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A Mini Ratna Company

ISSN 0970-7204

खनन विज्ञान
minetech

खण्ड 44, अंक 4
अक्टूबर–दिसम्बर 2023

Volume 44, No. 4
October-December 2023

ISSN 0970-7204

खनन विज्ञान
minetech

सीएमपीडीआई प्रकाशन

वार्षिक शुल्क : ₹ 800 (Handling and postage charges
₹ 50 per copy extra)

A CMPDI PUBLICATION
Inland ₹ 800 (Annually) (Handling & postage
charges ₹ 50 per copy extra)
Overseas US $ 200 (including airmail)

For free internal circulation within CIL Subsidiaries

खनन, गवेषण एवं सम्बन्धित विषयों का
मुख्य भारतीय त्रैमासिक

कोड नं. 015 : 8/एमटी
खण्ड : **चौवालिस**
अंक : **चार**
अक्टूबर-दिसम्बर, 2023

India's premier quarterly journal of mining, exploration and allied subjects

Code No. 015 : 8 / MT
Volume : **FORTY FOUR**
Number : **Four**
October - December, 2023

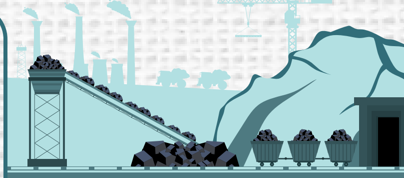
प्रकाशक
सेन्ट्रल माइन प्लानिंग एंड डिजाइन इन्स्टीच्यूट
लिमिटेड गोंडवाना प्लेस, काँके रोड,
राँची - 834 008

Published by
CENTRAL MINE PLANNING & DESIGN INSTITUTE
LIMITED, GONDWANA PLACE, KANKE, ROAD,
RANCHI - 834 008

मुद्रक :
कैलाश पेपर कन्वर्शन प्रा. लि.,
3 पार्ट कोकर इण्डस्ट्रियल एरिया, राँची

Printed at
Kailash Paper Conversion Pvt. Ltd.
3rd Part, Kokar Industrial Area, Ranchi

Printed April 2024



ISSN 0970-7204
खनन विज्ञान
minetech

विषय सूची
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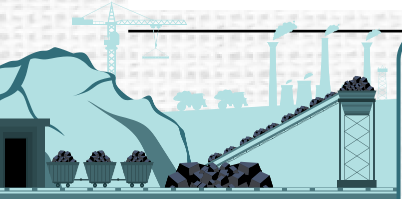
नोटः पत्रिका में प्रकाशित रचनाओं की मौलिकता एवं उनमें व्यक्त विचारों के लिए रचनाकार स्वयं उत्तरदायी हैं। पत्रिका में व्यक्त विचारों के लिए संपादक मंडल तथा सीएमपीडीआई प्रबंधन किसी भी प्रकार से उत्तरदायी नहीं होगा।



AIR POLLUTION ON MINING ENVIRONMENT: A GLOBAL REVIEW

Dr. Shilpi Mondal[1]

Abstract

Mining activities play a crucial role in meeting the global demand for minerals and raw materials, driving economic development. Since minerals are essential for producing steel as well as important energy sources, mining is important. But residents of mining areas are compelled to live in a highly polluted environment as a result of deteriorated ambient air quality and inadequate environmental management. A review study has been carried out to provide the mining area's picture, with a focus on air pollution and its effects on human health and vegetation. The use of clean coal technologies in mining regions will benefit from the current study.

1.0 Introduction

Air pollution is any biochemical, physiological, or biological factor that contaminates the interior or exterior environment and alters the natural properties of the atmosphere. Air pollution is generally caused by domestic ignition, motorized vehicles, industrial operations, and biomass burning causing the emission of Particulate Matter, carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, heavy metals, and complex organic compounds. Air pollution, both outdoors and indoors, is a leading cause of respiratory and other ailments, as well as a significant source of morbidities.

According to **World Health Organization (1971)**, air pollution may be defined as “substances put into the air by the activity of mankind into concentrations sufficient to cause harmful effect to the health, vegetation, property or the enjoyment of his property."

As per the **Engineer’s Joint Council in Air Pollution and its Control, USA**, "Air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities, of characteristics, and of duration, such as to be

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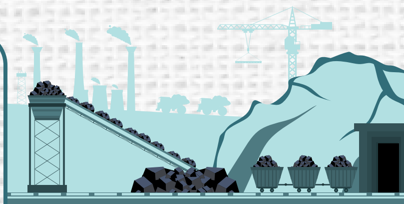


injurious to human, plant, or animal life or to property which unreasonably interferes with the comfortable enjoyment of life and property."

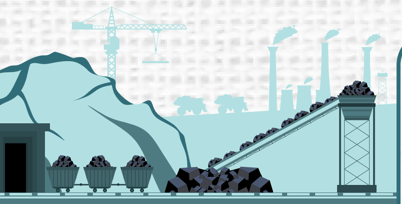
> The **Air Pollution (Prevention and Control of Pollution) Act, 1981** defined air pollution as “the presence of any solid, liquid or gaseous substances in the atmosphere in such concentrations as may be or tend to be injurious to human beings or other living creatures or plant or property or environment.”

Air pollution in metropolitan areas, particularly contamination caused by Particulate Matter, gases, and trace elements, is gaining growing attention across the world (Aneja et al., 2012; Zheng et al., 2019). Human health is threatened by the exposure to air pollution (Anderson et al. 2012; Ranjan et al., 2016; Torres et al., 2018). Particulate Matter (PM) is by far the most critical factor in air quality degradation, as many clinical studies showed a significant positive correlation between airborne Particulate Matter and detrimental human health risks (Alessandrini et al., 2013; EEA 2013; WHO, 2016; Landrigan et al., 2017).

Particulate Matter is a heterogeneous combination of particles with varying sizes, origins, and chemical compositions, rather than a distinct pollutant. Particulate Matter has the potential to transport phytotoxic chemicals. Although PM may be classed in a variety of ways, one of the most important criteria for determining its potential to convey in the atmosphere and/or inhaled through the human respiratory system is its aerodynamic diameter. The Environmental Protection Agency segregated Particulate Matter into two sizes depending on their projected lung penetration capacity: (i) Coarse Particulate Matter (PM10) with an aerodynamic diameter of 10 m, and (ii) Fine Particulate Matter (PM2.5) with an aerodynamic diameter of 2.5 m. (Esworthy, 2013).

Fine PM (PM2.5) makes up the majority of the surface area in the atmosphere, whereas Coarse PM (PM10) makes up the majority of the mass. Fine PM is composed of Sulfate (SO24-), Nitrate (NO3-), Ammonium (NH4+), Hydrogen ion (H+), elemental Carbon (C), Polycyclic Aromatic Hydrocarbons (PAH), trace elements (Mn, Cu, Mn, Zn, Cd, Cr, Pb, Co, As, and so on), particle-bound water, and various biogenic organics. On the other hand, Coarse PM is composed of re-suspended dust, soil dust, street dust, coal and fly ash, metal oxides of Si, Al, Mg, Ti, Fe, CaCo3, NaCl, sea salt, pollen, mold spores, and plant parts. Coarse PM resides in the atmosphere for a few minutes to some hours whereas fine PM persists for several days to weeks. The traveling distance of coarse PM is only 1 to 10 km, while that of fine PM is 100 to 1000 km. Sources of both categories of PM are also distinct, i.e., Coarse PM is primary and is mainly emitted from a point/area source like resuspension of soil tracked onto roads and streets, suspension from disturbed soils like farmlands, mining activities, industrial emissions, construction activities, fossil fuel combustion, and ocean spray, whereas fine PM is more diverse and secondary emitted by a chemical reaction from gaseous precursors through nucleation, condensation, and coagulation, or remained following evaporation of water from contaminated fog and cloud droplets (Cheung et al., 2011; Srimuruganandam and Nagendra, 2012). Both Fine and coarse particles react differently to variations in relative humidity, rainfall, and wind, modifying their deposition properties in distinct ways.

Meteorological conditions like weather, climate, and rainfall are all known to have a significant impact on the effectiveness of PM exposure (Jena and Singh, 2017). Even though the consequence of PM exposure varies depending on a person's physical attributes (e.g., respiratory rate, and capacity), particle size was found to be the primary source of health concerns (Mondal et al., 2020). In general, the finer a particle is, the deeper it will penetrate the pulmonary system and settle at a faster pace. Most particles larger than 10 µm in diameter (coarse particles), after



inhalation via nose and throat pass through the cilia and mucus in the respiratory tract due to their faster settling capacity and get deposited in the trachea or bronchi. Particles with a diameter of 5 to 10 µm are most probably accumulated in the tracheobronchial tree, whereas those with a diameter of 1 to 5 micrometers are deposited in the bronchial tubes and alveoli, where gas exchange takes place. These particles after escaping into the lungs and bloodstream cause serious health concerns by translocating into the cell tissue or circulatory system. Finally, via sneezing and coughing, human bodies react to remove these invading PM (Fu et al., 2011; Cadelis et al., 2014).

Increases in PM exposure may lead to asthma, bronchitis, Chronic Obstructive Pulmonary Disease (COPD), cardiac arrest, arrhythmia, myocardial infarctions, ventricular fibrillation, impaired lung function, lung cancer, and several other cardiovascular diseases as well as early mortality rate (Pope et al., 2002; Peled, 2011; Anderson et al. 2012; Ranjan et al., 2016; Torres et al., 2018). Furthermore, high particle levels have been linked to a variety of symptoms, including low birth weight in newborns, pre-term births, and perhaps fetal and infant fatalities. Shortness of breath (dyspnea), chest discomfort and pain, coughing, and wheezing are among the mild symptoms linked to inhalation of PM2.5 (Dockery et al. 1993; Hoek et al. 2009; Hsu et al. 2017). Nationwide epidemiologic research in the United States discovered a substantial, direct link between adult diabetes, obesity, and Particulate air pollution (Pearson et al., 2010). Particles provide a far greater risk to elderly persons, children, and those with heart (or lung) illness than to the general public. Children's lung development has been observed to be affected by PM exposure, with transient impairments in pulmonary activity, and persistently decreased lung development rate (Guaita et al., 2011; Brauer et al., 2012). McCormack et al., 2011 observed a statistically significant relationship between PM and asthmatic children in East Baltimore, Maryland. Similarly, Cadelis et al., 2014 found a higher rate of hospitalization among asthmatic children of Guadeloupe due to the effect of Saharan PM.

Particulate exposure has been linked to higher rates of myocardial infarction in older people, as well as a worsening of ischemic heart disease (Wellenius et al., 2006). Sun et al., 2010 have proposed a link between shifting PM levels and rapid increase in blood permeability, endothelial dysfunction, and alterations in cardiac autonomic regulation. Furthermore, PM's significant involvement in increased cardiac risk may be explained by the fact that it initiates and promotes atherosclerosis development, which is responsible for the majority of cardiovascular illnesses (Dominici et al., 2006). Even though the consequence of PM pollution has mostly been studied in terms of the visible physiological harm to human health, it also has a large economic impact. People and their families may suffer financial and non-financial losses as a result of PM-related illnesses, as well as a considerable amount of the country's Gross Domestic Product (GDP) (Zhang, 2008).

Sulfur Dioxide (SO2) is a caustic acid gas that interacts with water droplets in the air producing acid rain. SO2 gas is mostly generated by power plants and sulfur-containing fossil fuels.

