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The era of ESG consciousness and its effects on coal handling and processing plants

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Abstract. The emphasis on Environmental, Social, and Governance (ESG) criteria is reshaping Coal Handling and Processing Plants (CHPPs). This paper examines the impact of ESG on coal processing, focusing on innovative practices for sustainability and efficiency. A key focus area is the reprocessing of old coal dumps, which has emerged as a crucial strategy for minimizing environmental impact and maximizing resource utilization. Another critical aspect discussed is the improvement of medium consumption and the associated advantages. The choice of materials for constructing process equipment has also evolved under the influence of ESG considerations. There is a growing trend towards using materials that offer greater durability and corrosion resistance, thereby extending equipment life and reducing the frequency of replacements. The discussed practices and technologies not only contribute to environmental stewardship but also enhance the economic viability of coal processing in an increasingly ESG-conscious era.

1 Introduction

It is widely considered that a 2004 UN report entitled *Who Cares Wins*, was the first to officially mention that environmental, social and governance (ESG) factors should be included in capital allocation and business management processes [1]. The ESG framework is used globally to measure and assess a company's impact and sustainability for future generations [2]. The typical factors considered in the three pillars of ESG are highlighted in the following schematic

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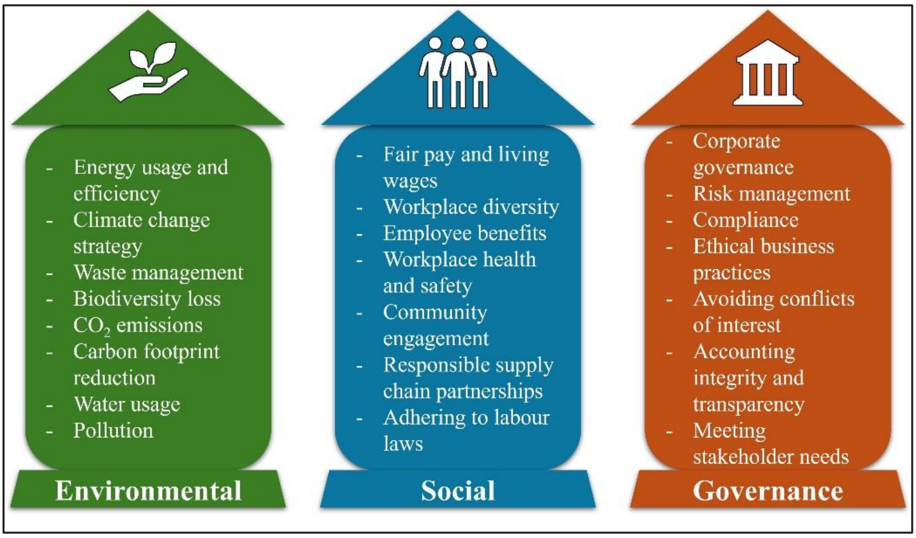

Fig. 1. Typical factors considered in ESG (adapted from [2] and [3])

ESG considerations stretch much further than just additional expenses on a mine's income statement, however. Compliance with ESG standards can now be considered a way to potentially create business value. The growing emphasis on adhering to ESG criteria, coupled with political initiatives aimed at reducing coal dependency in various regions, is diminishing the appeal of new mining ventures. Additionally, securing funding for coal-related projects is becoming more difficult as financial institutions prioritize decarbonizing their investment portfolios [4]. Since The Paris Agreement on climate change was reached in 2015, more than 40 countries have set target years for phasing out coal power [5]. The following is a summary of some of the major events in terms of phasing out coal that have happened since The Paris Agreement:

