International Harmonisation Sampling Curve (ISO/CEN/ACGIH):

Background and its influence on dust measurement and exposure assessment in the South African mining industry

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Abstract

In the late last century there was a call for global harmonisation of size-selective respirable sampling of dust at workplaces. The impact of such switchover has not been widely publicised or had few investigations. The influence of switching over to the new curve has automatic influence on measured dust levels and occupational exposure limits. In South Africa, the switchover to the new international harmonisation curve has already been incorporated into the new airborne pollutant guidelines of the Department of Minerals and Energy Affairs (DME) and mines have adopted the new respirable curve. Lack of information on the newly adopted curve has resulted in further confusions such as claims of 'increase' in measured dust levels due to the switch over.

This paper attempts to clarify the misgivings through a field study carried out in an underground coal mine. The results suggest that switching over to the new size-selective curve (ISO-CEN-ACGIH) using the locally made Higgins-Dewell type cyclone results in a decrease in measured dust levels by about 11% on average at the current compliance limit of 2 mg/m^3. It appears that this will have an influence on the analysed quartz content of the dust samples as the analytical methods depend on the particle size distribution of the collected dust samples. By switching over to the new harmonisation curve in gold mines would probably result in higher estimated quartz levels due to the collection of fine dust particles than heretofore using XRD or IR techniques.

1. Introduction

Dust sampling is pivotal in estimating the 'dose' of dust exposure and in deriving dose-response curves in epidemiological studies. Dose can be measured by dust sampling but it is not an accurate reflection of the "true dose." This indicates that the dose received by different groups of miners may not be completely characterised by their exposures. This can be attributed firstly, to a diverse mine work force in terms of race, gender, body size, and secondly, miner lung dose depends on breathing rate, particle size, solubility and mouth versus nose breathing.

After the research in the 1950s, it was accepted that dangerous particles are those with particle sizes smaller than 5.0 μm in diameter. This lead to the size-selective sampling curve widely known as British Medical Research Council (BMRC) curve or Johannesburg curve. These curves are actually lung penetration rates of dust particles that instruments attempt to replicate. Some of the recent scientific evidence concerning the hazard from very small particles argues that it may not be appropriate to ignore a specific effect of these on worker's health. Proposed international conventions for respirable size selective sampling (Soderholm, 1989, 1991) for international harmonisation to some extent precisely measures smaller particles than the BMRC curve. Therefore, adapting this curve and its impacts in South Africa are not known and are addressed in this paper.

2. Background

The primary purpose of dust sampling is therefore to characterise (with regard to mass and size) the environment of miners to evaluate their dust exposure. Other reasons include evaluating the effectiveness of engineering controls and changes in dust levels as a result of process changes, and finally as a measure of dose in epidemiological studies. The mass of respirable dust inhaled can be determined by sampling.

The measurement of dust in mines worldwide is usually carried out through various sampling instruments. The collected dust sample is expressed as a mass of dust (mg) per cubic meter (m^3) of air and generally referred to as "dust concentration" in the air. Over the years, various types of dust sampling instruments have been evolved so as the various size-selective sampling curves and the occupational exposure levels (OELs).

OELs provide the necessary guidance for planning, engineering, monitoring and controlling the hazard and work practices for effective control of exposure to substances. There are wide variations in the exposure limits as defined by regulatory and research authorities or scientific associations. The exposure limits set by regulatory authorities of countries worldwide need not be the same, and must not be compared directly with each other because of the differences in each country's exposure measurement, control and assessment strategies. Moving from one size-selective sampling to the other has some basic implications such as using OELs for compliance monitoring and dose-response estimation. Therefore, international harmonisation in dust sampling may avoid all confusions.

