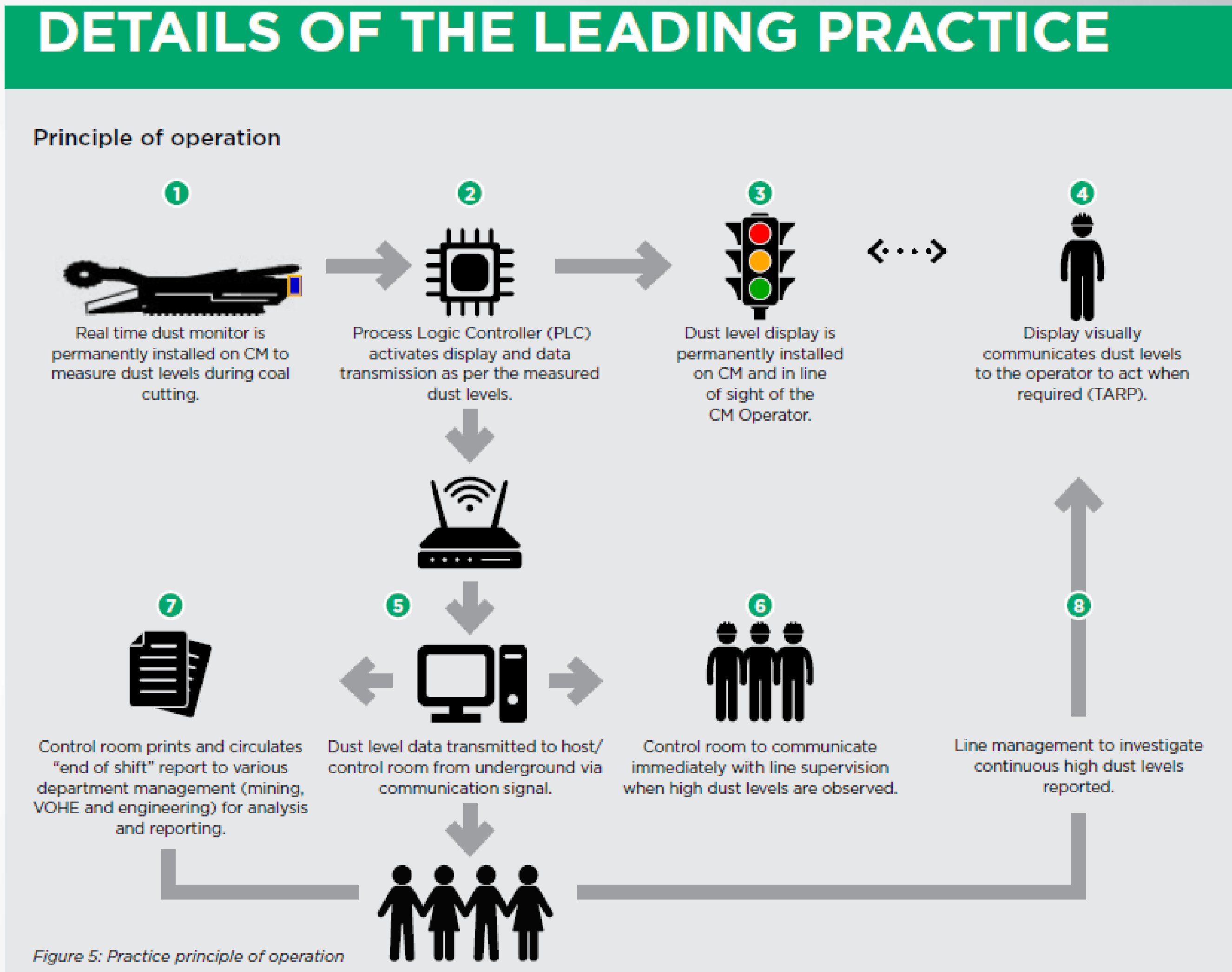


Figure 5: Practice principle of operation

Useful/usable information

Table 2: Dust trigger action and response plan displaying the action to be taken by the responsible persons.