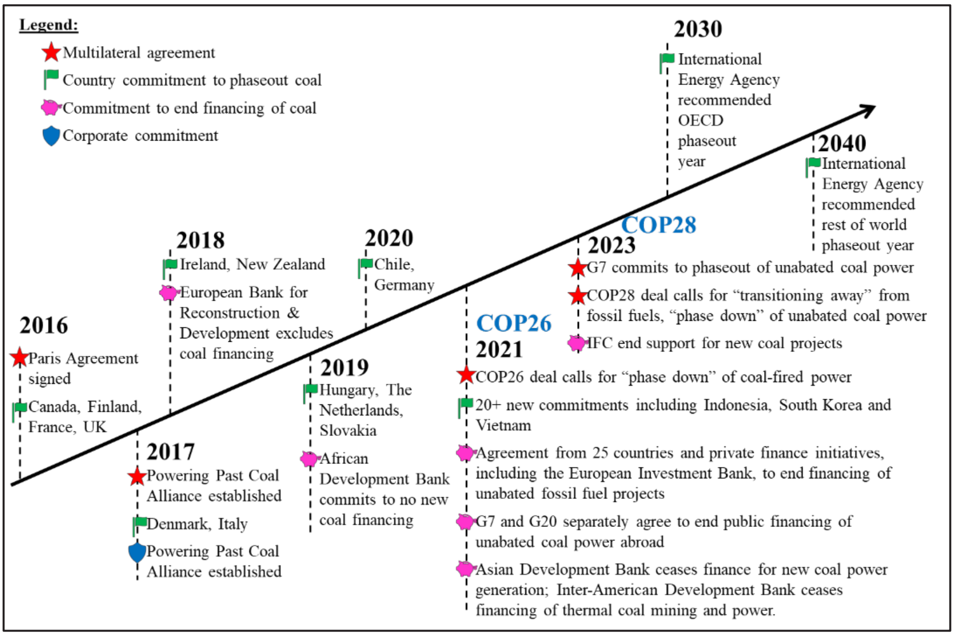

Fig. 2. Coal phaseout commitments [5]

Despite all these challenges along with diminishing raw coal qualities, the proportion of coal in global power generation has seen only a modest decline since The Paris Agreement, dropping from 39% in 2015 to 36% in 2022, as reported by S&P Global Commodity Insights [5]. The coal fraternity has proven itself to be resilient and to have a pioneering spirit time and time again. The following are examples of how the mining industry successfully addressed the increasing ESG requirements.

2 Reprocessing of old coal dumps

An inevitable truth of mining and processing coal is the fact that there will be the generation of discarded material. Over the years, the accumulation of these so-called discard dumps is of a substantial volume [6]. In 2013, Belaid et al. [7] already reported that the amount of discard coal stockpiled in South Africa is more than 1.5 billion tons in total, with approximately 60 million tons added annually. This discard coal signifies not only a loss of potential energy resources but also poses an environmental hazard, as the stockpiles can sometimes ignite spontaneously. From a survey conducted by the South African Department of Minerals and Energy in 2001, the typical qualities of these discard dumps were quantified:

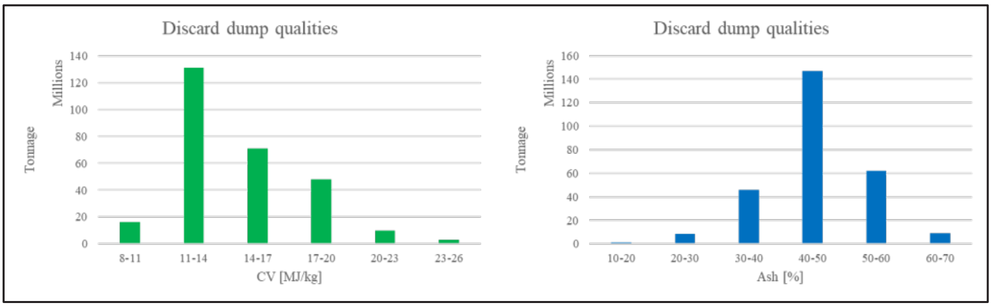

Fig. 3. Distribution of discard dump qualities in South Africa [8]

The International Organization for Standardization (ISO) highest "ash category" for coal falls between 30% and 50% [11]. As can be seen from these graphs, coal discard dumps in South Africa still contain large amounts of usable coal. By recycling these discard dumps, companies are able to generate additional revenue streams from resources that were previously perceived as waste. Besides the obvious benefit to the company's bottom line, these practices also have a positive environmental and social effect.

On the environmental front, the advantages include the reduction of the overall carbon footprint of processing coal and reducing the site's physical discard footprint. Furthermore, the re-deposition of the "new" discard can be done more safely, requiring a reduced footprint and using the most up-to-date deposition methods, which should render the facilities more environmentally friendly. The associated social benefits of treating coal discard dumps and dams can possibly include the provision of potable water to the surrounding communities via the site's water treatment facilities, creating job opportunities, potentially freeing land for agricultural developments, and creating opportunities for communities to share in a resource [9].

Although the treatment of some coal discard dumps may appear to be commercially attractive, due diligence is required to ensure that the specific dump material under consideration is amenable to be able to produce a coal product at a yield that is commercially viable and at a product quality that the market will accept. Many such studies have been conducted in the past which resulted in successful coal processing plants. Various float-and-sink tests conducted on these discard dumps produced washability[1] data that indicated that although the resources are difficult to wash by means of most gravity methods, dense medium cyclones could be incorporated to make an economically viable business case [10]. As an example, the following washability data (generated from a sample taken at a discard dump in the Witbank coalfields) indicates that it is theoretically possible to wash this material with a raw quality of 43% ash, to a 26.5% ash by cutting at a density of 1.7t/m^3 and achieving a product yield in the order of 44%.

[1] Coal washability is the determination of the theoretical parameters for the removal of mineral inclusions from coal by beneficiation practices that effect separation based on specific gravity [10].