Nitrogen Oxides (NOx) are produced by the burning of nitrogen in the air. The two primary Nitrogen Oxides are NO (Nitric Oxide) and NO2 (Nitrogen Dioxide), which are cumulatively referred to as NOX. Almost 90% of NOX occurs in the form of NO (Nitrogen Oxide), which is then transformed to NO2 in the environment. The major source of Nitrogen Oxides in the atmosphere is vehicular emissions. NO, and NO2 levels are higher in metropolitan centers, where traffic emission is higher as compared to the rural areas. Other prominent contributors of NOx in the environment are industrial operations and power plants.

CLASSIFICATION OF AIR POLLUTANTS

Pollutants are categorized into two classes: Primary and Secondary.

- ❖ Primary pollutants are emitted into the environment directly from a source, like the emission of ashes from volcanic eruptions, Particulate Matter (PM) from mining industries, automobile exhaust, domestic fossil fuel burning, and so on.
- ❖ Secondary pollutants are not emitted directly from a source, rather they are formed by the interaction of primary pollutants with the atmospheric sunlight. Secondary pollutants include Ozone, which is produced by the combination of Hydrocarbons (HC) and Nitrogen Oxides (NOx) in the presence of sunlight causing photochemical smog.

SOURCES OF AIR POLLUTION

Depending on the nature of the source, air pollutants are classified into: a. natural and b. anthropogenic sources. Similarly, depending on the number and spatial distribution, sources of air pollutants are categorized into 1. point sources, 2. mobile sources, 3. area sources, and 4. fugitive sources.

a. Natural Sources

Natural air pollutants include radon, fog, ash, soot, salt spray, and Particulate Matter of various sizes emitted from various natural sources like a volcanic eruption, forest fires, and so on.

b. Anthropogenic Sources

Anthropogenic sources of pollutants are produced directly by human activities like mining operations, various industrial activities, waste incineration, landfill disposal activities, transportation, as well as construction and demolition activities.

1. **Point Sources:** A point source is a specific, recognizable source of air pollution. Point sources include stationary sources like thermal power plants, oil refineries, chemical processing industries, smelters, and so on.

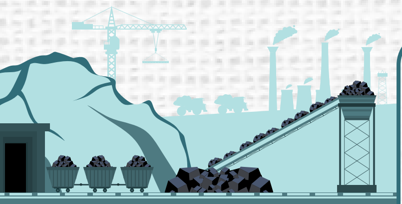
2. **Line Sources:** One-dimensional source of air pollution is recognized as a Line source, such as the emissions generated by heavy vehicular exhausts. Line sources are of two types: on-road line sources and off-road line sources (USEPA, 2006). Line sources pollute the environment due to fossil fuel combustion, and evaporation of fuel from fuel Storage.

3. **Area Sources:** An area source is a two-dimensional source of air pollution, such as emissions from a forest fire. Other sources include multiple flue gas stacks from a specific industry and evaporation of volatile liquids from spills. The US Environmental Protection Agency has classified area sources of air pollution into 70 separate categories (www.epa.gov).

4. **Fugitive Sources:** Fugitive emission means the emission of any pollutants into the ambient atmosphere through the leakage from an industrial stack or unpaved roads or construction activities i.e., not discharged through a confined flow stream.

Effects of Meteorology on Air Pollution

Pollutants can be influenced by meteorological characteristics directly through physiological processes such as the link between radiation and ozone, or indirectly can affect other meteorological parameters such as the relationship between high temperatures and low wind speed (Ordonez et al., 2005, Jacob and Winner, 2009). So, to properly comprehend the true nature of meteorological-



pollutant relationships, different techniques are required. Higher air pollutant concentrations in the metropolitan environment are often caused by climatic instances that limit dispersion in the atmosphere or result in higher pollutant generation, rather than by abrupt surges in emissions (Cheng et al., 2007). Temperature, winds, radiation, atmospheric moisture, dry deposition, and mixing depth are all crucial meteorological factors in interannual variability in air quality. As a result of their interactions with solar and terrestrial radiation, ozone and PM have been identified as key climatic forcing factors (Forster et al., 2007). For this two-fold function, the impact of climate change on ambient air quality is frequently considered in the context of chemistry-climate interactions (Giorgi and Meleux, 2007, Gustafson and Leung, 2007).

Air Pollution From Mining Activities

Mining activities are the leading cause of air pollution directly or indirectly in the coal mining areas (Baldauf et al., 2001; Collins et al., 2001). Drilling, blasting, loading, and unloading of coal, active and excessive coal mine fire hotspots, contribute significantly to air pollution (Ghose and Majee 2000a). The occurrence of coal mine fire has a prolonged background of worldwide significance and has contributed to the loss of natural resources. It also has a strong detrimental effect on the ecosystem, as well as on human health. Coal fires are now a problem worldwide; nevertheless, they are of significant concern in Asia, the USA, China, South Africa, Australia, Indonesia, Turkey, and Germany (Kuenzer et al., 2007; Kuenzer and Stracher, 2012). Several physicochemical processes are responsible for the spontaneous combustion of coal seams and associated strata, such as increase in temperature, mineral oxidation, smoke emission, changes in rock color, formation and deposition of new materials on the surface, subsidence on the surface with multiple cracks, etc. (Guan and Genderen 1997; Zhang et al. 2004). These sources ultimately lead to an increase in the concentration of Particulate Matter (Patra et al., 2016) and gaseous pollutants (SO2 and NOx) in the surrounding areas of coal mines (Tripathy and Gautam, 2007) which adversely affect ambient air quality and thereby threaten the life of humans residing close to those areas (Gautam et al., 2016).

Ambient Air Quality Standards

As a result of the rapid growth of the industrial sector and an increase in motorized traffic, both developing and rapidly emerging nations now face the issue of air pollution. Pollution is worse in developing nations. Several nations have formulated National Ambient Air Quality Standards (NAAQS), which are routinely assessed to ensure that populations, particularly vulnerable subgroups, have an acceptable margin of safety to address the problem of air pollution.

The World Health Organization (WHO) also helps countries reduce the negative health effects of air pollution by assisting countries in establishing national ambient air quality standards through the WHO Ambient Air Quality Guidelines.

Countries use the WHO guidelines, which were first published in 1987, as a preliminary step for creating strategies to reduce air pollution. The standards specify the contaminant levels at which exposure to a pollutant for a longer duration neither poses a health risk nor the least harm to health. Additionally, all methane-emitting automobiles must abide by air quality laws and limits on Particulate Matter and other pollutants set out by organizations like the European Union (EU).

In the US, there are defined criteria for air quality. Its standards and procedures have been adopted by other nations. Table 1.1 below lists the national ambient quality status of several nations along with WHO recommendations.

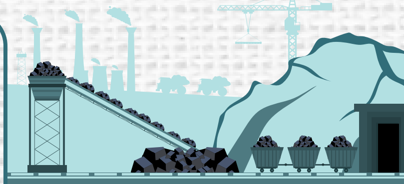


Table 1.1: Comparison of National Ambient Quality Standards of various countries with WHO Guidelines

Countries	PM2.5		PM10		SO2		NOX		CO (mg/m3)		O3		Pb	
	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	1-Hr	8-Hr	1-Hr	8-Hr	24-Hr	Annual
WHO Guidelines	25	10	50	20	500 (10-Minute)	20 (24-Hour)	200 (1-Hour)	40	-	-	-	100	-	-
US EPA NAAQS	35	15	150	-	75 ppb (1-Hour)	0.5 ppm (3-Hour)	100 ppb (1-Hour)	53 ppb	9 ppm	35 ppm	-	0.070 ppm	-	0.15 µg/m3 * Rolling three-month period
India NAAQS	60	40	100	60	80	50	80	40	4	2	180	100	1	0.5
European Union	-	25	50	40	350 (1-Hour)	125 (24-Hour)	200 (1-Hour)	40	-	10 mg/m3	-	120	-	0.5
China: Grade I	-	-	50	40	50	20	80	40)	10 (24-Hour)	4 (Annual)	160	-	1.5 (Seasonal)	1
China: Grade II	-	-	150	100	150	60	120	80	10 (24-Hour)	4 (Annual)	200	-		
China: Grade III	-	-	250	150	250	100	120	80	20 (24-Hour)	6 (Annual)	200	-		
Hong Kong SAR	75	35	100	50	500 (10-Minute)	125 (24-Hour)	200 (1-Hour)	40	30	10	-	160	-	0.5
Republic of Korea	50	25	100	50	0.05 ppm	0.02 ppm	0.006 ppm	0.003 ppm	25 ppm	9 ppm	0.1 ppm	0.06 ppm	-	0.5
South Africa	-	-	75	40	125	50	200 (1-Hour)	40	30	10	-	120	-	0.5
Bangladesh	65	15	150	50	365	80	-	100	40	10	235	157	-	0.5
Pakistan	35	15	150	120	120	80	80 (1-Hour)	40	10	5	130	0	1	1.5

China: Grade I = applies to specially protected areas, such as natural conservation areas, scenic spots, and historical sites; China: Grade II = applies to residential areas, mixed commercial/residential areas, cultural, industrial, and rural areas; China: Grade III = special industrial areas.

Countries	Ammonia ($\mu g/m^3$)		Benzene ($\mu g/m^3$)		B[a]P (ng/m^3)		As (ng/m^3)	Ni (ng/m^3)	Cd (ng/m3)
	24-Hr	Annual	24-Hr	Annual	24-Hr	Annual	Annual	Annual	Annual
WHO Guidelines			-	-	-	-	-	-	-
US EPA NAAQS			-	-	-	-	-	-	-
India NAAQS	400	100	-	5		1	6	20	-
European Union			-	5	-	1	6	20	5
China: Grade I			-	-	0.01	-	-	-	-
China: Grade II									
China: Grade III									
Hong Kong SAR			-	-	-	-	-	-	-
Republic of Korea			-	5	-	-	-	-	-
South Africa			-	5	-	-	-	-	-
Bangladesh			-	-	-	-	-	-	-
Pakistan			-	-	-	-	-	-	-

Air Quality Index (AQI)

A huge amount of data gets generated after regular monitoring at numerous sites cannot convey the air quality status to the various concerned people such as the scientific community, government officials, policymakers, and most importantly to the general public in a simple manner, that is why determination of the ambient air quality of a specific region by estimation of Air Quality Index (AQI) is considered to be an important tool.

The Air Quality Index (AQI) of the study area was calculated according to the National Air Quality Index guidelines given by Central Pollution Control Board, 2014. This National Air Quality Index (AQI) transforms complex air quality data of the pollutants into a single number (index value), nomenclature, and color to disseminate information on air quality and its associated health impacts in an easily understandable form for the common people. The pollutant concentration (Ip) values were calculated and the maximum Ip values were considered as the air quality index (AQI) of an area according to the following formula:

$$Ip = [\{(IHI - ILO)/(BHI - BLO)\} * (Cp - BLO)] + ILO$$

Ip is the sub-index, BHI the breakpoint concentration greater than or equal to the concentration given, BLO the breakpoint concentration less than or equal to the concentration given, IHI the AQI value corresponding to BHI, ILO the AQI value corresponding to BLO, Cp is the concentration of pollutants. Finally,

$$AQI = \max (Ip),$$

where p = 1, 2, …, n denotes n pollutants.