In principle, widely available different cyclones or dust samplers require to follow the specified size-selective sampling curves such as BMRC curve or the ACGIH curve or the new ISO/CEN/ACGIH curve. The performance of cyclones is typically described in terms of the 50% (or median) cut-point or D50. The median cut-point reflects the size of dust that the cyclone collects with 50% efficiency. The cut points are defined in relation to the particle penetration into the gas exchange region of the lung. The D50 of the BMRC Curve is 5 μm while the D50 of the new ISO/CEN/ACGIH curve is 4 μm (ACGIH, 1985, Soderholm, 1989, ACGIH 1999, ISO 1995, CEN, 1993). Figure 1 shows the two different size-selective curves that the dust samplers need to follow.

From the curve and as demonstrated below, we notice that a cyclone with a 5 μm cut-point will ideally collect higher mass of dust than that with a 4 μm cut-point:

$$M_{D50} = \rho \times \pi \times \frac{(D50)^3}{6} \qquad (1)$$

where,

M_{D50} = Mass of the dust particle (cut-point) in mg

ρ = Density of the dust particle in mg/m^3

D50 = Aerodynamic diameter of the cut-point in μm.

From the above equation (1), calculated mass of the quartz dust particle with cut-points of 5 μm and 4.0 μm are 0.000000173 mg and 0.000000088 mg respectively. Therefore, the respirable dust collected using different size selective curves will result in different dust masses. While the OEL is set in accordance with the specific size selective curve in mind, the comparison of measured dust mass collected using a different sampling curve and comparing it to the OEL would be incorrect. A study by Kenny et al., (1996) suggested that switching over to new size-selective curve using Higgins-Dewell type samplers would result in apparent decrease in measured levels by about 20 % on average.

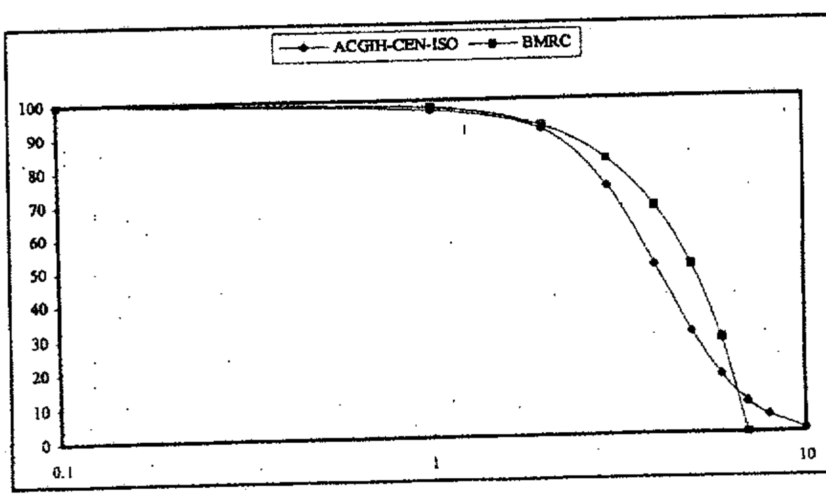

Figure 1: Respirable dust sampling or size-selective curves

3. Dust sampling

The paragraph and table below emphasise the importance of adhering to accepted sampling procedures for any given sampling instrument. In most of the South African underground mines, dust samplers (both mine operator and DME) were operated at 1.9 L/min in agreement with the BMRC respirable convention (BMRC, 1952). However, according to the new ISO/CEN/ACGIH respirable dust curve, the recommended flow rate of the dust samplers was 2.2 L/min (Kenny, Baldwin and Maynand, 1998). As a matter of interest, measurement of the size-selection characteristics of the South African cyclones confirmed that they are similar to the Higgins-Dewell designs commonly used in the UK and Europe, and hence for sampling according to the new ISO/CEN/ACGIH respirable convention with a 50% cut-point (D50) of 4 μm. Table 1 summarises the BMRC and ISO/CEN/ACGIH size-selective curves for dust sampling in mines.

BMRC Curve		ISO/CEN/ACGIH Curve	
Particle size μm	Particle mass %	Particle size μm	Particle mass %
0	100	0.1	100
1	98	1	97
2	92	2	91
3	82	3	74
4	68	4	50
5	50	5	30
6	28	6	17
7	0	7	9
		8	5
		10	1

Table 1. Size-selective curves.