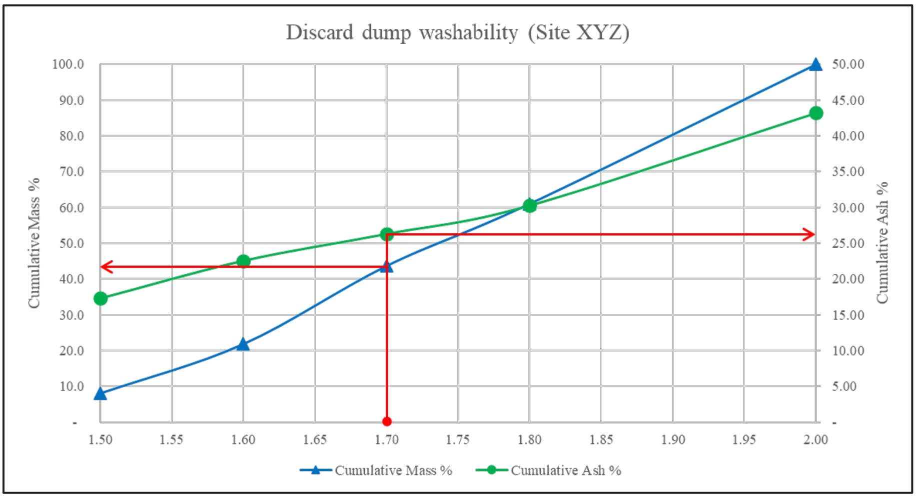

Fig. 4. Washability data of a discard dump in the Witbank coalfields [10].

It is worthwhile to also mention, however, that the near gravity material (±0.1 density points) at this specific cut density is in the order of about 40%, which will require accurate process control with a Dense Medium Separation (DMS) technology that can separate at very specific cut densities. The following are product qualities and yields collected from a Coal Handling and Processing Plant (CHPP) just outside the town of Middelburg in the Witbank coalfields, rewashing coal discard using a Tri-Flo separator:

Table 1. Qualities and yields of a discard washing plant.

Date of sample	Feed CV [MJ/kg]	Product CV [MJ/kg]	Product Yield [%]	D_{50} cut density [kg/cm^3]
04 Feb'19	14.39	22.55	37.41	1.77
11 Feb'19	14.39	23.35	6.57	1.45
18 Feb'19	14.77	22.50	54.87	>1.8
25 Feb'19	13.42	22.49	32.80	1.65
04 Mar'19	16.93	22.63	57.52	1.72
11 Mar'19	14.22	22.18	35.39	1.78
18 Mar'19	16.90	21.90	68.00	>1.8

Although the feed quality is relatively consistent, the washability is extremely variable, and the variation in yield and required cut densities requires a process design capable of handling these variations. This includes making provision for an adequate screen drainage area and a medium circuit capable of operating within these large density fluctuations via the incorporation of a properly designed densification circuit that is capable of handling various magnetic loadings while minimizing medium losses.

The following is a simplified schematic of this specific plant's process flow diagram:

