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REDEFINING RESOURCES

WHITE PAPER

Air Pollution in the Mining Sector: Sources to Solution

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Introduction

The mining industry is the backbone of the manufacturing and infrastructure industry and is a significant polluting industry. In the coming years, demand for metals and non-metals will increase significantly due to the transition to greener technologies in the energy sector and infrastructure expansion due to a growing population. Sustainability Reporting in the Mining Sector, published by the UNEP, indicated that the global extraction of minerals increased three folds from 1970 to 2017 and is expected to increase from 79 Giga tons in 2011 to 167 Giga tons in 2060.

India is a major producer of crucial minerals with 3527 mine leases for 40 major minerals covering an area of approx 3,15,986 hectares and total mineral production valued at 1,299,500 million in 2020.

An ore is defined as a natural rock or sediment deposit that contains minerals in concentrated form. Mining is the extraction of mineral deposits from the earth's surface and subsurface from ore. Ores with higher Ore Grades have a more concentrated presence of the desired minerals. For example, magnetite is the finest ore for iron extraction, with total iron content ranging from 68-71%.

Quarrying, a term interchangeably used with mining, is primarily associated with surface mining operations like open-pit, opencast mines, and excavation of shallow deposits. It is primarily used to extract construction materials like sand and gravel.

Different mining methods are used for the extraction of minerals. Surface, underground, Placer, and In-Situ mining are commonly used methods. The primary considerations when selecting an appropriate mining method are the mineral's location, the deposit's financial value, environmental considerations, and chemical composition. The best mining method for extracting a particular mineral is the one that presents the cheapest problems.

The production of 1 tonne of copper results in 110 tons of tailings (waste ore) and 200 tonnes of waste rocks. This leads to the generation of a significant amount of waste from the mining industry in the form of waste rocks, overburden, tailings, slag, wastewater and sludge, and gaseous wastes from various processing processes.

Air Pollution in the mining industry

Mining is a polluting industry that significantly pollutes the land, water, air, and soil, leading to biodiversity loss and global greenhouse gas emissions, thus driving climate change.

Major air pollutants in the mining industry include dust in the form of particulate matter and gases from various processes like calcination, roasting, and smelting. Dust is regarded as the most significant air pollutant in the mining industry, released from several sources and mechanisms such as land clearing, removal of topsoil (during the opening of new mines), removal of ore body/ore, drilling, blasting, crushing, and screening. Processing ore, loading, and unloading material on site and subsequent transport off sites also contribute heavily to air pollution. In addition, wind action affecting stockpiles, dry tailings, exposed mining areas, and waste dumps generates significant amounts of toxic dust contaminated with heavy metals.

A Preliminary review of mine air pollution in Zambia, South Africa, a place endowed with mineral wealth, states that the main identified air pollutants were SO2 and particulate matter in the Copperbelt region. The main source of these pollutants was flue gas from smelter operations and dust within the mines, and those blown from operational and abandoned waste rocks tailing dump sites.

In 2000, the Air Pollution Information Network for Africa (APINA) conducted a study to ascertain the levels of air pollution in Zambia. This study showed that the highest total emissions in Zambia were PM10 emissions which recorded 406.8 kilotonnes/year (kt/yr) and accounted for 35% of the total emissions that year. This was followed by SO2, which recorded 359.6 kt/yr, accounting for 31%, while PM2.5, NH3, and NOx were at 252.7 kt/yr, 75.8 kt/yr, and 72.8 kt/yr, respectively. The main source of SO2 pollution from the Zambian mines is the roasting and refining of copper-bearing sulfide ores, chalcopyrite (CuFeS2), primarily due to old inefficient smelting operations.

$$2CuFeS_2+2SiO_2+4O_2 \longrightarrow Cu_2S+2FeSiO_3+3SO_2$$

$$2CuFeS_2+3O_2 \longrightarrow 2CuS+2FeO+2SO_2$$

$$Cu_2S+O_2 \longrightarrow 2Cu+SO_2$$

The air in the mines can be contaminated by gases such as NOx, SOx, methane, hydrogen sulfide, carbon monoxide, and excess carbon dioxide. Due to the lack of ventilation and the confined nature of mines, gases build up. These gases create a combustible, explosive, and toxic environment within the mines. These gases are often referred to as Mine Damps. Several mine damps are responsible for creating this toxic atmosphere - some major types are fired damp, black damp, white damp, and stink damp.