The switch over to the international harmonisation curve has already been incorporated into the new airborne pollutant guidelines (SAMOHP, 2002) of the Department of Minerals and Energy Affairs (DME) and mines have adopted the new respirable curve. Lack of information on the newly adopted curve has resulted in further confusions such as claims of 'increase' in measured dust levels due to switch over.

4. Data collection

4.1 Dust Measurement

To date in South Africa, there is no scientific study either underground or in the laboratory on systematic comparison on quantifying the influence of switching over to the new international curve on measured dust levels. In this study, dust samples were collected replicating conditions encountered during the actual production shift using BMRC and ISO/CEN/ACGIH size-selective criteria. Personal and area dust samples were collected in a bord-and-pillar continuous minor (CM) section. The personal samplers were worn in the breathing zone and samples were collected at the section intake and nearest to the face area. The area samples were collected at the CM operator position, section intake and in the section return airway.

The objective of the study was to quantify the effect of switching over to new size-selective criteria on measured dust levels under dynamic conditions and its implications in dust exposure assessment.

4.2 Test samplers

For all tests, the locally manufactured and DME-approved 10 mm plastic cyclone (GME-G05) was used. The study involved a total of 5 shifts of measurements representing the actual underground production conditions. Out of the 21 pairs of samples, five pair-wise samples were rejected as one of the pumps of the pairs failed.

The dust-monitoring set-up contained two dust samplers, positioned side by side for personal (left and right lapel) and area sampling. Individual pair-wise SA cyclones were operated at 1.9 L/min and 2.2 L/min according to the BMRC and the new ACGIH/CEN/ISO size-selective curves respectively. The sampler operated at 2.2 L/min of air selectively collects the fraction of airborne respirable dust less than 10 μm particles on a pre-weighed filter disc. Similarly, the sampler operated at 1.9 L/min of air selectively collects the fraction of airborne respirable dust less than 7.0 μm particles on a pre-weighed filter disc. Filters from the samplers were weighed on an analytical electronic balance with readable 0.0001 mg. The procedure for determining the particulate mass was followed as per the DME guidelines (DME, 1997). Pumps were calibrated with 3-digits after the decimal using digital Gillibrator. The flow rates of the pumps were measured before and after the shift.

5. Results and discussions

From the underground measurements, a total of 16 pair-wise sample data was obtained. The data contained five personal sampling data and 11 area-sampling data. The flow rate data of the pumps before and after the shifts operating at 1.9 L/min and 2.2 L/min are summarised in Table 2.

From the analysis it was noted that the average measured flow rate using BMRC size-selective curve was 1.891 L/min. Similarly, the average measured flow rate using ISO-CEN-ACGIH size-selective curve was 2.202 L/min. The average sampling period for the pair wise sample data was 294 minutes representing the actual production shift. The measured dust levels using BMRC and ISO-CEN-ACGIH size selective curves is summarised in Table 3 and plotted in Figure 2.

Test #	Sample #	Flow Rate, Lpm Before	Flow Rate, Lpm After	Sampling Time Minutes
1	1	1.904	1.968	226
	2	2.201	2.187	226
	3	2.200	2.243	236
	4	1.904	1.907	236
	5	1.902	1.587	272
	6	2.206	2.195	272
2	7	2.201	2.187	347
	8	1.904	1.968	347
	9	2.200	2.010	348
	10	1.907	1.899	348
	11	1.902	1.587	360
	12	2.206	2.195	360
3	13	2.208	2.205	311
	14	1.906	1.906	311
	15	1.902	1.926	310
	16	2.206	2.223	310
	17	1.904	1.906	310
	18	2.204	2.211	310
4	19	2.205	2.211	361
	20	1.906	1.906	361
	21	1.903	1.926	361
	22	2.205	2.223	361
	23	2.200	2.208	340
	24	1.906	1.906	340
5	25	2.200	2.222	236
	26	1.906	1.929	236
	27	2.204	2.242	222
	28	1.904	1.925	222
	29	1.903	1.883	236
	30	2.205	2.239	236
	31	2.208	2.212	224
	32	1.906	1.904	224

Table 2. Pump Flow Rate Data Before and After Sampling.