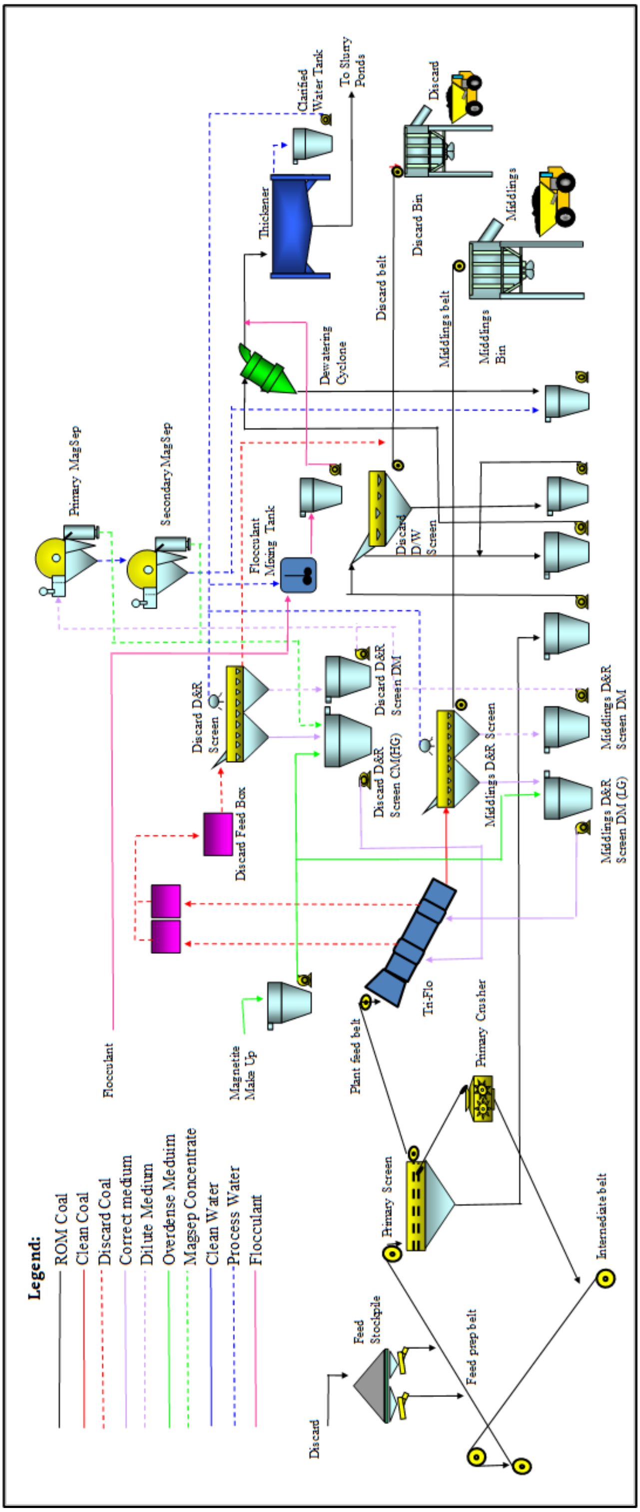

Fig. 5. Simplified PFD of a CHPP in the Witbank coalfields washing discard material by means of a Tri-flo separator.

The plant was originally designed to produce both a low ash (for export) and high ash product (for local power generation) with the Tri-flo separator, but since the plant started washing discard material, they combined the middlings product with the discard stream. By washing previously discarded material (since the availability of virgin coal is diminishing), the site was able to extend the expected life of the operation, continue to generate revenue, and secure the jobs of the operators on site.

3 Reduction of medium consumption

Sripriya et al. report that 10-20% of the total operating cost of a conventional dense medium CHPP can be ascribed to medium costs [12]. The typical industry standard for magnetite consumption for South African CHPPs is to use less than 1kg of magnetite per ton of ore fed to the plant. Below is a typical conventional DMS process flow diagram indicating how Magnetite is recovered in a CHPP.

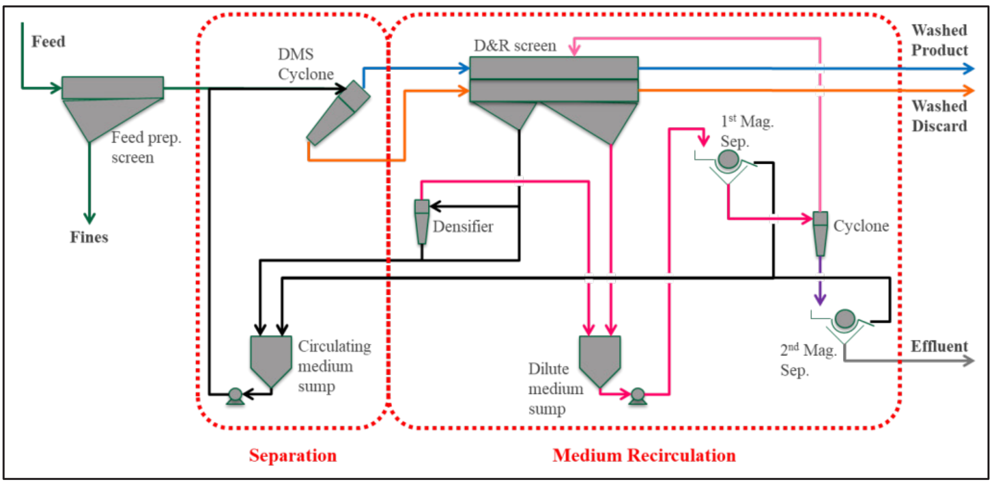

Fig. 6. Typical medium recovery circuit in a conventional CHPP.

In 1995, Napier-Munn et al. reported that there are mainly two routes through which medium gets lost in a DMS circuit [13]. These losses can be ascribed to magnetite particles still adhering to ore particles after the drain-and-rinse screens or the inefficient operation of magnetic separators, which causes magnetite loss from the process via the effluent streams. A third possible method of losing magnetite in a CHPP is through spillages and leaks. In fact, Kumar et al. state that the single largest potential for magnetite losses is from leaks, spills, and the magnetic content of effluent leaving the circuit [18].

The required volume of water to effectively rinse off the magnetite particles from the product and discard on the drain-and-rinse screens is a function of the size distribution of the material. Since smaller particles have a higher total surface area than bigger particles, more rinse water is required for drain-and-rinse screens for fine particle size distribution (PSD) applications. The following graph can be used as a reference. Care should be taken that the dilute medium circuit is designed to handle this water requirement.