Firedamp

CH_4

Methane

- Colorless
- Odorless
- Explosive

Whitedamp

CO

Carbon Monoxide

- Colorless
- Odorless
- Explosive / Toxic

Blackdamp

CO_2

Carbon Dioxide

- Colorless
- Slight Acrid Smell
- Toxic

Stinkdamp

H_2S

Hydrogen Sulfide

- Colorless
- Rotten Egg Smell
- Explosive / Toxic

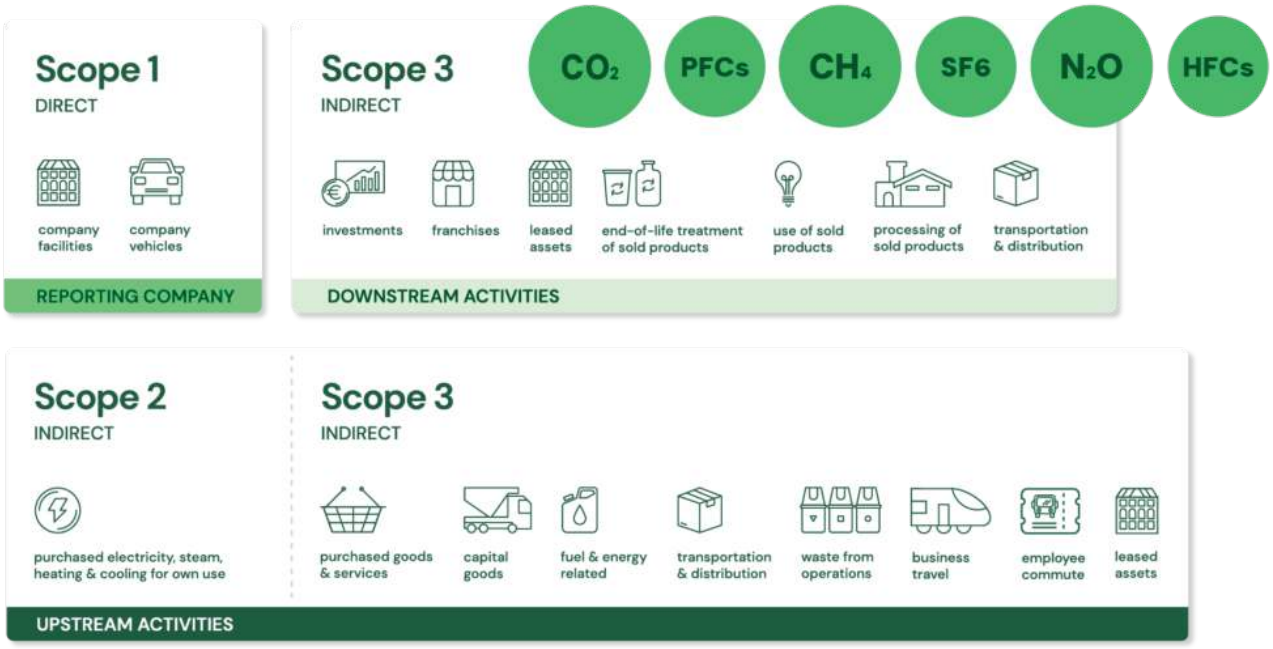
GHG Emissions from the mining industry

According to McKinsey & Company, mining accounts for 4-7% of the global GHG emissions, directly through operations and indirectly through power generation. Most fugitive coal-bed methane emissions from underground coal mines during coal mining account for 1.4-4.5 GT of CO2eq. Power consumption accounts for 0.4 GT.

Because of their prevalence in the atmosphere, three major greenhouse gases are carbon dioxide, methane, and nitrous oxide. However, water vapor, regarded as the most abundant greenhouse gas, is not considered a cause of anthropogenic global warming because it does not persist in the atmosphere for more than a few days.

