Coal Mine Dust Exposure Monitoring and Sampling in Underground Mines in South African Mining Industry

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Some SA coal key facts

- South Africa is home to 3.5% of the world’s coal resources
- The country’s production is 3.3% of the world’s annual total
- Exports are 6% of global exports
- This ranks South Africa as 6th in the list of coal-exporting nations
- Coal provides 81% of the power generated by state-owned power utility Eskom
- Eskom operates 16 power stations and is building two more to come on stream by 2021
- 25 collieries
- Sector employs approx 80 000 people
Summary: Compliance testing SA Mining Industry

(SAMI) Code of Practice

GROUPING by constitution of Homogeneous Exposure Groups

1. Sampling areas by common intake- and return air
2. Subdivide into Activity areas e.g. conventional mining, stoping, development, etc.

SAMPLE SIZE: randomly selected 5% of HEG or N=5 (whichever is the greatest), full shift sampling!

OEL-TESTING criterion

1) Arithmetic mean (AM) * and empirical 90th percentile** (of observed data points) of HEG fall in same exposure category

* Normal distribution assumed
** Implicitly 10% exceedance accepted

A Exposures ≥ OEL
B Exposures ≥ 0.5 OEL and < OEL
C Exposures ≥ 0.1 OEL and < 0.5 OEL
1 Regulatory Standards for Dust in Underground Coal Mines

OEL Coal Dust: 2 mg/m³ 8hTWA, respirable dust. No STEL

<table>
<thead>
<tr>
<th>Coal dust [respirable particulate]</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>2</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5% crystalline quartz/silica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt;5% crystalline quartz/silica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coal tar pitch volatiles [as]</td>
<td>-</td>
<td>65996-93-2</td>
<td>0.14</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

NOTE: crystalline quartz should be < 5%

‘Nuisance dust’ Particles Not Otherwise Classified (PNOC)

<table>
<thead>
<tr>
<th>Particles not otherwise classified [PNOC]: &lt;5% crystalline quartz/silica</th>
<th>-</th>
<th>10</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>inhalable particulate</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>respirable particulate</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>
2 Monitoring technology, sampling etc (1)

• Personal Sampling + gravimetric analysis
  
  – Respirable fraction (according to ISO/CEN definitions (D50=4 µm) ACGIH/CEN

• Majority NIOSH 0600 (HD cyclone. PVC filter)
• Minority: MDHS 14-4, using IOM samplers, 25mm PVC filters, and cyclones
2 Monitoring technology, sampling etc (2)

Continuous Miner (CM) strategic sampling inside cabin (during each shift)

To measure this efficiently one gravimetric dust (respirable) sample per day is required from each mechanical miner. The sampling is to be conducted on a full production shift.

The sampler is to be placed in a stationary position inside a cab of the mechanical miner. The above sampling will be classified as Environmental Engineering method. The results of this method of sampling are actual sample concentrations, and are hence not corrected to the 8 hours equivalent.

Ninety percent (90%) of the readings should not exceed the concentration of 5mg/m³.
CoM Real Time monitoring pilot projects (Chamber of Mines)
# 2 Monitoring technology, sampling etc (3)

Time basis: 8hTWA

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>MINIMUM FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sample 5% of employees within a HEG on a 3monthly basis with a minimum of 5 samples per HEG, whichever is the greater.</td>
</tr>
<tr>
<td>&gt;OEL</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Sample 5 % of employees within a HEG on a 6 Monthly basis with a minimum of 5 samples per HEG, whichever is the greater</td>
</tr>
<tr>
<td>0.5&lt;OEL&lt;1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Sample 5 % of employees within a HEG on an annual basis with a minimum of 5 samples per HEG, whichever is the greater</td>
</tr>
<tr>
<td>&lt;0.5 OEL</td>
<td></td>
</tr>
</tbody>
</table>
2 Monitoring technology, sampling etc (4)

