A Comparative Investigation Into The Characteristics of Different Coal Dusts Generated via Pulverization and A Laboratory-scale Wind Tunnel

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Background

- Mining operations, metal extraction processes, and wind erosion all contribute to the generation of airborne respirable mine dust (ARMD).
- Prolonged coal mine dust inhalation prompts the development of respiratory diseases like black lung, silicosismassive fibrosis from respirable and inhalable PM2.5 and PM10 particles respectively[1, 2].
- Since 2000, a prevalence of pneumoconiosis in mine workers has been reported despite the improved dust suppression control[1].
- Coal dust particles toxicity lies in the complex coal composition; a mixture of varying fraction of organic and inorganic matter with embedded minerals and trace elements.[3]
- Toxicity research suggests that physicochemical characteristics of ARMD like mineralogy and particle size influence pulmonary toxicity of inhaled dust[4].

Objectives

- Analyze the characteristics of coal dust particles suspended in a wind tunnel.
- Compare obtained results against the characteristics of coal dust-sized particles generated via pulverization of same sample.

Hypothesis

The physicochemical properties of coal dust-sized particles generated by pulverization vary from those of coal dust suspended in a wind tunnel. Different methods of dust generation results in ARMD of different particle morphology and minerology

Experimental Programme

1. Collection of suspended coal samples from the wind tunnel.

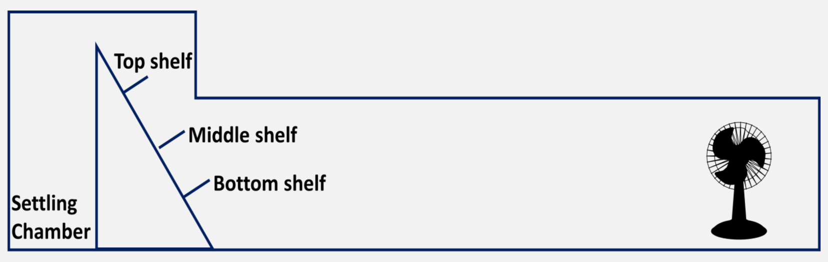


Fig. 1:Wind tunnel schematic showing different sampling sites

2. XRF for element concentration analysis
3. Laser diffraction for particle size distribution(PSD)
4. QEMSCAN for mineralogy and particle morphology
5. Ash Analysis to determine coal content

Fig. 2: QEMSCAN and sample blocks.

Results

Particle Size

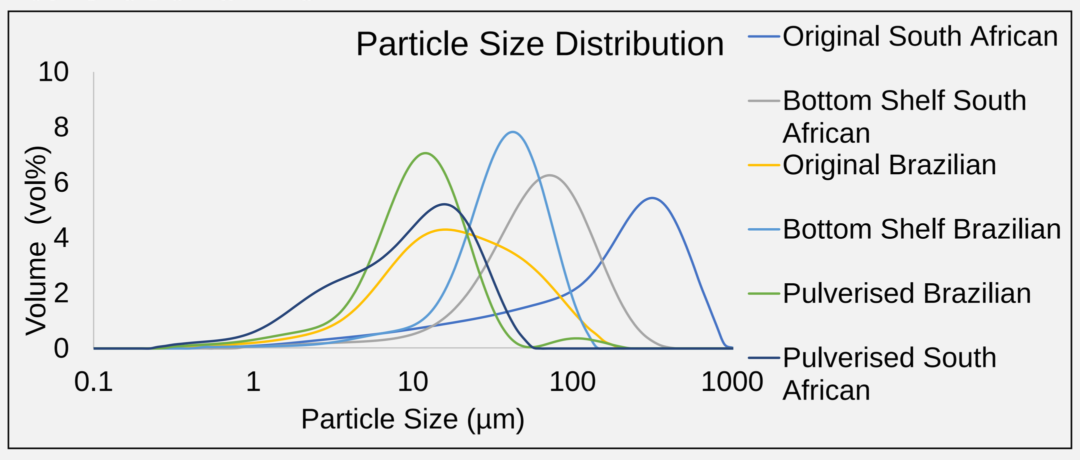


Fig.3: Particle size distribution (PSD) of the in volumetric basis obtained from Malvern Mastersizer

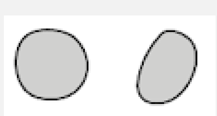
- Pulverized samples have increased fine particles.
- Bottom shelf has intermediate size range between original and pulverized particles.

Tab.1: Cumulative percentage of from number distribution of particles below particle matter below 1, 2.5 and 10 µm as PM1, PM2 and PM10 respectively.