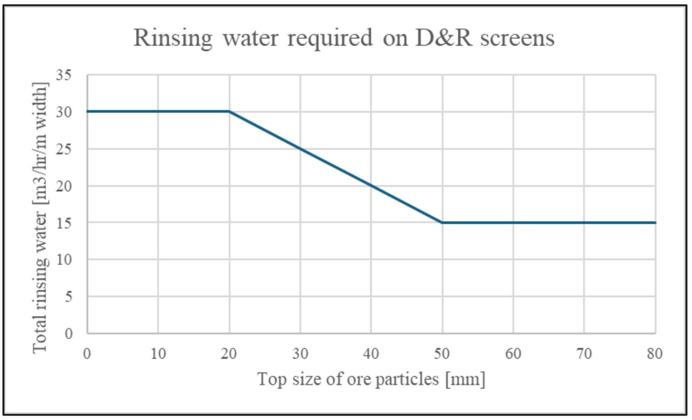

Fig. 7. Reference graph for volume of rinse water on a Drain-and-Rinse (D&R) screen (adapted from [14]).

It is further of utmost importance that the water spray profile forms a continuous curtain of water over the width of the screen. This will ensure that all the ore particles travelling over the length of the screen have an opportunity to be rinsed off. The following photograph indicates that other operational aspects like missing, or blocked spray nozzles and bed depth will also influence the ability of the water sprays to efficiently rinse off magnetite particles.

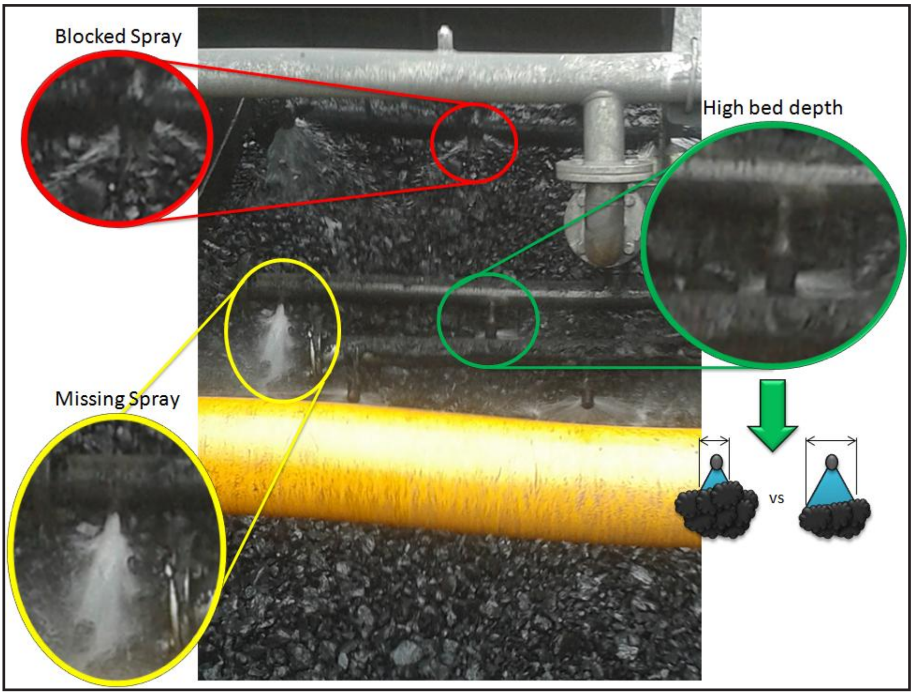

Fig. 8. Rinsing inefficiencies on a D&R screen.

Medium losses via the effluent of magnetic separators account for 20% – 40% of the total medium consumption in a CHPP [12]. The most prominent feed parameters to a wet drum magnetic separator that influence the machine's ability to recover magnetite efficiently include:

- Magnetic separator feed slurry density.
- Magnetic separator feed particle size distribution.
- Magnetics to non-magnetics ratio.
- Magnetic separator feed distribution into the machine.

By ensuring that the plant has the right wet drum magnetic separator installed that complies with all the requirements, it is reported that efficiencies exceeding 99.9% can be achieved [12]. As an example, the following graph plots the % magnetite recovery as a function of % magnetite in the feed to the wet drum magnetic separator, based on empirical data. This illustrates that a balance needs to be achieved between the amount of water used on the drain and rinse screen and the amount of magnetite carried over into the dilute circuit.