- Mines are responsible for sampling, often subcontracted/out sourced to Approved Inspection Authorities (AIA)
- Mandatory reporting of mines to Department of Mineral Resources (DMR)
- Reporting frequency aligned with frequency of sampling
### Reporting sheet
(from mines to DMR)

#### Example of a Gold Mine

**Annual Personal Exposure Report**

<table>
<thead>
<tr>
<th>Main Commodity Code:</th>
<th>AU</th>
</tr>
</thead>
<tbody>
<tr>
<td>DME Mine Code:</td>
<td>00965</td>
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<tr>
<td>Sample Area:</td>
<td>2</td>
</tr>
<tr>
<td>Activity Area Code:</td>
<td>08</td>
</tr>
<tr>
<td>Quarter Ending:</td>
<td>September</td>
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<tr>
<td>HEG Classification Band:</td>
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</table>

#### Table:

<table>
<thead>
<tr>
<th>HEG Code</th>
<th>Occupations in HEG Codes</th>
<th>No of persons per Occupations</th>
<th>Pollutant Code</th>
<th>Concentration Per Occupation mg/m³</th>
<th>Average of HEG</th>
<th>90th percentile of HEG %</th>
<th>Analysis</th>
<th>Dose allocated to medical record mg/m³</th>
<th>OEL mg/m³</th>
<th>Pollutant Index</th>
<th>AQI</th>
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<tbody>
<tr>
<td>20402</td>
<td>50</td>
<td>C644</td>
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<td>0.74</td>
<td>0.955</td>
<td>10.1</td>
<td>0.07</td>
<td>0.10</td>
<td>0.75</td>
<td>0.75</td>
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<td>0.75</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>
2 Monitoring technology, sampling etc (5)
Dissemination of sampling results

A) Feedback:
Reporting to each personal sampled: occasionally, more often on monthly management meeting with safety reps.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Number of Persons Exposed to Airborne Pollutants per Exposure Classification Band</th>
<th>% Persons Exposed to Airborne Pollutants per Exposure Classification Band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Gold</td>
<td>3698</td>
<td>9334</td>
</tr>
<tr>
<td>Platinum</td>
<td>839</td>
<td>1721</td>
</tr>
<tr>
<td>Coal</td>
<td>1426</td>
<td>7147</td>
</tr>
<tr>
<td>Diamonds</td>
<td>0</td>
<td>80</td>
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<tr>
<td>Copper</td>
<td>0</td>
<td>671</td>
</tr>
<tr>
<td>Chrome</td>
<td>162</td>
<td>711</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>0</td>
<td>240</td>
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<tr>
<td>Manganese</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Other Mines</td>
<td>1688</td>
<td>24479</td>
</tr>
<tr>
<td>Total</td>
<td>7822</td>
<td>44406</td>
</tr>
</tbody>
</table>

B) General public:
Reporting by Mine Health & Safety Inspectorate
3 Implementation of requirements

• 95% CI of Mean concentration (as required by Report template) not met in practice
• No clear indications when additional analysis for crystalline silica is needed
• Role of CM sampling is unclear
Effectiveness monitoring on dust exposure?

Overall decline in occupational disease 2004 - 2015

Pneumoconiosis (including silicosis), NIHL, TB and HIV continue to be the key challenges

![Graph showing the decline in occupational diseases from 2004 to 2015](image-url)
Coal dust data analysis across 6 mines (2015 n=860)

Clearly + possibly @risk represent > 11,000 workers

10 HEGs ≥ 10% OEL
15 HEGs < 70% prob X0.95 < OEL

Clearly @risk
Possibly @risk
Not @risk
Results of CoM pilot project real-time monitoring
# Monitoring & Sampling requirements

## Strengths

- **Sampling frequency & size**
  - Randomly selection of workers to be monitored
  - Representability okay (5%)
  - High frequency