Sample	PM1	PM2.5	PM10
South African Coal Sample			
Original	65.12	94.81	99.82
Bottom Shelf	43.51	92.17	99.37
Pulverized	91,44	98.19	99.91
Brazilian Coal Sample			
Original	89.98	97.86	99.89
Bottom Shelf	88.70	97.74	99.76
Pulverized	91.97	98.90	99.97

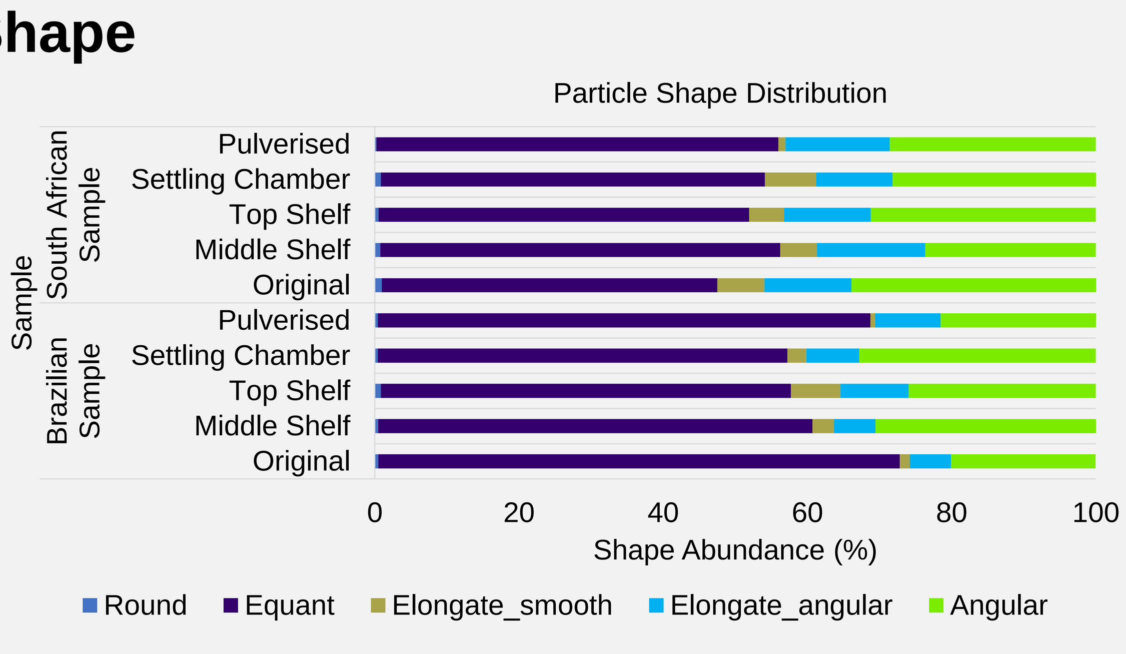
- The bottom shelf and original South African samples have the lowest PM1 particles.
- Pulverized sample has more than 90% respirable PM1 for all samples.

Particle Shape

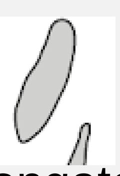


Round

Equant



Angular



Elongated

Fig. 4: Particle shape profile of the coal dust sized particles from QEMSCAN using roundness and aspect ration.

Results

- Equant and angular are the dominant particle shapes.
- In each shape class less than 10% difference occurs for suspended dust and pulverized particles.

Mineral Liberation

- Brazilian sample: Clay liberation in wind tunnel samples increases as distance from wind source increases but decreases with pyrite
- SA sample: High clay liberation, liberation of minerals across samples vary slightly (±4%).

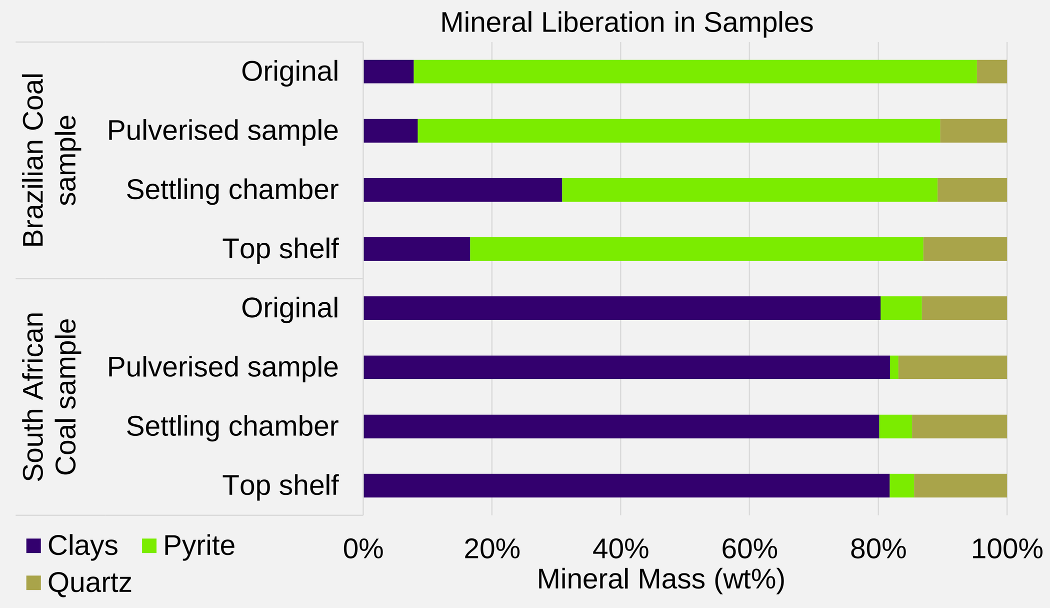
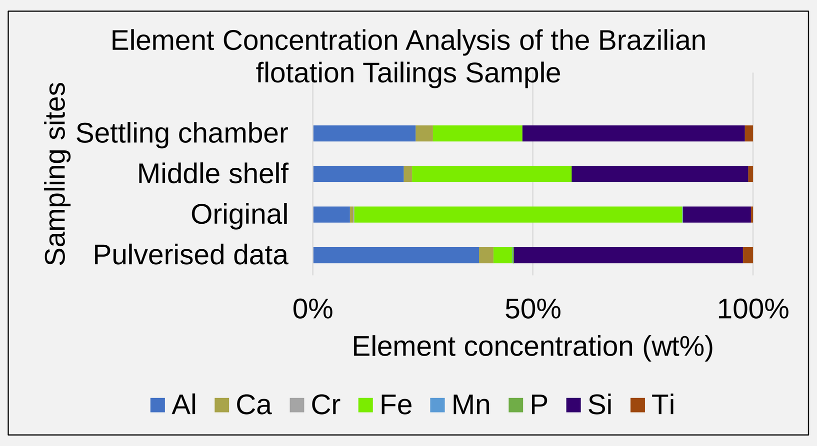