Table 1.2: Breakpoint for Indian National Air Quality Index

AQI Category (Range)	PM_{10}	$PM_{2.5}$	NO_2	CO	SO2	Pb
	24-hr	24-hr	24-hr	24-hr	24-hr	24-hr
Good (0-50)	0 – 50	0-30	0-40	0-1.0	0-40	0-0.5
Satisfactory (51-100)	51 – 100	31- 60	41-80	1.1-2.0	41-80	0.5-1.0
Moderately Polluted (101-200)	101 – 250	61-90	81-180	2.1-10	81-380	1.1-2.0
Poor (201-300)	251 – 350	91-120	181-280	45613	381-800	2.1-3.0
Very Poor (301-400)	351 - 430	121-250	281-400	18-34	801-1600	3.1-3.5
Severe (401-500)	430+	250+	400+	34+	1600+	3.5+

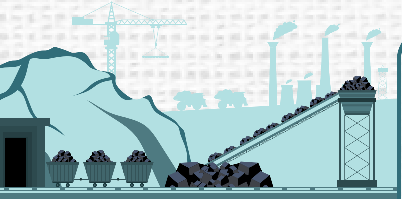
Table 1.3: Health Effects for AQI Categories

Air Quality Index Values	Air Quality Index Categories	Associated Health Impacts
0-50	Good	Minimal Impact.
51-100	Satisfactory	May cause minor breathing discomfort to sensitive people.
101-200	Moderately Polluted	May cause breathing discomfort to people with lung diseases such as asthma and discomfort to people with heart disease, children, and older adults.
201-300	Poor	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease.
301-400	Very Poor	May cause respiratory illness to the people on prolonged exposure. The effect may be more pronounced in people with lung and heart diseases.
401-500	Severe	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity.

Previous Studies on Air Quality Status in Urban and Mining Areas

Aneja et al., 2012 performed a study on the ambient air quality assessment with special reference to PM_{10} at two monitoring sites in the surface coal mining sites of Appalachia. The authors revealed that the mean adjusted 24-h concentration at the Campbell Site was 138.5µg/m^3, which exceeded the U.S. EPA National Ambient Air Quality Standards (150 µg/m^3) by 1.5 times whereas the mean adjusted 24-h concentration at the Wilis Site was 250.2 µg/m^3, which is within the permissible limit.

Shaltout et al., 2013 evaluated the concentration of PM2.5 in some industrial and residential areas of Taif, Saudi Arabia. Average PM2.5 concentrations of 47 ± 15 and 46 ± 31 µg/m^3 were seen in the



industrial and residential areas, respectively which exceeded the ambient air quality standards published by the European Commission (European Commission, 2012). The study detected 16 PM-bound trace elements such as Si, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Rb, Sr, Pb, and Black Carbon in the atmospheric environment.

Javed et al., 2015 identified the concentration of PM2.5 and PM-bound trace elements in Faisalabad, Pakistan. The study revealed that annual PM2.5 concentrations varied between 124 – 209 µg/m^3, the highest being observed during winter. A higher concentration of PM2.5 was found during winter due to low temperature, wind speed, lower atmospheric mixing along with higher anthropogenic activities like biomass burning. The major trace elements identified in the study area were Ca, Fe, Mg, Na, Pb, Cd, Ni, Cu, and Zn due to various crustal and anthropogenic activities.

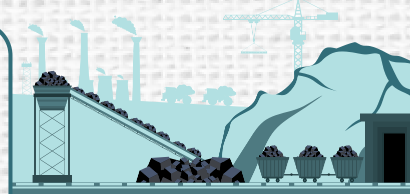
Jena and Singh, 2017 performed ambient quality status of a critically polluted coal-mining city, Dhanbad of India. The authors observed the average annual concentration of PM10 (216 ± 82 mg/m^3), which is about 3.6 times the NAAQS (CPCB) and 10.8 times the WHO air quality guidelines. The highest concentration of PM10 was found during the winter season (249 mg/m^3), followed by the summer (217 mg/m3) and the post-monsoon (183 mg/m^3). Zn, Fe, Cu, Mn, Pb, Ni, Cr, As, Cd and Co were the major PM-bound trace elements observed due to heavy vehicular exhausts, tire erosion on the roads, and adjacent mining industries, and re-suspension of road dust.

Hsu et al., 2017 estimated the concentration of PM2.5 and PM-bound trace elements in a residential area near the industrial complex of Central Taiwan. The annual average concentration of PM2.5 was observed at 24.1 µg/m^3, which exceeded the Taiwan EPA Air Quality Standard (15 µg/m^3). The concentration of PM2.5 was observed highest during the winter, followed by that in the spring and in the summer due to pollution dispersion mechanism, lower temperature, reduced wind speed, and shallow mixing height. Among the detected PM-bound trace elements, the concentration of Al and Fe was observed highest followed by Ti, Cr, Pb, V, Mn, Ni, Cu, Zn, As, Se, Sr, Mo, and Ba. On the other hand, La, Ce, Pr, Nd, Sm, Yb, Lu, Co, Cd, Sb, and Pt were found in minimal concentration.

Gao et al., 2018 evaluated the concentration of PM10 and PM2.5 along with PM-bound trace elements in a densely populated area of urban Beijing for one year. It was observed that the average concentration of PM10 and PM2.5 was 102.45 µg /m^3 and 144.75 µg /m^3, respectively. The maximum concentration of the pollutants was observed during winter as compared to other seasons, especially during the haze conditions. The concentration of PM bound trace elements was found in the order of Ba>Zn>Mn>Sr>Cu>Pb >Cr>V>Ni>Cd>Sb.

Nie et al., 2018 performed a study on the ambient air quality status concerning PM2.5 samples collected from an urban site in Yangzhou, China. The annual average concentration was 135.9 ± 48.9 µg/ m^3, which is approximately 5.5 times higher than the World Health Organization (WHO) air-quality daily average standards (25 µg/ m^3) and 1.8 times higher than the National Standard of the People's Republic of China Ambient Air Quality Standard (75 µg/ m^3). The PM-bound trace elements were observed in the order of Pb > Mn > Cu > Ni > Cd > As > V > Co due to heavy vehicular exhausts and other industrial emissions.

Al-Hemoud et al., 2019 studied the concentration of PM2.5 in the ambient air quality of Kuwait. The authors observed that the annual average PM2.5 concentration during a period of four years (2014–2017) was 63.46 µg/m^3, which is almost 6 times higher than the WHO Air Quality Guidelines, 2006 (10 µg/m^3) and the US-EPA recommended National Ambient Air Quality Standards (NAAQS) (12 µg/m^3).



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Source Apportionment of Air Pollutants

Source apportionment is a way of estimating the contributions of various sources to PM concentrations in the atmosphere. PM comes from a variety of natural and manmade sources, including re-suspended dust, windblown soil, biomass burning, automotive emissions, volcanic eruptions, sea salt spray, pollen, spores, and forest fire debris. Particulate emitted from various manmade sources come in a variety of sizes. Trace elements like Cd, Cr, and Pb, are emitted into the atmosphere through vehicular exhausts (Pandey et al., 2014), whereas Fe, Mn, Zn, Cu, Ni, Co and, As are emitted into the atmosphere mainly through the mining of minerals and various industrial operations in India (Jena et al., 2019). As a result, it is necessary to identify the sources of the atmospheric contaminants to regulate environmental quality. Furthermore, primarily after the emission sources have been individually determined, appropriate mitigation techniques to lower pollutant levels be implemented.

Various multivariate models are used for the identification of the sources of the air pollutants such as Principal Component Analysis (PCA), Factor Analysis (FA), Positive Matrix Factorization (PMF), Chemical Mass Balance (CMB), UNIMIX, and so on by interpreting the inter-relationship among the resulted value of the study.

Singh and Gupta, 2016 identified various anthropogenic sources like vehicular emission (27.39%), incineration/agricultural waste (35.41%), industrial emissions (20.77%), and crustal re-suspension of dust (12.39%) as the possible source of PM1.0 bound trace elements from the results of Principal Component Analysis (PCA) done at Indo-Gangetic plain of Kanpur, India.

Results of Principal Component Analysis (PCA) revealed that biomass burning (35%) and coal combustion (22.6%) are the major sources of emission for PM10-bound trace elements in the coastal city of Visakhapatnam, India (Police et al.,2016).

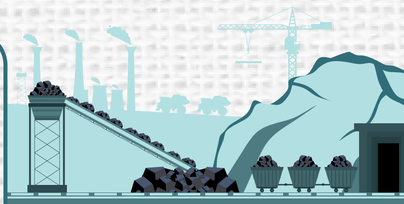
Cheng et al., 2018 by using the Positive Matrix Factorization (PMF) model identified soil dust (48.4%), road dust (19.4%), fossil fuel combustion (14.9%), electroplating industry (13.8%), and metallurgy industry (3.5%), as possible sources of PM10 bound trace elements in Chengdu, a Southwest megacity of China.

Zhang et al., 2018 while evaluating the Spatio-temporal variation in the concentration of PM2.5 bound trace elements in Shandong province, identified coal combustion and various industrial emissions as the major sources of emission of the air pollutants by utilizing Positive Matrix Factorization (PMF) model.

Hwang et al., 2018 identified emissions from the iron and steel industry (66.2%), vehicular exhausts (58.4%), road dust re-suspension (22.0%), and coal burning (2.8%) as the key source of emission of PM2.5 bound trace elements by utilizing Positive Matrix Factorization (PMF) at coastal areas of Southwestern Taiwan.

Jena et al., 2019 identified Coal mining activities, vehicular emission, tire and brake wear, and re-suspension of road dust as dominant sources of PM2.5-bound trace elements from the results of a source apportionment study done by Principal Component Analysis (PCA) at mining and transportation routes of Dhanbad, India.

The positive matrix factorization (PMF) model revealed four factors, including vehicular emissions (29.7%), crustal dust resuspension (24.8%), demolition and construction activities (23.5%), and industrial emissions (22%) for the higher concentration of atmospheric deposition at Tehran megacity, Iran (Ali Taleshi et al., 2022).



According to the study done by Inerb et al., 2022, a source apportionment study was done by using Principal Component Analysis (PCA) at Hat Yai city of Thailand which revealed that vehicular transportation on roadways (38.3%), various industrial emissions (26.8%) and biomass burning (11.9%) are the major sources of emission for PM1.0 bound trace elements in the ambient air.

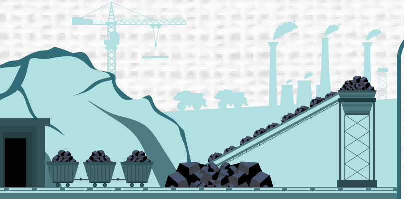
Effect of Air Pollution on Human Health

Particulate Matter (PM) is by far the most critical factor in air quality degradation, as many clinical studies showed a significant positive correlation between airborne Particulate Matter and detrimental human health risks (Alessandrini et al., 2012; EEA 2013; WHO, 2016; Landrigan et al., 2017). Other studies have been performed on human health risks correlated to atmospheric Particulate Matter in various mining cities in the USA and China (Aneja et al., 2012; Zheng et al., 2019). Of the various sizes of PM, PM10 and PM2.5 (due to their smaller particle size) penetrate deeply into the lung, irritate and corrode the alveolar wall, and consequently impair lung function (Dockery et al. 1993; Hoek et al. 2009; Hsu et al. 2017). Various studies across the world reported that exposure to ambient PM2.5 accounted for about 2.9 million deaths and has been identified as the 5th-highest risk factor (State of Global air, 2019). Acute exposure to Particulate Matter causes variations in coagulation and platelet stimulation by forming a more proximal link between PM and coronary heart disease. Chronic exposure to PM leads to asthma, bronchitis, Chronic Obstructive Pulmonary Disease (COPD), cardiac arrest, arrhythmia, myocardial infarctions, ventricular fibrillation, lung cancer, and several other cardiovascular diseases (Pope et al., 2002; Peled, 2011; Anderson et al. 2012; Ranjan et al., 2016; Torres et al., 2018). According to the International Agency for Research on Cancer (IARC 2013), PM falls under Group 1 contaminants and they are the conveyers of various trace elements like As, Cd, Cr, Cu, Zn, Pb, Ni, Co, and Mn in the atmosphere (Bunekreef and Holgate, 2002). These trace elements are detrimental to human health when they come in contact with the human body through ingestion, inhalation, and dermal exposure (Liu et al., 2015; Roy et al., 2019a). Due to the higher level of toxicity, even at a lower level of exposure, Cd, As, Cr, and Pb are considered systemic toxicants (Tchounwou et al., 2012). Previous studies have shown that Pb and Cd cause detrimental effects on the liver, renal tissues, the reproductive and central nervous system through increased oxidative stress (USEPA 1990; Johri et al., 2010; Flora et al., 2012). Cr has carcinogenic effects (Mancuso 1975) and shows both teratogenic and human carcinogenic effects (Cr (VI)) (Danielsson et al., 1982; Iijima et al., 1983; Matsumoto et al., 1976). As is a human carcinogen causing various cardiovascular diseases, as well as lung and skin cancer (USEPA, 1984).