Trigger levels	Main display	Action required	Responsible person
Normal conditions Shift average dust reading below 3mg/m³		**No action required** – maintain dust controls	CM Operator
Level 1 Shift average dust reading above 3mg/m³ but below 4mg/m³		Check condition of all dust critical controls i.e., CM scrubber, water sprays, ventilation controls, condition of picks and pick sleeves.	CM Operator
Level 2 Shift average dust reading above 4mg/m³		**Stop and check condition** of all dust critical controls i.e., CM scrubber, water sprays, ventilation controls, condition of picks and pick sleeves.	CM Operator, Faceboss, Artisan, Shiftboss & Engineering Foreman)
Level 3 Shift average dust reading above 5mg/m³ – **trip settings activated**		CM will not operate, check all dust critical controls i.e., CM scrubber, water sprays, ventilation controls, condition of picks and pick sleeves.	CM Operator, Faceboss, Artisan, Shiftboss, Engineering Foreman, General Engineering Supervisor, Mine Overseer and VOHE Officer

"All real time data measurements must be transmitted to surface where the daily analysis report will be generated, flagging incidents of high dust."

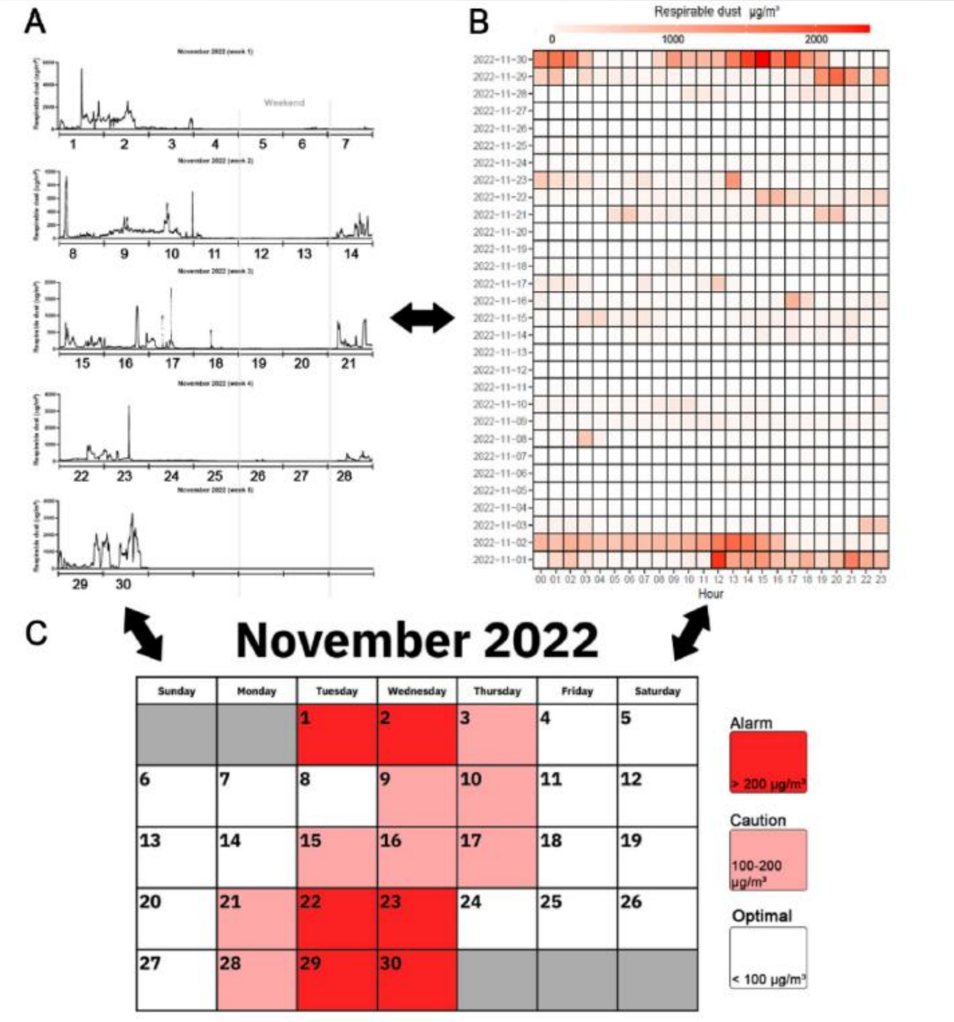


Fig. 2 Progression of data visualizations. Analysis of the data progressed from line charts (**A**) to heatmaps (**B**), and finally calendar view heatmaps (**C**)