Sample	Ratio of BMRC and ISO/CEN/ACGIH Dust Level
Personal	1.1102
Area	1.1055
Area	1.3233
Personal	1.3136
Area	1.0443
Area	1.2258
Personal	1.0666
Area	0.9979
Area	1.1635
Personal	1.2282
Area	1.4287
Area	1.1016
Personal	1.2503
Area	1.4575
Area	1.1231
Area	1.0255

Table 3. Ratio of measured dust levels using two size-selective curves.

From the results it was noted that when the cyclone operated in accordance with the BMRC curve, the average measured dust level for the sampling period was 5.323 mg/m³ (16 samples). Similarly, when the cyclone operated in accordance with the new ISO/CEN/ACGIH curve, the average measured dust level for the sampling period was 4.604 mg/m³ (16 samples).Personal dust samples were contaminated due to stone dusting in the section.

Overall, from the underground measurements, it was noted that by switching over to the new size-selective criteria, there is a 13.5% reduction in measured dust values. Statistical analysis on the pair-wise data indicates that there is a significant difference ($p=0.001$) between the measured dust levels between the two size-selective criteria. From the linear regression plot of the data, it can be inferred that there is a reduction in measured respirable dust levels by approximately 11.47 % at the current coal dust compliance limit.

6. Conclusions

The underground study has demonstrated that by switching over to the new ACGIH/ISO/CEN size-selective curve from the old BMRC curve would result in the reduction in measured respirable coal dust levels by approximately 11.47% at the current compliance limit of 2 mg/m³.

The impact of the 'switch over' on occupational exposure limit (OEL) values needs to be addressed in detail with all the relevant stakeholders. It appears that this will have an influence on the analysed quartz content of the dust samples in gold mines as the analytical methods depend on the particle size distribution of the dust. By switching over to the new harmonisation curve in gold mines would probably result in higher estimated quartz levels due to the collection of fine dust particles than heretofore and analysing using XRD or IR techniques. A systematic comparative study in gold mines may give clear indications on the measured silica levels by switching over to the international harmonisation respirable curve. Finally, the paper reminds the careful handling of dust exposure data in deriving the 'dose' for the dose-response studies in future and compliance determination.

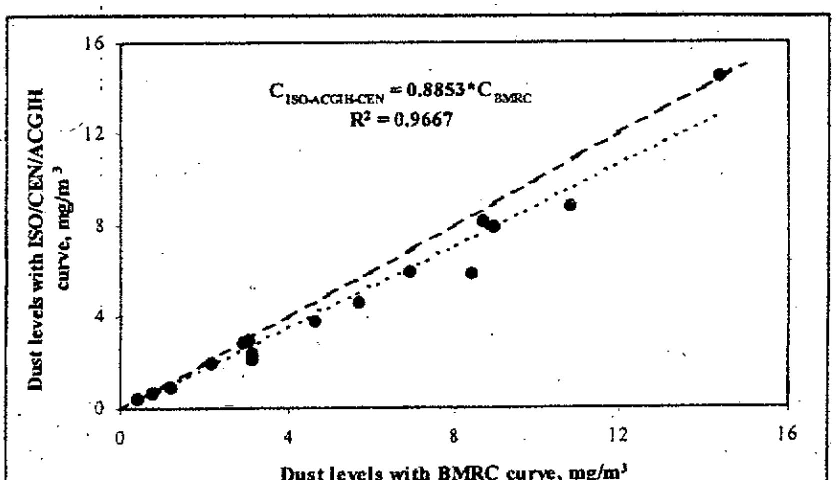

Figure 2. Relationship between measured dust levels using BMRC and ISO/CEN/ACGIH respirable curves.

7. Acknowledgements

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