Jan et al., 2016 performed a human health risk assessment for PM10 and PM2.5 bound trace elements at Pune, India. They observed that Hazard Quotient (HQ) for Cd, Co, and Ni exceeded the safe dose (HQ = 1), implying a significant non-carcinogenic risk to the adults and children of the city. HQ varied from 9.1 ×10-5 for Cu (coarse) to 8.3 for Ni (fine) Particulate Matter. The carcinogenic risk for Cd, Ni, and Cr in both sized PM exceeded the permissible limits of USEPA.

Heydari et al., 2019 estimated the carcinogenic risk and non-carcinogenic risk of PM10 and PM2.5 bound trace elements in a highly polluted city, Tehran, Iran. The authors observed that the mean Hazard Quotient (HQ) for PM2.5 varied between 0.82 – 18.4, and for PM10 varied between 0.16 – 3.28 respectively, indicating significant non-carcinogenic risk to the population of Tehran. Excess Lifetime Cancer Risk (ELCR) for PM2.5 bound trace elements varied between 0.64 × 10-5 – 14.98 × 10-5, which exceeded the acceptable limits of USEPA and WHO as well as EPA standards, implying potential cancer risk.

Guo et al., 2020 performed human health risk assessment due to inhalation of atmospheric



Particulate Matter in a mining and smelting area in Southwest China. A significant non-carcinogenic risk was observed due to exposure to Pb, because of its higher hazard index (4.45) among the children in the study area. Similarly, the potential carcinogenic risk was observed due to exposure to Cr, Cd, and Pb among children (4.33 × 10-5) and adults (7.58 × 10-5) respectively.

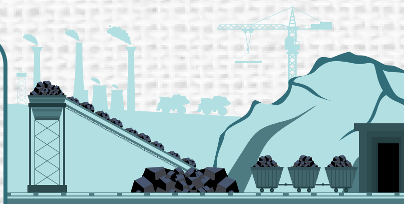
Lara et al., 2021 calculated non-carcinogenic and carcinogenic risks of the population in the city of Gijon, Spain. A significant non-carcinogenic risk was observed due to exposure of Pb (HIPb = 3.87) in children and Fe (HIFe = 1.07) in adults respectively, which exceeded the acceptable limit. The authors also observed that the carcinogenic risk (CR) value was higher than the safe dose (1×10-5) for As in children via ingestion.

Zhang et al., 2018 performed a health risk assessment of PM2.5 bound trace elements in the Shandong province of China. The authors observed that cumulative non-carcinogenic risk for adults was observed mainly due to Cd and Mn, whereas for children it is due to Pb and Co. A significant carcinogenic risk was observed among the population of Shandong province due to exposure to As and Pb. Adults are more prone to non-carcinogenic risk whereas children are more prone to carcinogenic risk in the study area.

Effects of Air Pollution on Plants

When plant species are confronted with hazardous air pollutants and PM-bound trace elements, their metabolism, and morphological characteristics get affected, their photosynthetic rate is reduced, and their chlorophyll content is considerably reduced (Khalid et al. 2019). Heavy traffic on highways pollutes roadside soil and has an impact on plant growth and the survival of soil organisms. Trace elements cause environmental problems by producing acid rain, reducing soil and water pH, and rendering hazardous trace elements bioavailable to plants. Many conventional air pollution mitigation measures have been developed, but they are expensive and frequently create additional emissions. The bioremediation method is thought to be a cost-effective and practical way to measure air pollution levels in the atmosphere (Bharti et al. 2018; Karmakar and Padhy 2019). Plants can purify the atmosphere. Various plant species can absorb toxins from the air and produce a vegetation barrier in urban areas. By absorbing gaseous pollutants and by lowering PM concentrations through leaves, stomata, and plant surfaces in severely polluted locations, these barriers can decrease gaseous pollutants and lower PM concentrations (Abhijith et al., 2017). Through atmospheric stabilization, vegetation minimizes pollutant dispersion. Other advantages include temperature regulation, noise control, a decrease in heat waves, and an increase in the aesthetic value of the region. Previous research has revealed that pollutant removal in urban environments is influenced by the number of pollutant concentrations, the amount of atmospheric precipitation, and other climatic factors, all of which influence the plant's deposition and transpiration rates (Abhijith et al. 2017). Depending on their tolerance potential, the plants that are most suited for plantations in severely polluted areas play a critical role in air pollution abatement. Ascorbic acid, water content, leaf extract pH, and chlorophyll content are some of the biochemical and physiological characteristics that define the plant's tolerance capacity and dust absorbing ability (Roy et al. 2020). These characteristics are used to construct the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API).

Govindaraju et al., 2012 studied the negative impacts of emissions from a lignite-based thermal power station at Neyveli, Tamil Nadu in India. Based on higher Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) values, the authors identified Mangifera indica (APTI:19.03 API: 6) and Anacardium ocidentale (APTI: 16.73; API: 4) as keystone species for plantation as greenbelt.



Gupta et al., 2016 calculated the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) values of some locally available plant species at NCR Delhi, India. The study revealed that Terminalia arjuna (APTI:10.04; API:5), Morus alba (APTI:9.25; API:5), Dalbergia sissoo (APTI: 9.03; API:4), Polyalthia longifolia (APTI:8.22 API: 4) were very good performers for air pollution abatement and can be used for green belt development.

Banerjee et al., 2019 calculated the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) of 36 plant species of Durgapur, West Bengal, India and identified that Lagerstroemis speciosa (APTI: 233.78; API:11), Schleichera oleosa (APTI: 87.76; API:11), and Thespesia populnea (APTI: 126.23; API:11) are the outstanding categories of plant species and can be expected to perform well against air pollution.

Alotaibi et al., 2020 studied the impacts of air pollution on the locally available plant species of Riyadh city, Saudi Arabia. The authors observed that leaves of Ficus altissima showed the lowest leaf area reduction (11.6%), whereas leaves of Prosopis juliflora showed the highest leaf area reduction (34.8%). While estimating the Air Pollution Tolerance Index (APTI) coupled with the Anticipated Performance Index (API) for each species, it has been concluded that Ficus altissima followed by Ziziphus spina-christi, Albizia lebbeck can be planted on the roadside of the industrial area for air pollution abatement due to their higher APTI and API values.

Conclusion

This comprehensive review synthesizes current knowledge on the environmental impacts of mining, emphasizing the need for a holistic and sustainable approach to resource extraction. It provides valuable insights for policymakers, industry professionals, and researchers seeking to address the challenges associated with mining activities and promote environmentally responsible practices. Plants, the key greenbelt component, serve as sinks and living filters to reduce air pollution through absorption, adsorption, detoxification, and aggregation without significant foliar disruption, thereby enhancing air quality by supplying oxygen to the atmosphere. The establishment of a green belt around the various mining sectors, using pollution-tolerant plants, can make a substantial contribution towards improving air quality and creating a sustainable environment.

References:

Alessandrini, E.R., Faustini, A., Chiusolo, M., et al., (2013). Air pollution and mortality in twenty-five Italian cities: results of the EpiAir2 Project. Epidemiol Prev 37:220–229

Anderson, J.O., Thundiyil, J.G., Stolbach, A. (2012). Clearing the Air: A Review of the Effects of Particulate Matter Air Pollution on Human Health. J Med Toxicol, 8, 166–175. https://doi.org/10.1007/s13181-011-0203-1

Aneja VP, Isherwood A, Morgan, P. (2012) Characterization of particulate matter (PM10) related to surface coal mining operations in Appalachia. Atmospheric Environment 54:496–501. https://doi.org/10.1016/j.atmosenv.2012.02.063

Baldauf, R. W. (2001). Ambient air quality monitoring network design for assessing human health impacts from exposures to airborne contaminants. Environmental Monitoring and Assessment, 66(1), 63–76. https://doi.org/10.1023/A:1026428214799

Brauer, M., Amann, M., Burnett, R. T., Cohen, A., Dentener, F., Ezzati, M., & Thurston, G. D. (2012). Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. Environmental science & technology, 46(2), 652-660.

Cheng, H., & Hu, Y. (2011). Lead (Pb) isotopic fingerprinting and its applications in lead pollution studies in China: A review. Environmental Pollution, 158(5), 1134–1146. https://doi.

org/10.1016/j.envpol.2009.12.028

Cheng, W. L., Chen, Y. S., Zhang, J., Lyons, T. J., Pai, J. L, & Chang, S. H. (2007). Comparison of the revised air quality index with the PSI and AQI indices. Science of the Total Environment, 382(2-3), 191-198.

Collins, M. J., Williams, P. L., & McIntosh, D. L. (2001). Ambient air quality at the site of a former manufactured gas plant. Environmental Monitoring and Assessment, 68(2), 137–152. https://doi.org/10.1023/A:1010747225479

Dockery, D.W., Pope, C.A., Xu, X. et al. (1993). An Association between Air Pollution and Mortality in Six U.S. Cities. N Engl J Med 329:1753–1759. https://doi.org/10.1056/NEJM199312093292401

Dominici, F., Peng, R. D., Bell, M. L., Pham, L., McDermott, A., Zeger, S. L., &Samet, J. M. (2006). Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. Jama, 295(10), 1127-1134.

EEA, (2013) Status of black carbon monitoring in ambient air in Europe. EEA Technical report no. 18/2013. https://doi.org/10.2800/10150. Accessed 05 May, 2018.

Esworthy, R. (2013, January). Air quality: EPA's 2013 changes to the particulate matter (PM) standard. Washington, DC, USA: Library of Congress, Congressional Research Service.

Giorgi, F., & Meleux, F. (2007).Modelling the regional effects of climate change on air quality. ComptesRendus Geoscience, 339(11-12), 721-733.

Guaita, R., Pichiule, M., Maté, T., Linares, C., & Díaz, J. (2011). Short-term impact of particulate matter (PM2.5) on respiratory mortality in Madrid. International journal of environmental health research, 21(4), 260-274.

Guan, H., Van-Genderen, J.L. (1997). Report on environment monitoring of spontaneous combustion in the coal field of North China, Aero-Photogrammetry and Remote Sensing Bureau of China and International Institute for Aerospace survey and Earth Sciences, Enscheda, The Netherland.