Source: Wolfe et al. (2024)

Useful/usable information

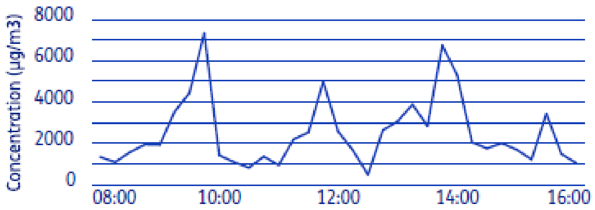
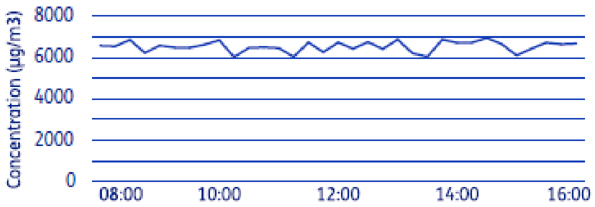
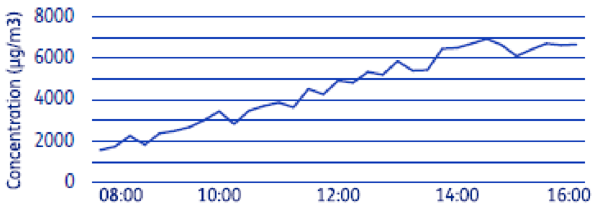
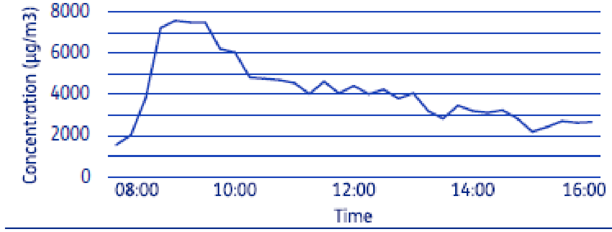
8 Converting Data to Information

After a measurement, the data is processed and interpreted. This chapter provides examples of how sensor data can be corrected to improve accuracy. Additionally, examples are given on how to convert measurements into actionable information.

Figure 8.1: Sensor measurements can be corrected to better match actual concentrations or desired forms, or analyzed to extract key information from the measurements.

Correcting Sensor Data >	Analyzing Sensor Measurements
Calibration >	Interpreting Exposure Profiles
Converting Particle Counts to Mass Concentrations >	Summary Statistics
Converting Size Bins to Relevant Dust Fractions >	Visualizing Comparisons: Boxplots

Figure 8.3: Interpretation of Exposure Profiles.

Exposure Profile	Description	Interpretation
	Many peak exposures	Exposure comes from temporary sources. Likely specific tasks or locations.
	Constant high concentrations	Exposure is related to a continuous process and/or activity.
	Concentration increases during measurement	Dust may repeatedly enter the air, causing accumulation. For example, dust blows up after initially settling on the ground.
	Concentration decreases slowly after a peak	Combination of a dust-generating activity and limited general control measures (such as room ventilation).