Fig. 5: Common mineral phases in dust samples

Element Concentration



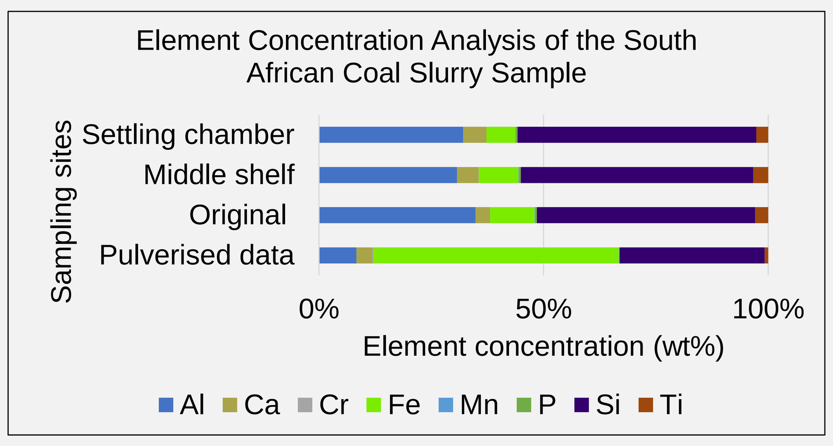


Fig. 6:Element of health interest concentration profiles for the SA and Brazilian coal dust samples

Brazilian sample: Pulverized sample has increased Aluminum (Al) and Silicon (Si) concentration compared to wind tunnel samples.

- Iron (Fe) concentration decreases of sampling sites up the wind tunnel ramp and in pulverized sample.
- The element distribution of the wind tunnel samples is different to original sample.

South African sample:

- High Fe content and decreased Al and Si in pulverized sample relative to wind tunnel samples
- Wind tunnel samples have element concentration profile similar to the original sample
- **Confidence in results**: Low, RMSE>0.5
Sample quantity limitation

Discussion

- PSD in wind tunnel is a multi-dependent variable, can be influenced by fan wind speed, venturi effect on wind-flow and the difference in density of common mineral phases in particle size range.
- Impact and particle attrition during sample pulverization as a result of sieving and screening leads to an increase in the fraction of fine particles.
- The wind tunnel suspends fine particles in the original sample, leading to less dense and smaller particles settling at a lower rate and depositing further in the wind tunnel ramp.
- Differences in element profiles are as a result of the differences in particle fractionation in samples
- There is solid-to-solid induced fractionation during pulverisation and low energy abrasion solid-to-fluid interaction during dust suspension
- Modification of mineralogy via ash analysis reduces the confidence in mineral composition results.
- Low confidence in shape distribution from challenges experienced during QEMSCAN sample preparation.

Conclusions

- The characteristics of dust particles generated via pulverization are different to dust particles that have been suspended in a wind tunnel.
- Mineral profile of dust particles are proposed to be different as a result of different dust generation techniques impact on ARMD characteristics.

Recommendations

- Retrofit wind tunnel set-up to generate adequate dust quantity for analysis.
- Repeat the experiments to increase accuracy of and confidence in the results.

References

1. Moreno et al. (2019). Trace element for fractionation between PM10 and PM2.5 in coal mine dust: Implications for occupational respiratory health.
2. Laney et al. (2010).Pneumoconiosis Among Underground Bituminous Coal Miners in the United States: Is Silicosis Becoming More Frequent?. Occupational and Environmental Medicine, Volume 67, pp. 652-656.
3. Dalal, N. S. et al., 1995. Hydroxyl Radical Generation By Coal Mine Dust: Possible Implication To Coal Workers' Pneumoconiosis (CWP). Free Radical Biology & Medicine, 18(1), pp. 11-20.
4. Huang and Finkelman. (2008). Understanding the Chemical Properties of Macerals and Minerals in Coal and its Potential Application for Occupational Lung Disease Prevention. Journal of Toxicology and Environmental Health