Hoek, G., Boogaard. H., Knol, A., et al. (2010). Concentration Response Functions for Ultrafine Particles and All-Cause Mortality and Hospital Admissions: Results of a European Expert Panel Elicitation. Environ Sci Technol , 44 , 476–482. https://doi.org/10.1021/es9021393

Hsu, C. Y., Chiang, H. C, Chen, M. J., et al. (2017). Ambient PM2.5 in the residential area near industrial complexes: Spatiotemporal variation, source apportionment, and health impact. Science of The Total Environment 590–591:204–214. https://doi.org/10.1016/j.scitotenv.2017.02.212

http://www3.epa.gov//ttn/atw/socatlst/socatpg.html. Accessed on 14.011.2018.

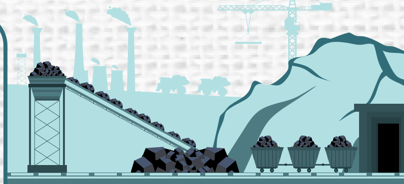
Jacob, D, J., & Winner, D. A. (2009). Effect of climate change on air quality. Atmospheric environment, 43(1), 51-63.

Jena, S., & Singh, G. (2017). Human health risk assessment of airborne trace elements in Dhanbad, India. Atmospheric Pollution Research, 8(3), 490–502. https://doi.org/10.1016/j.apr.2016.12.003

Jena, S., Perwez, A., & Singh, G. (2019). Trace element characterization of fine particulate matter and assessment of associated health risk in mining area, transportation routes and institutional area of Dhanbad, India. Environ Geochem Health, 41, 2731–2747. https://doi.org/10.1007/s10653-019-00329-z

Kuenzer,C., & Stracher, G. B. (2012). Geomorphology of coal seam fires. Geomorphology, 138(1), 209–222. https://doi.org/10.1016/j.geomorph.2011.09.004

Mondal, S., Singh, G., & Jain, M. K., (2020). Spatio-temporal variation of air pollutants around the coal mining areas of Jharia Coalfield, India. Environ Monit Assess 192,405. https://doi.org/10.1007/s10661-020-08324-z



Pearson, J. F., Bachireddy, C., Shyamprasad, S., Goldfine, A. B., & Brownstein, J. S. (2010). Association between fine particulate matter and diabetes prevalence in the US. Diabetes care, 33(10), 2196-2201.

Peled, R. (2011). Air pollution exposure: Who is at high risk? Atmospheric Environment 45, 1781–1785. https://doi.org/10.1016/j.atmosenv.2011.01.00

Pope, III C. A. (2002). Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. JAMA 287, 1132. https://doi.org/10.1001/jama.287.9.1132

Ranjan, O., Menon, J. S., & Nagendra, S. S. (2016). Assessment of air quality impacts on human health and vegetation at an industrial area. Journal of Hazardous, Toxic, and Radioactive Waste, 20(4), A4016002. DOI: 10.1061/(ASCE)HZ.2153-5515.0000316

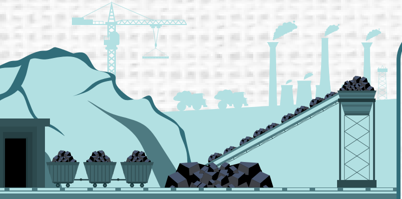
Ranjan, O., Menon, J. S., & Nagendra, S. S. (2016). Assessment of air quality impacts on human health and vegetation at an industrial area. Journal of Hazardous, Toxic, and Radioactive Waste, 20(4), A4016002. DOI: 10.1061/(ASCE)HZ.2153-5515.0000316

Sun, Q., Hong, X., &Wold, L. E. (2010). Cardiovascular effects of ambient particulate air pollution exposure. Circulation, 121(25), 2755-2765.

Torres, P., Ferreira, J., Monteiro, A., et al. (2018). Air pollution: A public health approach for Portugal. Science of The Total Environment, 643, 1041–1053. https://doi.org/10.1016/j.scitotenv.2018.06.281

Zhang, X. Y., Tang, X. L., Zhao, C. L., Zhang, G., Hu, H. S., Wu, H. D., & Wei, J. G. (2008) Health risk evaluation for the inhabitants of a typical mining town in a mountain area, South China. Annals of the New York Academy of Sciences, 1140(1), 263-273.

Zheng, L., Ou, J., Liu, M., et al. (2019). Seasonal and spatial variations of PM10-bounded PAHs in a coal mining city, China: Distributions, sources, and health risks. Ecotoxicology and Environmental Safety, 169, 470–478. https://doi.org/10.1016/j.ecoenv.2018.11.063



A Strategic Outlook for Just Transition for India's Coal Sector

Chandra Bhushan[1], Srestha Banerjee[2]

I. Introduction

During the United Nations (UN) Conference of Parties (COP) on climate change held in Sharm el-Sheikh last year (COP 27), India called for a phase down of all fossil fuels to accelerate action on climate change. The call has been supported by various countries, including the European Union and the United Kingdom, considering the comprehensive reduction on fossil fuel consumption that is necessary to combat the climate crisis (Sarkar, 2022).

Over the past years, the growing body of scientific research on climate change has made it clear that a shift away from the fossil-fuel economy is inevitable. The Paris Agreement in 2015 and the report of the Intergovernmental Panel on Climate Change (IPCC) in 2018 have also set the timeframe for the transition. To avoid catastrophic impacts of climate change, the world needs to limit global warming well below 2°C above the pre-industrial levels and pursue efforts to limit the temperature increase even further to 1.5°C (United Nations, 2015). For this, global carbon dioxide (CO2) emissions will have to reduce by 45% by 2030 from 2010 levels and reach net-zero by 2050. This will necessitate a massive reduction in the use of fossil fuels for electricity generation and various industrial uses and build a low-carbon economy.

In response to the need accelerate climate action, the Government of India (GOI) has also announced important targets of emission reduction and clean energy augmentation over the next four decades. In November 2021, at the Glasgow Climate Conference (COP 26) the GOI announced a net zero emission target by 2070 (Ministry of Environment, Forest and Climate Change. 2022). Earlier that year in August, the Government had also announced an energy independence target by 2047, the intention of which is to move away from high-cost fossil fuel imports and strengthen the domestic clean energy market. A major emphasis has been laid on electric mobility, production of green hydrogen, and augmenting the supply of natural gas, among others (Office of the Prime Minister of India, 2021). In 2022, under India's updated NDC under the Paris Agreement (as submitted to the UNFCCC in August 2022), the Government has also set a target of achieving 50% of the cumulative electric power installed capacity from non-fossil fuel-based energy sources by 2030 (GOI, 2022).

The achievement of all these targets for India means that there will be a massive reduction of coal, oil and gas consumption in the coming decades. At present, about 70%of India's primary

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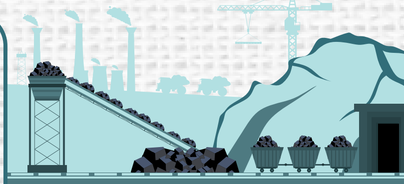


energy supply relies on two fossil fuels, coal and oil. Of this, coal has a share of 44%, and oil about 26% (IEA, 2021). Therefore, for a country which is heavily reliant on fossil fuels for its energy needs and industrial growth, while also being highly vulnerable to climatic impacts, the next three to four decades will be critical in every aspect.

However, the fossil fuel transition will not simply be a technical exercise. It will have implications for the workers and local communities who are dependent on these sectors, jobs, government revenue and social welfare investments (Bhushan and Banerjee, 2023). Therefore, building a low-carbon economy requires understanding of the socio-economic consequences of the transition in various fossil fuel-dependent regions and developing measures to minimise disruptions. In essence, the fossil fuel transition requires a well-planned and systemic approach to ensure a just transition that can help to achieve net positive environmental, social and economic outcomes.

2. Transition strategy for India's coal sector

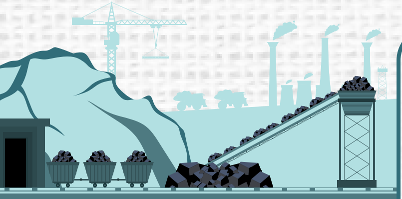
While the consideration for a just transition cannot be solely focussed on coal, however, considering the centrality of the coal sector in India's primary energy mix, it remains one of the most important aspects of the transition discourse. Therefore, planning a systemic roadmap for just transition of the coal mining sectors is a key aspect of developing India's energy transition and just transition roadmap.

Currently there are 417 coal and lignite mines spread across 51 districts in India. However, in terms of coal production, 86% is concentrated in 21 districts across nine states, including districts producing over 100 million tonne of coal per annum (MTPA). The top three coal-producing districts currently are Singrauli (Madhya Pradesh), with a production of nearly 120 MT of coal in 2022, followed by Korba (Chhattisgarh) with 113 MT, and Angul (Odisha) with 97 MT. These three districts account for over 41% of the country's production. Overall, only 12 districts collectively account for more than 72% of coal production. For many other districts, coal production is either plateauing or declining (Bhushan and Banerjee, 2023).

In fact, there are multiple coal realities across various coal states and districts. Considering the production trend and expansion plans of the various coal companies, the coal regions of India can be broadly categorised into three stages of coal resource development. These include, regions with declining coal resources, such as in the old coal mining regions of eastern India, including Jharkhand (Dhanbad, Bokaro, Ramgarh, etc.) and West Bengal (West Bardhaman); regions with plateauing coal resources (while some districts still with high production), such as in the states of Chhattisgarh (Korba), Madhya Pradesh (Singrauli, Sidhi), Maharashtra (Chandrapur, Nagpur); and regions with increasing coal production, such as in Odisha (Angul).

These regions will experience transition issues at different times. Therefore, plans and measures of just transition will need to be developed accordingly for different timeframes, and not just for every region at the same time.

Considering the coal landscape, a just transition strategy for India's coal sector should initially focus on the mines that are old, low-producing and economically unviable. There are a large number of old and economically unviable mines in India's top coal states. An assessment of the economic status of 290 coal mines in India in six states (for which data could be obtained and in states where there is at least one unprofitable mines) shows that at least 188 mines in these states are economically unviable. Nearly 50% of the unprofitable mines are also at least 33 years or older (the average period considered under the mine closure guidelines and by the industry as the time by which a mine should extract coal profitably and recover its investment),



which suggests there is no likelihood of extracting coal profitably from these mines in the future. Many of these mines are concentrated in the states of Jharkhand, West Bengal, Chhattisgarh, Madhya Pradesh, and Maharashtra (Table 1).

The unprofitable mines employ over 100,000 workers formally (as per information obtained on department and contractual workers from PSUs for operational mines), which is nearly 29% of the coal industry formal workers. Besides, twice as many workers are informally engaged in these mines, going by the trend of informal workers associated with the coal mining industry.

A just transition of these mines will not compromise the country's energy security or the development ambition. Conversely, developing necessary policies and plans for a phased transition of this mines over the next decade can minimise socio-economic disruptions, and provide the opportunity to design and showcase best practices of planned and just closure, including repurposing of the land available with these mines for productive economic use. In the subsequent years, balancing the country's energy security and development needs, a phased transition of the coal sector can be planned and implemented.