- **Time-aggregated sampling;**
  - Quality standards (AIA)
  - SOPs

## Weaknesses

- No consequences exposure category A (> OEL)
- **Constitution of HEGs**
  - Job title
- No appropriate data analysis
  - Statistics
  - ‘historical data’ ignored
- In practice no observations during sampling
  - No indication on specific events etc.
- Currently real-time monitoring not acceptable for reporting
4 Medical surveillance

- 4.1 Extent to which medical surveillance results have been used to inform monitoring and sampling protocols

**Major role:**
- establishing the need for removal or return to a particular work
- ensuring appropriate medical treatment
- planning awareness campaigns

**Minor role:**
- Monitor effectiveness prevention & control measures.
4.3 types of tests and their frequency

- Routine health questionnaires --- done every year
- Physical exam/eye test/hearing/lung function test/urine test/Chest x-rays—all these are done on yearly basis but in certain cases can be done every 6 or even every 3 months depending on the results
  - Initial/preplacement examination --- done on first encounter, usually to decide on suitability
  - Periodical examination – this is usually monitoring, all tests are compared to baseline tests
  - Exit examination – upon leaving the employment an exit medical exam is done and copies given to the employee and the employer keeps records for 40 years
  - Special examination – if safety or health concerns are raised by employer or employee themselves special examination can be conducted on adhoc basis
4 Organisation that performs the tests and that pays for the tests

- **Occupational health centres (OHC) or clinics either inhouse or contracted to the company**, perform and manage all the different exams and tests that are associated with the examinations, however other tests are performed externally by relevant accredited bodies e.g. blood tests are be done by accredited laboratories (lancet, pathcare, Ampath, medilab etc) and sputum by National Health Laboratory Services.

- X-rays, side room tests like audiograms, spirometry and urine testing are provided for by the OHC

- The company that requires the services is liable for paying and this usually on fee for service basis. In very rare circumstances, an individual might fund for his own examination.
5 How the results are made available to the miners, coal mine companies, and inspection agencies.

- Miners are informed of their results and this is usually after all the tests have been performed, this is a one to one engagement and referral to appropriate external practitioners or providers happens at this stage.

- Mine companies usually get informed through various platforms (SHE meetings, safety bulletins, monthly or quarterly reports). They get to be informed about numbers of people with a certain occupational problem rather than names of people with those conditions (confidentiality issues).

- Inspection agencies, maintaining confidentiality, they get to be informed via formal and structured audits. Other bodies get informed as part of legal reporting e.g. Medical Bureau of Occupational Diseases (MBOD) requires that all Occupational Lung Disease be reported within a month of diagnosis.
Action taken on the basis of the surveillance tests results

• The occupational medical practitioner (OMP) will inform the employer via the hygiene department of the possible risk associated with a particular exposure and also the OMP with further give recommendations as to what steps should be taken ranging from preventing or limiting further exposure to removing employee from dangerous environment. These results are also used to plan and even improve the medical surveillance system itself.
Rock dust

5.1. Typical rock dust composition used in underground mines: No specification is made but mostly Dolomitic rock dust and limestone dust are used in the industry.

5.2. Rock dusting requirements, including composition, particle size, percentage of inert content of coal mine dust, and other requirements. Minerals Act (1991) required that the material used for inertization purposes (of coal dust underground) should be light colored so that it will easily seen in the environment. Minimum percentage Incombustible content must be 95% and free silica must have a maximum of 5 %. 100 % of the product must go through 600 micron sieve and 50% thereof must go through 75 micron sieve.
5.3. Effects of rock dust applications on sampled dust concentrations. Not much work was done to this regard.

5.4. Research being conducted on rock dusting (including composition and application techniques) that might alter the impact respirable dust concentrations. Additives are being investigated in recent research to apply the product wet to reduce respirable dust during application. Several additives are undergoing trials in the industry with very promising results. One such successful product was known as AiroDust and it was comprehensively tested at CSIR in the past 5-years.
Acknowledgments

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