Constant improvement

ICMM
International Council on Mining & Metals

CONSIDERATIONS FOR THE ADOPTION OF REAL-TIME PARTICULATE MONITORING

January 2022

Table 2. RTPM implementation maturity model

	Level 1 Unaware or Unable	Level 2 Exploratory	Level 3 Defined	Level 4 Adoptive	Level 5 Adaptive
Leadership	Company's primary airborne particulate exposure approach is focused on legislative compliance in the absence of leadership or commitment to improve.	Some initial leadership and commitment to real-time particulate monitoring demonstrated by leadership. Company is actively investigating real-time approaches to mitigate, monitor, and control airborne particulates.	Management demonstrates some level of leadership and commitment to airborne particulate control and RTPM. Company is actively pursuing RTPM technologies in design, operating procedures, and control validation. Limited utilisation at specific points within the operation.	Management demonstrates leadership and commitment to RTPM and airborne particulate exposure mitigation, control validation, and environmental monitoring. Demonstrated success in adoption of RTPM to achieve risk mitigation and hazard control objectives. RTPM data used to optimise operational designs and work practices.	Management demonstrates exceptional leadership and commitment to airborne particulate control and RTPM. Implemented leading industry practices in the design of critical controls for airborne particulate exposure elimination. Coupled with integrated use of RTPM digital data to optimise industry designs and monitoring of work practices.
Airborne particulate hygiene programme	No current agent-specific hygiene programme to eliminate, mitigate, and monitor airborne particulate exposures in real-time.	Airborne particulate programme exists with some elements of real-time particulate monitoring, mostly limited to a few measures and surveys (mostly outsourced services). Data management limited to simple post-sampling reports with no temporal, statistical, or trend analyses.	Company has a airborne particulate hygiene programme that incorporates RTPM. Programme not informed or based on findings of most recent (less than 24-months) most contemporary RTPM data or latest technology advancements.	Company has a airborne particulate hygiene programme that integrates RTPM technologies (within 24 months). The programme is based on airborne particulate risk assessment findings that eliminate, mitigate, and monitor particulate exposures. The programme has not been verified by a certified aerosol scientist or occupational hygienist within 24 months.	Company and sites have current airborne particulate hygiene programme with full integration of RTPM and in accordance with findings of the risk assessment to eliminate, mitigate, and monitor airborne particulate exposures. The programme has been verified by a certified aerosol scientist or occupational hygienist within 24 months.
Design guidelines	The operational standards and procedures are focused on minimal airborne exposure monitoring to meet legislative compliance only.	The operational standards and designs are focused on airborne particulate exposure prevention and mitigation based on legislative compliance as a minimum standard. Limited to no ad-hoc RTPM data used to inform standards and designs.	Airborne particulates are included in critical control matrices with Company defined administrative, engineering, design, and training standards.	Airborne particulate exposures are identified as a critical hazard with the company actively integrating all levels of control, including RTPM, to eliminate risk.	Airborne particulate exposures are identified as a key critical hazard with the company actively integrating all levels of controls, including RTPM, to exceed industry leading practices.

Impactful research

1. Portable FTIR spectrometer

RCS concentration

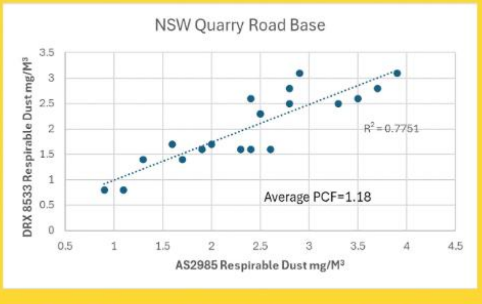
FAST
Field Analysis of Silica Tool

https://www.cdc.gov/niosh/publications/numbered/2021-118.html

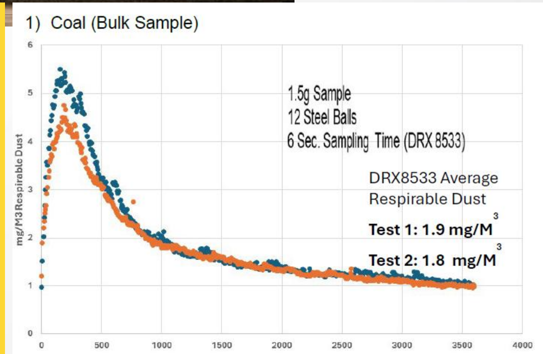
2. Rotadust® -Rotadome®

DEAS Pty Ltd
219 Shellharbour Road
Port Kembla NSW 2502,Australia
Tel: +61 (2) 4274 5097
Email: info@rotadust.com.au