Table 1: Transition opportunities of economically unavailable mines

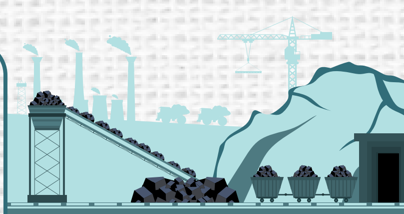
State	Total operational mines	Number of unprofitable mines			Profitable mines	Data not available	Formal workers in unprofitable mines*	Land with unprofitable mines (ha)
		Total	OC	UG				
Jharkhand	107	55	40	15	35	17	23,450	29,190
West Bengal	72	48	6	42	15	9	25,016	36,490
Chhattisgarh	49	31	7	24	9	9	22,468	28,087
Madhya Pradesh	52	30	4	26	8	14	17855	19063
Maharashtra	50	21	11	10	20	9	12843	19090
Odisha	22	3	0	3	15	4	1,629	2,650
Total	**352**	**188**	**68**	**120**	**102**	**62**	**1,03,261**	**1,34,570**

3. Policy considerations and way ahead

A just transition of the coal mining sector starting this decade will not be socially and economically disruptive for the country if the transition is planned strategically, appropriate policies and plans are developed, and the process is managed well. The following are the key policy and planning aspects for just transition of the coal sector.

i. Just transition of old and unprofitable coal mines

A first of just transition of the coal sector will be the old and economically unviable mines. As global best practices show, major coal economies such as Germany, Poland etc., has developed separate and targeted policies and plans for the transition of such mines and provide transition support for the impacted workers and communities (Bhushan and Banerjee, 2023). Similarly, India needs to develop a separate policy and plan for just transition of all unprofitable mines and old mines. The plan should include a year-on-year timeline for the closure of the mines to ensure just transition of the workers associated with such mines. The plan should also outline investments that will be necessary for transition of these mines and the impacted regions.



ii. Phased transition of coal mines

The Government will need to develop a policy and plan for a phased transition of coal mines considering the age, resources that can be extracted profitably, and aligning with India's net zero pathway. The plan should indicate the coal peak and set a reasonable timeframe for just transition. It should also include a regional, state, and national schedule for coal mine transition.

iii. Repurposing of coal mining land and infrastructure

Repurposing the land available with coal mines provides huge opportunity for undertaking various economic activities once the mines are closed. However, the design of the mine closure plans undermines the repurposing potential of coal mining land. The existing closure plans allow significantly high external overburden dumps to exist outside the pits and internal overburden dumps of considerable height inside the pits. Besides, it leaves a void of significant area and depth in the quarry area (Bhushan and Banerjee, 2023).

There is also ambiguity regarding land transfer to the state government once mines are closed. Under the Coal Bearing Areas (Acquisition and Development) Act, 1957 (CBA), the land is presumed to be given to coal companies in perpetuity. However, the coal mine closure guidelines, and notification(s) issued by the Ministry of Coal in subsequent years, specify that the land is 'leased' to coal companies for a defined period and must be surrendered to the state governments upon closure (Banerjee, 2022).

To optimise repurposing potential, a comprehensive policy needs to be developed covering abandoned mines, closed mines, and mines those which are operational and will be closing in the coming decades. The policy guidelines should take into account the following:

a) For mines currently in operation, will undergo expansion, or are upcoming, the existing coal mine closure guidelines should be revised to ensure that the closure plans are designed in a way that maximum land can be repurposed.

b) The provisions of the CBA Act (1957) related to granting coal mine leases and lease periods need to be revised. The law should include requirements for surrendering land after the closure of mines. At the same time, guidelines need to be developed for transferring land to the respective state governments, also considering the abandoned mines.

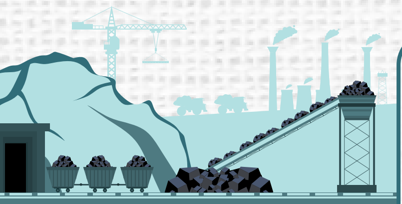
c) The guidelines should include aspect of social transition.

For infrastructure available with or supported by coal companies (such as housing, healthcare facilities, schools, etc.), a guideline should be developed to allow the productive use of these facilities once the company's operation ceases.

iv. Labour support and workforce development

One of the most important aspects of just transition for any sector is to ensure a transition of all workers who are dependent of these sectors for livelihood and income. Considering the large-scale formal and informal income dependence on the coal sector, developing policies and plans for worker transition will be necessary both by the Government, as well as the industries.

To ensure a just transition of both formal and informal workers, including women, the existing labour laws need to be strengthened, with specific reference to aspects of terms of engagement, retrenchment, and transition support in the event of industrial closure. The companies will also need to develop a 'worker transition plan' to support the transition of their workforce, including providing compensations, reskilling and skilling support, post-retirement benefits (as the case may be), among others. The Government may also create a special 'Workforce Transition Fund' to provide relief measures for displaced workers, such as temporary income support, mobility assistance, and training and re-skilling assistance for younger workers (Bhushan and Banerjee).



Apart from support to the existing workforce, investments will also be necessary for developing the workforce for the low-carbon economy. Investments will be required for education, green skilling (including higher order skills), vocational and technical institutes, among others (International Labour Organization, 2022).

v. Responsible environmental practices

Pollution and ecological degradation are critical problems in India's coal regions. Both coal mining activities, coal-based power generation, and other coal-dependent industries contribute to air, water, and soil pollution, which in turn affects public health, limits access to clean water, and reduces agricultural productivity, among other things. Given the high pollution levels, the union environment ministry (now MoEF&CC) in 2010 had identified most of the top coal mining areas as 'critically polluted areas'. These include Hazaribagh and Dhanbad in Jharkhand, Singrauli in Madhya Pradesh, Korba in Chhattisgarh, Angul-Talcher areas of Odisha, Chandrapur in Maharashtra, among others. These areas are required to implement short-term and long-term action plans to reduce pollution levels (Bhushan and Banerjee, 2023).

Abandoned coal mines are another significant source of pollution and risk to public safety. As per the information of the Ministry of Coal (answers to the Parliament of India, 2022) and information obtained through RTI by coal mining companies, there are at least 287 abandoned/discontinued coal mines in India (Table 2), concentrated in states such as West Bengal, Jharkhand, Chhattisgarh, Madhya Pradesh, and Maharashtra (Bhushan and Banerjee, 2023).

Therefore, going ahead ensuring environmentally responsible industrial practices will be crucial component for transitioning to the low-carbon economy. Environmental and carbon footprint of the extractive and manufacturing industries should be minimised through responsible mining (green mining) and associated environmental practices. It will be important to ensure scientific closure of coal mines, including planning for ecological restoration, remediation and repurposing of the land. Also, industrial pollution standards must be made stringent to ensure that the pollution is within the carrying capacity of the local airshed, water bodies and land, and material circularity should be practised through reuse, recycling, and safe disposal of waste materials (Bhushan, et.al, 2022).

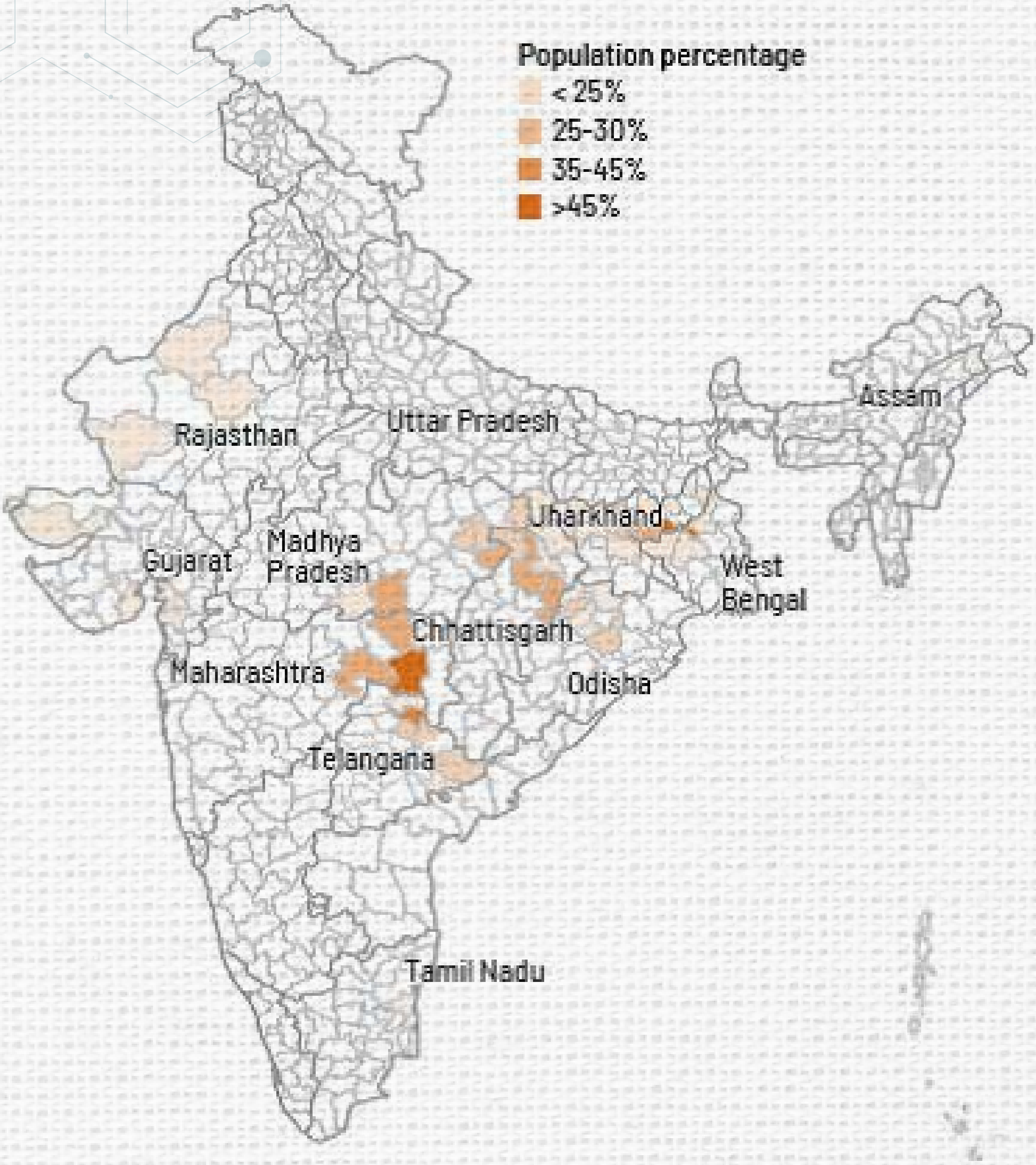
vi. Responsible social investments and building community resilience

The fossil fuel-dependent regions in India, particularly the coal districts, suffer from poor socio-economic indicators that increase their vulnerability to any poorly planned industrial and economic transition. For example, an assessment of multidimensional poverty indicators (exhibits the status of healthcare, education, and living standards of local communities) of all coal mining districts in India (51) shows that 35 districts out of the total (which is nearly 69%), have more than 25% of the population who are multidimensionally poor (NITI Aayog, 2021). The benchmark of 25% here reflects the Indian average. The districts with poor development indicators are highly concentrated in the states of Jharkhand, Chhattisgarh, and Madhya Pradesh (Bhushan and Banerjee, 2023).

At the same time, these regions have a high proportion of low-income coal dependency. For example, an all-India extrapolation of total coal workers based on district-level worker assessments undertaken for some of the top coal districts in Jharkhand, Chhattisgarh, and Odisha shows that 65% of workers related to the coal industry are informal with low levels of income. Considering the coal-centric economy, the districts also remain highly vulnerable to any industrial closure or transition. In many of the top coal districts in India, the industrial activities are centred around coal. For example, in districts such as Bokaro, Dhanbad, Hazaribagh, Korba, Angul, etc., more than 50% of the district's GDP is dependent on coal mining and coal-dependent industrial sectors (Bhushan and Banerjee, 2023).

Therefore, developing policies, programmes and investment plans for structural support and social welfare measures for the coal regions will be necessary. These should be aimed at alleviating poverty and deprivation, improving development indicators, and supporting revitalisation of local communities to be impacted by the transition.