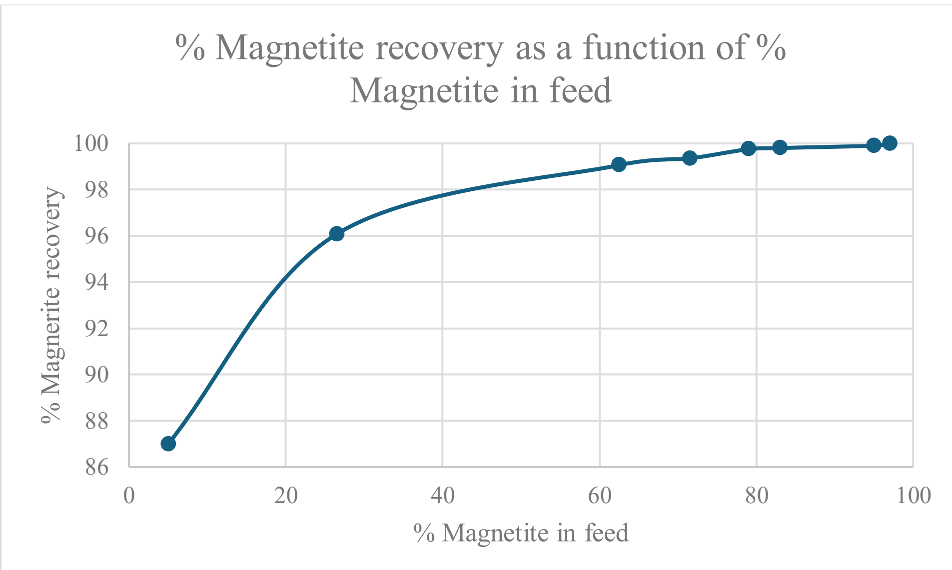

Fig. 9. Empirical data showcasing % Magnetite recovered as a function of % Magnetite in the feed to a wet drum magnetic separator [12].

It is not uncommon for conventional CHPPs to report magnetite consumption values in the order of 0.4kg/t. That is a 60% improvement from the 1kg/t convention. Considering that magnetite consumption can contribute up to 20% of the plant's operating costs, one can cut these costs by more than 10% by giving the required attention to the D&R screens and magnetic separators. Not only does this reflect on the plant's income statement, but it will also contribute to a smaller carbon footprint due to a lower magnetite demand.

4 Choice of materials of construction

When it comes to the selection of the material of construction (MOC) for a specific piece of equipment, the humble cyclone which is at the heart of plenty CHPPs comes to mind. Cyclones can be manufactured from many different materials both mundane and exotic, but the two most common in the DMS application are high Chrome cast iron and Alumina ceramic lined, mild steel units. Bookless [15] mentions that for a DMC to function as a usable piece of equipment, the cyclone's MOC must possess certain properties. It must be:

- Chemically inert to the material it treats.

- Dimensionally stable such that the cyclone exhibits near-constant geometry.
- Economically viable in terms of both capital and operating costs.
- Resistant to wear by the treated material as far as is practically possible.
- Easily maintained.

Based on these properties, other materials that surfaced as MOCs for cyclones include Tungsten Carbide, Silicon Carbide and Zirconium Oxide. Bookless also mentions further that the primary factor that determines the selection of a MOC above all others is the component's life cycle cost, which takes into consideration factors such as purchase cost, lifespan, and replacement expenses. While there are highly wear-resistant materials available that can reduce operating costs, their higher capital cost often makes them impractical for certain applications.

In some instances, there may be no viable alternative but to bear the higher initial expense. Cheaper materials may offer lower upfront costs, but the ongoing expense and inconvenience of frequent replacement make them unsuitable, not to mention the degradation in performance resulting from the progressive changes in cyclone geometry. Unfortunately, this latter factor is often overlooked when calculating the life cycle cost. The following graph, produced by M.F. Ashby [16], illustrates the normalised wear rate versus hardness for various engineering materials. A high k_a value represents rapid wear at a given bearing pressure.