The British Geological Survey has published surveys on world mining every year since 1913. The recent survey on World Mineral Production from 2016-2020 mentions that the global coal extraction in 2020 was 7 658 000 000 metric tons making it the most mined material globally. Coal is an affordable choice for electricity generation in many markets, mainly in emerging economies, and remains the only option for many crucial industries like steel and cement manufacturing. It accounts for 37% of the world's electricity and 70% of steel production. In addition, 200-240kgs of coal is required to produce 1 kg of cement, 60% of the energy required for aluminum production is derived from coal, and around 20% of hydrogen production comes from the coal-to-gas process. According to the World Coal Association (WCA), coal would still contribute 22% to the world's electricity generation in 2040.

Emissions from the mining industry



In what is considered to be the scope 3 emissions, the metal industry releases 4.2 GT CO2eq by the production of steel and aluminum.

Proposed Solutions

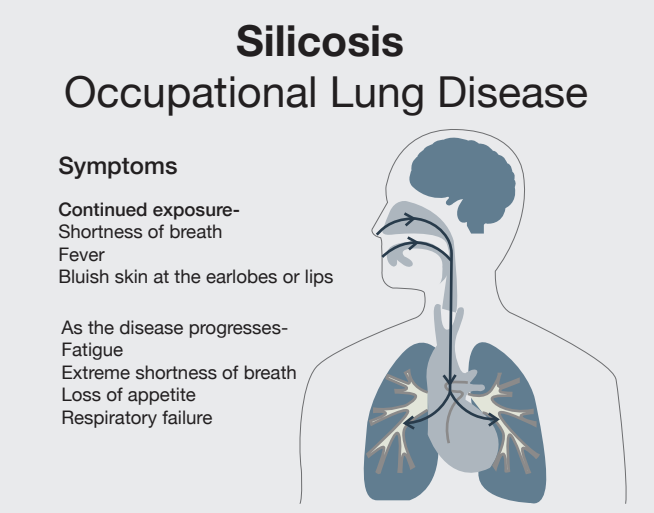
Dust from mining operations can severely impact the workers and local communities nearby. Modern mine planning and the use of specialized types of equipment can manage these impacts. Dust is generated from unpaved roads, loading and unloading of coal in trucks, crushing, and drilling operations. These dust emissions can be minimized by spraying water on roads, stockpiles, and conveyor belts. These techniques are used worldwide by major mining groups like BHP and are also recommended by WCA.

The coal industry requires serious efforts to decarbonize the mining industry, mainly because of the release of fugitive methane emissions. World Coal Association (WCA) says that the coal industry can be clean, given the investment in Clean Coal Technologies. For example, coal cleaning, electrostatic precipitators (ESP), fabric filters, wet scrubbers, and hot gas filtration systems can reduce particulate emissions. These technologies can reduce emissions in the coal industry by up to 99% and are used worldwide.

Health and Safety in Mining Industry

Mine workers are at risk of developing pneumoconiosis due to exposure to respirable dust from various sources in the mines during operational activities and transportation.

Pneumoconiosis meaning dusty lungs, can lead to the premature death of the worker if the exposure is prolonged. Coal Workers' Pneumoconiosis (CWP) and silicosis are the two main types of pneumoconiosis affecting miners. CWP is more prevalent among coal mine workers, whereas silicosis can affect miners in various mines or quarries. The disease is incurable and irreversible, and prevention is the only option.



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In the case of India, a report published by Rajasthan State Human Rights Commission on 3rd December 2014 states that the problem of silicosis in the state is dire. Rajasthan is the state with the most sandstone mines, and due to the lack of safety, security, and health of the worker being ignored, silicosis is very prevalent in the mine workers. With a group of experts, the Rajasthan States Human Rights Commission has been working on the problem and has detected 891 cases of silicosis, including 57 cases of deaths.

Therefore, the state government has decided to give ex gratia payment of 1 lakh to the silicosis/asbestosis patient and 3 lakhs to the dependent of the deceased from the Rajasthan Environmental Health Cess Fund managed by the Rajasthan Environment & Health Administrative Board (REHAB). REHAB also provided 500 lakhs to address this problem, out of which 386 lakh rupees have been sent to district collectors for distribution. Based on the insights gained during its work on the issue and inputs from experts, it has been suggested that 'wet drilling' should be made mandatory as it can significantly prevent silicosis in mine workers.