Figure 1: Proportion of multidimensionally poor people in coal districts



Source: C. Bhushan and S. Banerjee, Just Transition Framework for India: Policies, Plans and Institutional Mechanisms. 2023. International Forum for Environment, Sustainability and Technology (iFOREST), New Delhi, India. Page 110

vii. Securing finances for just transition

Just transition experiences across the world shows that the financial requirements are extremely significant. Investments in several areas are required to ensure an environmentally and socially responsible transition of the fossil fuel sectors and fossil fuel-dependent industries, rebuild a resilient and equitable economy while addressing energy security concerns. An analysis of the just transition plans and financial needs of several coal regions reveals that these financial requirements are primarily related to coal mine reclamation and repurposing, decommissioning of thermal power plants, labour support and transition, economic diversification, community resilience, green energy investments, revenue substitution and energy price support, and planning and governance (Bhushan, 2023).

Considering the various cost components, the costs of just transition will be extremely high for India given the scale of our fossil fuel economy, of which coal is the most significant one. This will require mobilising resources through public sector financing, private investments, and international financial support (Tandon, Mitra and Robins, 2021).

An immediate opportunity in hand lies with utilising District Mineral Foundation (DMF) funds that is available in the coal districts to benefit the mining-affected areas and local communities, and improve livelihood opportunities and development outcome of these regions. As of latest estimates (February, 2023), over Rs. 76059.8 crores have been accrued in DMFs across mining districts, out of which the contribution of coal and lignite mining is over Rs. 29,237 crores. The top coal producing states, including Chhattisgarh, Madhya Pradesh, Jharkhand, Odisha, Maharashtra and Telangana account for 75% of the DMF funds (Ministry of Mines, 2023).

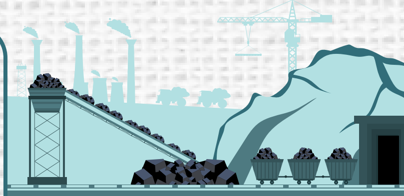
viii. Restructuring of the fossil fuel sectors to support just transition

Government-supported restructuring of the coal mining and coal-based power industry and diversifying their business portfolio will be an essential mechanism for revenue substitution of the Government and aiding economic diversification in the states and districts. Restructuring of the oil and gas sectors will also be necessary in the coming years.

For the coal mining sector this will involve restructuring of Coal India Limited (CIL) and its subsidiaries for diversification into solar, wind, energy storage, etc., which is also aligned to the public purpose of ensuring energy security (Bhushan and Banerjee, 2023). The industry is already taking measures to invest in green energy. In April 2021, CIL established two wholly-owned subsidiaries, Solar PV Limited and CIL Navikarniya Urja Limited for manufacturing of solar value chain products (ingot-wafer-cell module) and for undertaking RE projects. The Ministry of Coal has also insisted upon the coal company to take up decarbonisation and diversification initiatives. Following the 'mandate', in September 2021, CIL announced a plan to establish a 4 GW solar PV ingot wafer-cell-module manufacturing plant (CIL, 2021).

Overall strong government support and institutional mechanisms will be necessary to support a just transition. The central government will have a key role in formulating national level policies and institutional mechanisms and mobilising finances for a just transition. The Government needs to develop a comprehensive National Just Transition Framework which will have the overarching objective of guiding national policies and programmes, financial allocations, and institutional and governance mechanisms to support just transition. A key component of the national framework shall be the development of a National Just Transition Policy to set targets for phase down and transition, and focus on green growth, green jobs and the development of fossil fuel regions. Also, a dedicated administration system just transition, such as a Department of Just Transition need to be developed at the national level to facilitate inter-ministerial and inter-state coordination and for other administrative purposes.

At the state level, State Just Transition Framework(s) will need to be developed by



various state governments aligned with the national targets and considering state-specific circumstances. The state-level framework will primarily guide the formulation of state and district-level just transition plans, aid regional development, enable the convergence of programmes, facilitate negotiation with industries and labour, and help to implement and monitor just transition measures in a participatory manner. As a dedicated administrative system, an Office of Just Transition need to be established as the nodal authority to coordinate, plan and implement just transition measures.

In all cases, the process of developing policies, plans and implementation measures for just transition should be inclusive and participatory. To ensure this, an independent Just Transition Commission need to be developed at the national level, and independent Just Transition Task Forces at the state level, to facilitate stakeholder dialogue and integrate their perspectives and aspirations for developing a new economy.

References

Banerjee, S. 2022. Just Transition of End-of-Life and Unprofitable Mines: A Legal Assessment. International Forum for Environment, Sustainability and Technology (iFOREST), New Delhi, India.

Bhushan, C and Banerjee, S. 2023. Just Transition Framework for India: Policies, Plans and Institutional Mechanisms. International Forum for Environment, Sustainability and Technology (iFOREST), New Delhi, India.

C. Bhushan, S. Banerjee, C. Shalya and D. Pande. 2022. Angul: Planning a just energy transition and a new green economy. International Forum for Environment, Sustainability and Technology (iFOREST). New Delhi, India.

Coal India Limited (CIL). April 16, 2021. Incorporation of two wholly-owned subsidiaries of Coal India Limited. https://www.coalindia.in/media/documents/REG30.pdf

Government of India. 2022. India's Updated First Nationally Determined Contribution Under Paris Agreement (2021-20□0). https://unfccc.int/sites/default/files/NDC/2022-08/India□20Updated%20First%20Nationally%20Determined%20Contrib.pdf

International Energy Agency. 2021. India Energy Outlook 2021. IEA, Paris, France. https://www.iea.org/reports/india-energy-outlook-2021

International Labour Organization, Skills Development for a Just Transition. 2022. Geneva, Switzerland. https://www.ilo.org/global/topics/green-jobs/publications/just-transition-pb/WCMS_860617/lang--en/index.htm

Ministry of Environment, Forest and Climate Change. February 3, 2022. India's Stand at COP-26. Government of India. https://pib.gov.in/PressReleasePage.aspx?PRID=1795071

Ministry of Mines. 2023. DMF Fund Status till February 2023. https://www.mines.gov.in/

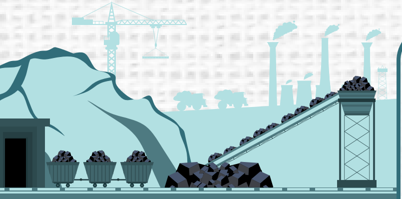
NITI Aayog, Government of India. Multidimensional Poverty Index 2021. Available https://www.niti.gov.in/sites/default/files/2021-11/National_MPI_India-11242021.pdf

Office of the Prime Minister. August 15, 2021. Government of India. Prime Minister's Address on 75th Independence Day. https://www.pmindia.gov.in/en/news□updates/pms-address-from-thered-fort-on-75th-independence-day/

Sarkar, S. 16 November, 2022. Many nations join India's call to phase down all fossil fuels. Mongabay. https://india.mongabay.com/2022/11/many-nations-join-indias-call-to-phase-down-all-fossil-fuels/

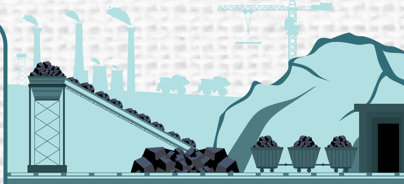
Tandon, S., Mitra, A. and Robins, N. 2021. Towards a Just Transition Finance Roadmap for India: Laying the foundations for practical action. https://www.bii.co.uk/en/news-insight/insight/articles/towards-a-just-transition-finance-roadmap-for-india/

United Nations. 2015. Paris Agreement to the United Nations Framework Convention on Climate Change. Paris, France. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

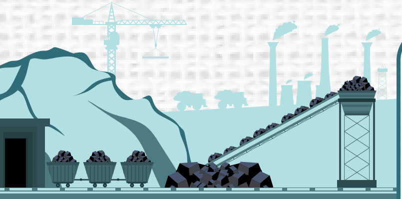


CMPDIs PUBLICATION

SI No.	Name of the Book
1	कोयले की गवेषणा
2	कोयला शैलिकी
3	खुली खान का आयोजन
4	झेन प्रबंधन तकनीक
5	खनन इलेक्ट्रॉनिकी
6	खान की गैसें
7	विस्फोटकों का सुरक्षित उपयोग
8	सपोर्ट प्लान एवं डिजाईन का मार्गदर्शन
9	रियर डंपर प्रचालकों के लिए नियमावली
10	नियमावली चाल एवं कांती की सुरक्षा एवं सपोर्ट
11	करणीय एवं अकरणीय: सूक्ष्मतर चूर्ण कोयला परिष्करण संयंत्र
12	करणीय एवं अकरणीय: मैग्नेटाइट प्रिपरेशन प्लांट
13	बेल्ट कन्वेयर के लिए क्या करें, क्या न करें
14	क्रशर के लिए क्या करें, क्या न करें
15	कोल बेड मिथेन: एक स्वच्छ ऊर्जा स्रोत
16	रक्षा के लिए
17	विस्फोटक
18	Coal Combustion
19	Mine Winders and winding Systems



20	Coal Atlas of India
21	Information on Indian Coal
22	Mine Pumps for Underground Drainage
23	Do's & Dont's for Belt Conveyors
24	Do's & Dont's for Crushers
25	Mine Fans & their use in Mine Ventilation
26	Electricity in Underground Coal Mines
27	Environment in Underground Coal Mines
28	Underground Mines Fires & Explosion
29	Coal Mine Roof Support
30	Underground Coal Mining in India
31	Artificial Recharge and Rainwater Harvesting Techniques
32	Coal: Its Properties & Characterizations
33	A Handbook on Dragling dump profile in Surface coal mines of India
34	Handbook of Coal Petrography
35	Rock Bolting in Indian Mines
36	Engineering Empirics
37	Explosives (English)
38	Ready Reckoner for Managing Environment of CIL Mines
39	Mind Behind Mines
40	Guidelines for Support Plan



Ecological Impact of Seasonal Nala (Water streams) diversions from Coal Mining Projects

Nirbhay Bhatnagar[1]

Abstract

Nala diversion in opencast coal mining poses substantial ecological risks, including habitat loss, water flow disruption, and sedimentation. This can lead to biodiversity decline, ecosystem service disruption, and invasive species introduction. While impacts may be lessened in seasonal nalas or with proper mitigation, careful planning and restoration efforts are crucial to minimize harm and protect surrounding ecosystems. The present study was carried out in Kedla OCP mines where there is a proposal of Kedla Nala diversion due to coal mining activity.

I. Introduction

Kedla OC & UG situated in the eastern part of West Bokaro Coalfield in Mandu Development Block of Ramgarh District of Jharkhand., Area- 1084.49 Ha. (OC) and 333.5 Ha. (UG). CMPDI undertake detailed flora & fauna impact study for Nala diversion for Kedla OCP. The general topography of the project area is undulating, broken by small hills, the elevation varying from 324m to 382 m above MSL. The drainage is by easterly flowing Bokaro River on the south and Chutua Nala, a tributary of Bokaro River on the North.

About Kedla Nala:

The existing Kedla Nala along with its tributaries is flowing across the lease area. The maximum discharge of the Existing Kedla shall be determined from the catchment area using Topo sheet. The alignment of diverted channel shall be decided with topography, utilising the existing surface features. Diversion of this Nala shall facilitate mining activities as well as to avoid flooding of mines, which is a serious threat to human life and property. The tentative route has been proposed for diverted channel from the existing Kedla Nala to western side of Mine Boundary as shown in the layout 1.2. The Existing Kedla Nala flows through Kedla block in eastern direction. The start point of diversion is the point where existing Supai Nala is as shown in the layout drawing in Figure 1.2.