Calibrate direct reading instruments



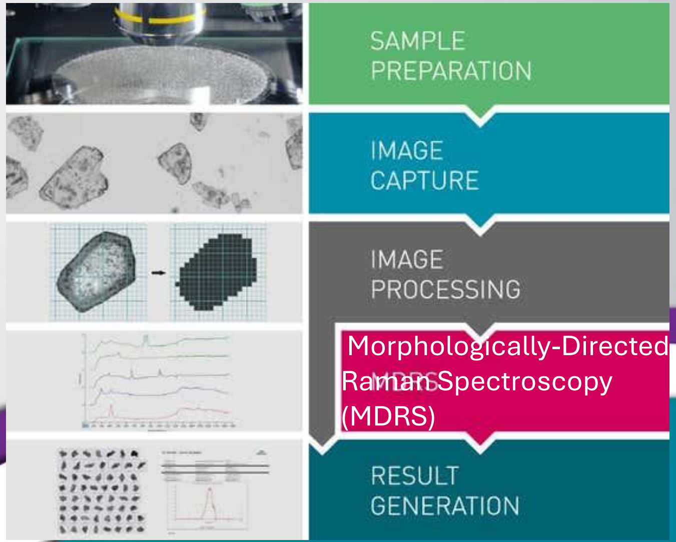
DRX 8533 User Calibration for a NSW Road Base