Similarly, data published by the Centre for Disease Control and Prevention, USA, states that CWP was the underlying or contributing cause of the death of 4118 miners from 2007 to 2016. This number was 75,178 from 1970 to 2016. the Black Lung Benefits Act is a federal program in the USA that provides medical costs and compensation to mine workers and their families. From 1971 to 2019, miners workers and their families received 46.168 billion dollars in federal benefits under this program. Unfortunately, monitoring of silicosis is not regular. Therefore, there is limited data from the 1900s, which suggests that more than 23% of the deaths were accounted to the mining sector.

A handbook published by NIOSH Mining on the Best Practices for Dust Control in Coal Mining suggests that dust suppression using water sprays during various processes in coal mining is one of the best solutions for suppression in coal mining and other types of mines. Additionally, measures suggested were efficient coal-cutting techniques, ventilation systems, enclosing the dust source, making physical barriers (belting, enclosed cabs), and regular maintenance of controls to retain effectiveness.

Benefits of Monitoring AQ in Mines Using Sensors Based Air Monitors

Air pollution monitoring is detecting pollutant levels in the atmosphere by measuring the quantity and types of pollutants present. Different methods are used to measure pollutants, and it is critical for the device to generate sufficient, accurate, reliable, and traceable data. Some commonly used methods are:-

	1st Generation : AAQMS Ambient Air Quality Monitoring System	2nd Generation : CAAQMS Continuous Ambient Air Quality Monitoring Station	3rd Generation : CAAQMS Sensor-based Continuous Ambient Air Quality Monitoring System
Technology	Gravimetric & Titration Analysis using HVS (High Volume Samplers)	Analyzer Instrumentation	Sensor Based
Data Monitoring Method	Manual Analysis in Laboratory	Automated Continuous Monitoring	Automated Continuous Monitoring
Data Frequency	1 data point from 8Hr sample	Continuous (every minute)	Continuous (every minute)
Man-power Required	16 Man Hours per monitoring	Not Required	Not Required
Electricity Required	600-800 Kw.Hr. / year	4-5 Mw.Hr. / year	25 Kw.Hr. / year (No power required if Solar Powered)
Cost	CAPEX : $7000 - $10,000 OPEX : $500,000 / year	CAPEX : $80,000 - $120,000 OPEX : $15,000 / year	CAPEX : $5000 - $ 8000 OPEX : $1000 / year

Reference monitors

Reference monitors are used to determine the National Ambient Air Quality Standards (NAAQS) and are designated as the Federal Reference Method (FRM) or Federal Equivalent Method (FEM). These monitors are required to meet strict operation and performance requirements. As a result, the data generated is of high accuracy. PM FRM sampling is done over 24 hours, where samplers collect particles on a filter. In the case of continuous FEM monitoring, pollutant concentrations are detected on a more frequent basis (continuous every hour). Therefore, quality assurance, quality control, andprecision in operation are necessary to ensure that the reference monitors produce accurate data.

Remote Sensing

Remote sensing is a method used to measure pollutants from a distance by measuring the reflected or emitted light and helps detect pollutants like PM, VOCs, and gaseous pollutants. It can be deployed on air crafts, satellite-based platforms in orbit, or ground-based sites.

Air sensors

Air Sensors are a class of technology that is lower in cost, portable, and easier to operate compared to FRM/FEM or other research instruments like near-reference E-BAM. USEPA, in its Roadmap for Next Generation Air Monitoring, has identified sensor-based systems as the next generation of air monitoring devices. Advances in air pollution sensors are also part of EPA's new E-Enterprise for Environment initiative. This sensor-based tech is the latest advancement in monitoring air quality and generates real-time data. Results are readily available to the concerned authorities, who can take further steps for monitoring and mitigation measures.