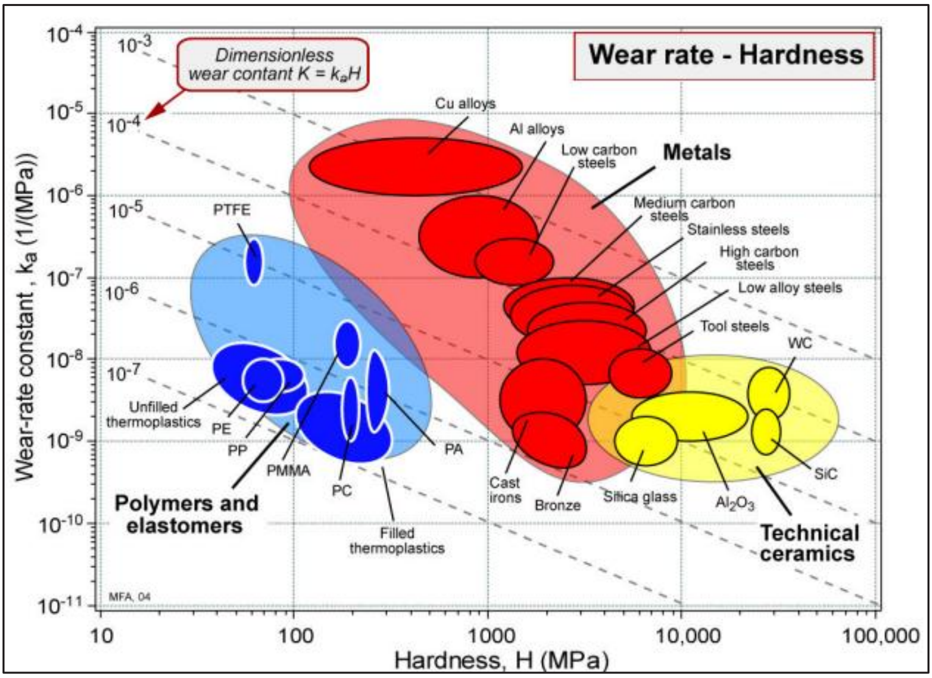

Fig. 10. The wear rate constant of various engineering materials plotted against the relevant hardness [16].

It is worth noting that a poorly performing cyclone due to excessive wear can swiftly result in the loss of valuable product, which far surpasses the original purchase cost in both value and speed [17]. It is therefore of utmost importance that the decision on the cyclone's MOC is not taken lightly. Although a ceramic-lined cyclone has the advantage of being refurbished to an "as new" condition at a fraction of the original cost, these cyclones tend to struggle when there are tramp metal (like Continuous Miner (CM) picks) present in the feed to the cyclone. For these applications, besides upfront metal removal from the plant feed, a high-Chrome cast iron unit may be more suitable since they are not prone to catastrophic failures associated with the likes of tramp metal in the feed. The selection of a cyclone's MOC can be further optimised with the selection of different MOCs for the different parts of a cyclone, tailored to the specific wear rates experienced across the cyclone in the specific plant.

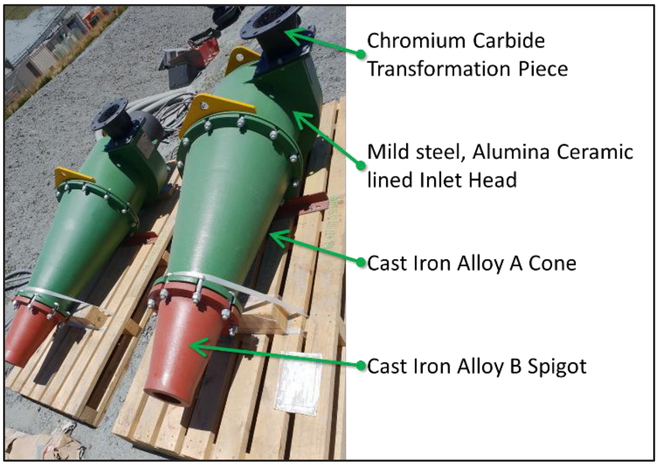

Fig. 11. Example of a customized hybrid cyclone with different MOCs.

One of the advantages of a customized, hybrid cyclone is the fact that one can reduce cyclone maintenance down times and increase the cyclone's lifecycle by selecting a MOC that addresses the specific mechanism of wear for the different parts of the cyclone the best. This option maximizes the life expectancy of each part of the cyclone until replacement and therefore reduces material wastage, which in turn impacts on the ESG objectives.

Care should also be taken not to settle for any MOC just because of its classification. As an example, one can consider the impact of using standard Alumina ceramic tiles versus Engineered Alumina ceramic tiles. The chamfered engineered tiles might be slightly more expensive, but the advantage is only realised over the life of the cyclone. The following schematic illustrates one of the advantages of using engineered tiles over standard tiles.

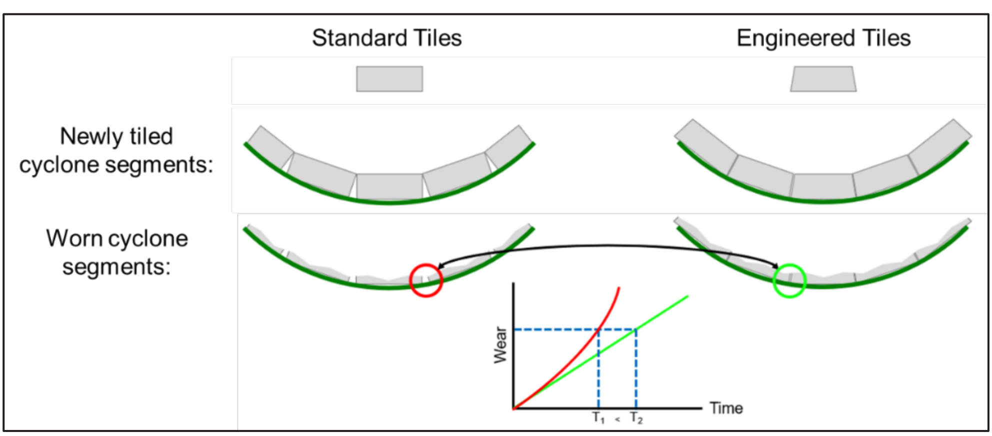

Fig. 12. Schematic indicating the mechanism of wear on both standard and engineered tiles.