https://www.rotadust.com.au/home

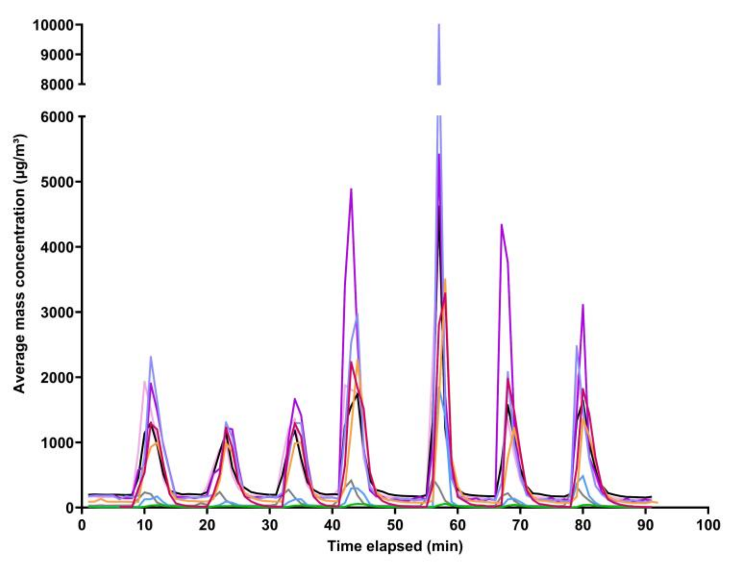
3. Malvern Morphologi 4-ID

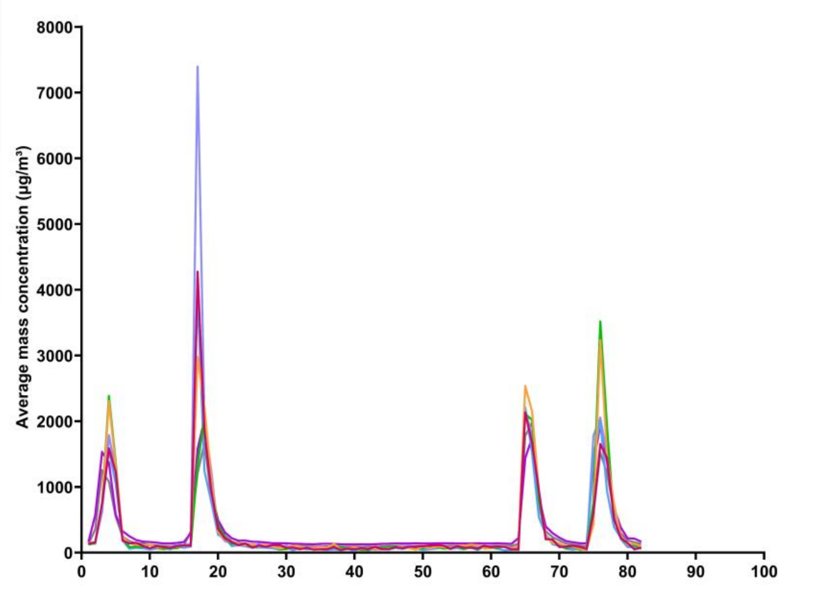
Particle size, shape and composition

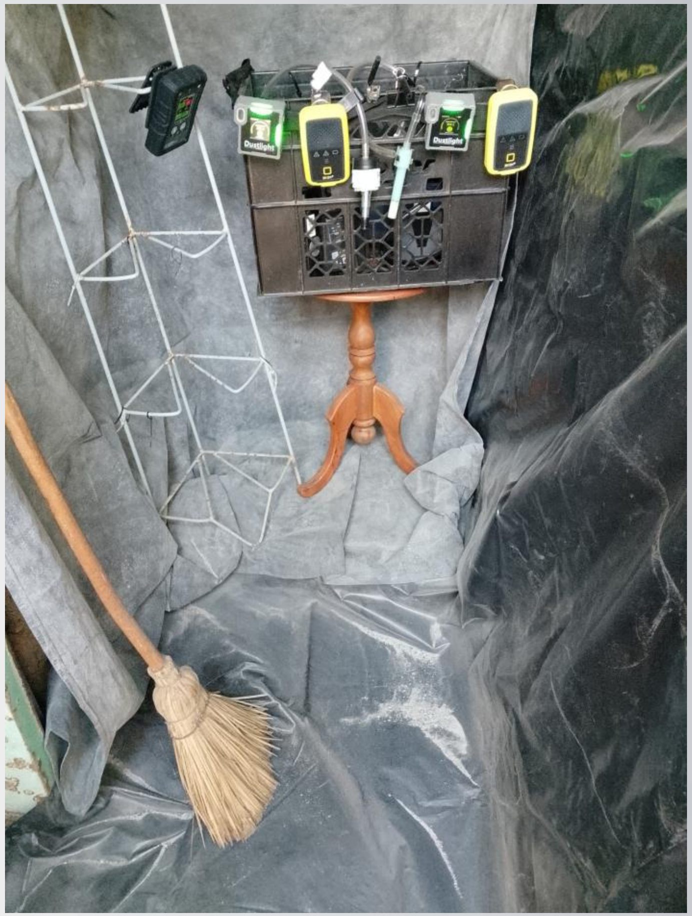


https://www.malvernpanalytical.com/en/products/product-range/morphologi-range/morphologi-4-id

Impactful research







	GRAVIMETRIC	A	B	C	D	E	F	H	I	J
% of Grav	100.00%	51.35%	32.34%	1.21%	4.49%	62.35%	58.16%	6.69%	57.91%	57.04%
% of Grav	100.00%	50.67%	43.89%	1.86%	10.19%	66.51%	77.84%	9.60%	59.21%	59.85%
	E/F 1	E/F 2	E/F 3	E/F 4	E/F 5	I	J			
Respirable Dust [ug/m^3]	323.90	359.66	333.26	291.24	386.48	364.30	298.89			
	G/H 1	G/H 2	G/H 3	G/H 4	G/H 5	I	J			
Respirable Dust [ug/m^3]	53.77	9.87	80.19	40.88	53.23	704.36	730.93			

Conclusion

The future of dust monitoring technologies and its implications for dust management strategies:

- How do we take the next step to use improving dust monitoring technologies to create better dust management strategies?
- How do we use the information and resources available to create proactive solutions for each specific mining site?:

\- Purpose of implementation.

\- Value case of implementation.

\- The correct team.

\- Translation of data into useful/usable information.

\- Practical considerations of implementation.

\- Constant improvement.

\- Impactful research.

Thank you

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