Sustainability Reporting in the Mining Sector, a report published by the UN, suggests that Mining companies and governments can consider modern technologies available for real-time monitoring of the social and environmental impact of mining operations. This can help in transferring information from mining companies to the government, such as for SDG reporting, but also to other stakeholders, such as local communities. In addition, open Data Principles are an emerging tool for governments to adopt for enhancing and streamlining the sharing of information.

Oizom's offerings

Oizom has a wide range of sensor-based air quality monitoring systems for applications that provide real-time air quality monitoring data along with meteorological parameters. Deep machine learning algorithms of Oizom ensure high data quality, which gives more than 90% accurate data when calibrated against the standard reference system. These devices are IP66 certified, meaning having a robust structure to be used in harsh environments like mines.

Dustroid is a Continuous Air Particulate Monitoring system to measure the concentration of dust particulates in the ambient air. Dustroid is an ideal choice for dust surveys in areas with dust-laden activities like construction, mining, quarrying, ports, metallurgical processes, and many more. The Dustroid measures all significant particulate matter like PM1, PM2.5, PM10, PM100, Temperature, and Humidity. Active Sampling method to count particulate matters using a highly accurate laser beam. Additionally, it has a heated inlet for dehumidification of the air sample. Its Anti-static inlet avoids loss of particulate during sampling. It offers remote calibration capabilities along with auto device firmware updates.

Another device used for air quality monitoring is AQBot. AQBot product range consists of critical ambient parameters and toxic gases like Total Volatile Organic Compounds (TVOC), Ammonia (NH_3), Hydrogen sulfide (H_2S), Methane (CH_4), Carbon Monoxide (CO), Formaldehyde (CH_2O), Particulate Matter (PM1, PM2.5, PM10, PM100), Ambient Noise, SO_2, NO_2, etc. The AQBot series is designed for easy operation to suit multiple applications in the industry.

Case Studies

1. Northern Coalfields Limited (NCL)

NCL is a subsidiary of Coal India Limited. NCL is India's highest producer of composite (Coal+OBR), contributing more than 1/10th of the energy supply for the country. It has a record of dispatching over 115 million tonnes of coal in 2020-21. It is headquartered in Singrauli and has an employee strength of more than 16,226 people worldwide. NCL is spread across Singrauli, Sonebhadra, Madhya Pradesh, and Uttar Pradesh, India. Since the mines are situated close to the residential area, it became crucial to monitor the air quality. The company wanted to monitor PM2.5 and PM10 levels regularly. Requirements were a compact, portable and accurate dust monitor that could be shifted to different locations around the mine.

2. Saudi Comedat Mining Co. Ltd (SCM)

SCM Is one of the leading mining corporations in the Arabian peninsula, offering complete mining services, including design, planning the mine operations, construction of the mine infrastructure, and environmental mitigation measures in remote and challenging locations. A mining site has emissions from dust and gases released from various processes. The mining projects being established in areas prone to sandstorms, high humidity levels, and harsh weather conditions, it was essential to safeguard the workers from such environmental hazards. Saudi Comedat Company wanted an IoT(Internet of Things) based Air Quality Monitoring system to warn the authorities of sandstorms or high levels of gases in the air. A self-reliant monitoring device in terms of energy was required due to limited energy capacity.

3. Mahavir Coal Washeries Pvt. Ltd. (MCWPL)

Mahavir Coal Washeries is a flagship company of Mahavir Group, incorporated in the year 2007. It is established as a heavy media bath-based coal beneficiation plant headquartered in Chhattisgarh. This means It is responsible for cleaning, sizing, and pulverizing the raw coal as per the requirement of various governmental and private sectors. A Coal washery process includes unloading raw coal, storing, handling, crushing, screening, and washing coal in a washery unit.

In this process, a high concentration of $PM_{2.5}$, PM_{10}, SO_2, and CO is emitted into the air. If emissions from these processes reach nearby villages, it will result in dire health impacts. So the requirement was a device that could monitor various parameters.

In all the above cases, Oizom provided the most suitable solutions according to the requirements in the form of the best suitable devices for air quality monitoring.

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Bhumik Nayak manages global projects at Oizom, with experience as a Research & Development Engineer with Electronics & Communication background, he deals with the technical aspects of global deployments.

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