When it comes to engineered tiles, the complete tile layout is designed using CAD, before manufacture, and only then are the tiles cast and fired. Each cyclone has a specific set of tiles where each tile has a set place in the cyclone. The advantage of the engineered tiles is that they tend to have a more consistent wear rate over the life of the tile as compared to standard tiles. This relates then to a longer expected wear life for the tiled section under consideration. In some cases, it has been reported that non-engineered tiles have shown wear lives of only 50% of engineered tiles and that engineered tiles deliver the most consistent operational results [15]. This feat brings along the additional advantage that cyclone maintenance can be planned better due to more accurate forecasts.

Overall, selecting the right MOC for a cyclone operating in a CHPP ensures improved durability, enhanced separation efficiency and reduced maintenance costs. This reduces downtime and increases the availability of the plant for continuous operation, resulting in improved productivity and profitability. Furthermore, since the cyclone's service life is prolonged, the frequency of replacement and associated waste generation is also reduced.

5 Conclusion

Coal remains a major fuel source globally for electricity generation and for metallurgical applications. It is also noteworthy to consider the growth seen in recent years for the top coal producing countries like China, India and Indonesia.

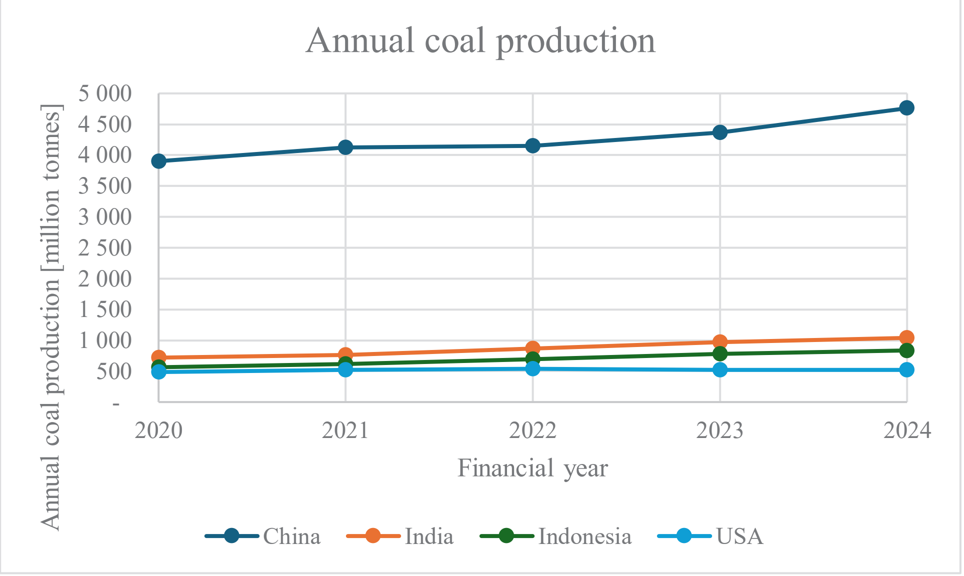

Fig. 13. Annual coal production of the top 4 coal-producing countries (adapted from [19 - 22]).

Although coal might be seen as a fuel of the past, it is also clear to see that coal processing will continue for the foreseeable future. Recent developments in ESG compliance forced the coal fraternity, however, to reconsider the footprint and legacy that is left behind for future generations and the communities we operate in. This paper discusses only a few aspects of how CHPPs can address ESG requirements.

In recent years, there has been a major emergence of sites starting to rewash previously discarded material, specifically in South Africa. Not only does this add an additional revenue stream, but it also reduces the operation’s tailings footprint and provides job security for thousands of households. Another relatively easy method to reduce a plant's carbon footprint and make it more profitable is to give attention to the reduction of magnetite consumption. The last aspect that was discussed in this paper was the various options available when it came to the selection of materials of construction for mineral processing equipment.

The link between a well-designed dense medium process and separation vessel and that of ESG has been illustrated in this paper, and although these are not the only measures CHPPs can take to address their ESG responsibilities, it focuses on some of the most straightforward applications to be considered.

The coal fraternity has always had a pioneering spirit and has been at the forefront of innovations and developments that have benefited the entire mineral processing industry. The era of ESG consciousness and its effects on CHPPs will yet again serve as motivation for more of these innovations.

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