The total length of the diverted Nala is approx. 5 KM. The proposed diverted Nala will meet the

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existing Bokaro Nadi as shown in Figure 1.1: The layout drawing. The diverted Nala for Kedla Nala will cater the same discharge as a result of proposed diversion.

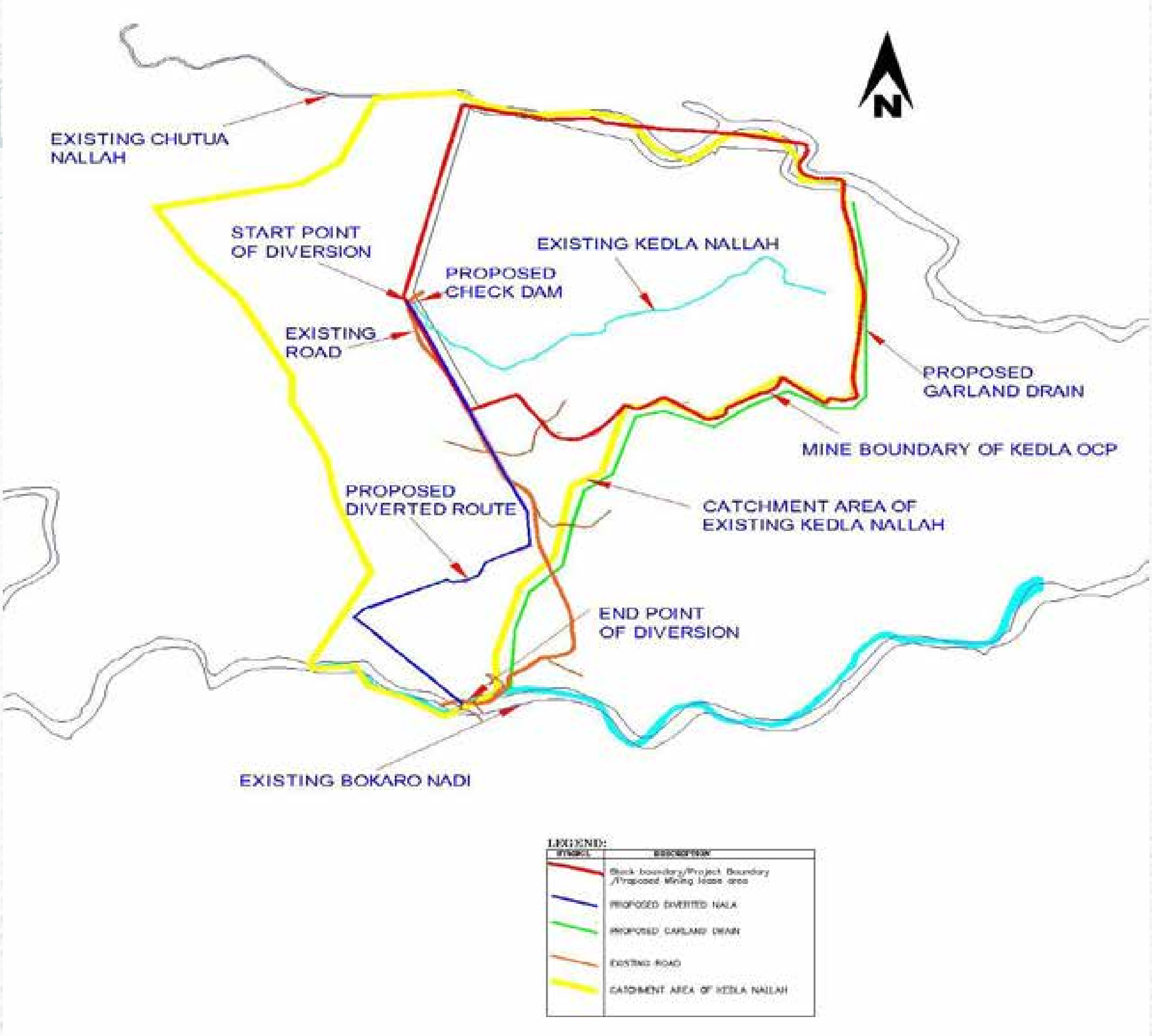


FIGURE: Proposed Nala Diversion Plan

Methodology Adopted:

Flora Assessment

The present study on the floral assessment for the proposed project activity is based on extensive field survey of the area. The study area comprises of flora of existing Kedla Nala, flora of proposed diversion of Nala and 10 km of buffer zone. The study was conducted in pre monsoon season (2022) the plant species were identified by field visit & with the help of taxonomists & local peoples. Plant community was studied by Quadrate method. Randomly quadrates were laid down with the size of each quadrate being 10 × 10 m for tree strata, 5 × 5 m for shrubs, and 1 × 1 m for herbs. While sampling, circumference at breast height (CBH) of tree species was measured at 1.37 m from ground level, along with the name of the species, phenology (flowering, fruiting, and flushes), and uses.

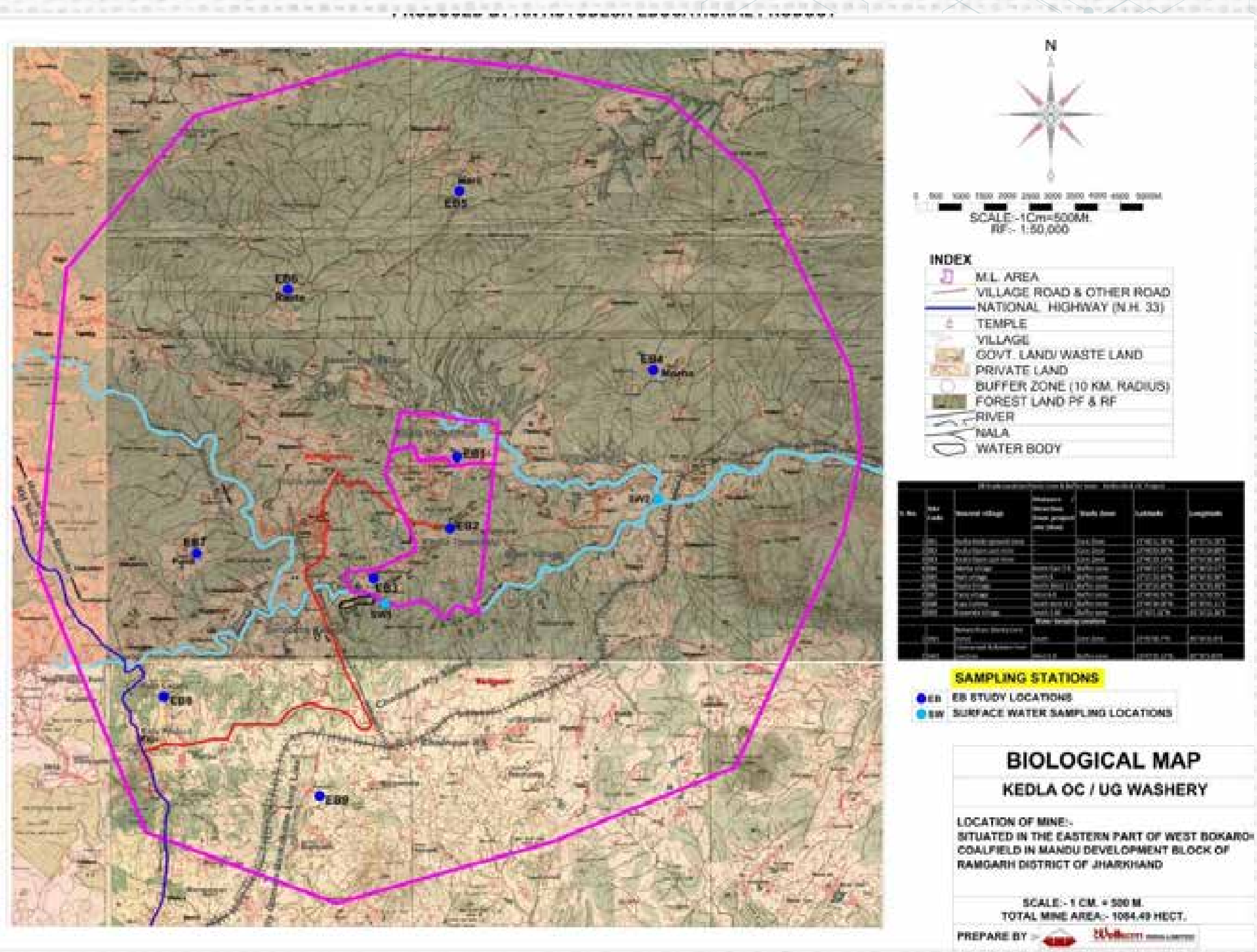


FIGURE: Biological sampling points in study area

FIGURE: Site Visit of Kedla OCP and Kedla Nala with CMPDI and CCL Team

FIGURE: Panoramic view of Kedla OCP

Equipment/Material used: -

Digital camera, GPS, Brunton Compass, Magnifying Glass, Hammer, Sample bag, Binocular, Rope, ballpoint pen, field notebook, etc.

FIGURE: Instruments used in ecological survey

Quantitative Assessment of plant diversity:

Quantitative characters are those that can be expressed in quantitative terms i.e. can be measured. These include characters such as Density, Frequency, Abundance, Cover & Basal area.

(i) Density:

Density is an expression of the numerical strength of a species where the total number of individuals of each species in all quadrates is divided by the total number of quadrates studied. Density is calculated by the equation:

$$\text{Density} = \frac{\text{Total number of individuals of A Species in all quadrate}}{\text{Total number of quadrates studied}}$$

(ii) Abundance:

It also called like density but in this case, only those quadrates are considered for calculation where a species actually occurs. The formula for calculation of species abundance is

$$\text{Abundance} = \frac{\text{Total Number of Plants in all Quadrates occurred}}{\text{Total number of quadrates in which the species}}$$

(iii) Frequency:

Frequency is another important parameter of vegetation analysis, which reflects the spread, distribution or dispersion of a species in a given area and given in %.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrates in which species occurred X100}}{\text{Total number of quadrates studied}}$$

Importance Value Index (IVI)

This index is used to determine the overall importance of each in the Community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative Dominance/ Abundance are summed up together and this value is designated as Importance of value Index or IVI.

Basal area

The basal area was calculated using the following formula:-

$$\text{Basal area of a single tree} = \pi \times r^2$$

$$r = \text{radius,}$$

$$\pi = 3.14$$

The total basal cover calculated by the multiplying mean basal cover and density of the species.

$$\text{Relative density} = \frac{\text{Individual Density of a Species X 100}}{\text{Total Density of All Species Encountered}}$$

$$\text{Relative frequency} = \frac{\text{Individual frequency of the species x 100}}{\text{Total frequency of all species Encountered}}$$

$$\text{Relative Abundance} = \frac{\text{Individual abundance Of a Species X 100}}{\text{Total abundance of All Species Encountered}}$$

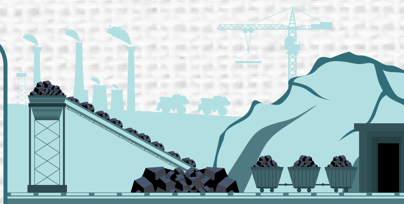
Indices used to determine Biodiversity of the Study Area

A. Simpson's Diversity Index is the most meaningful measure of evenness. Ds is the probability that two randomly sampled individuals are from two different classes. Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

$$D = 1- \left(\frac{\Sigma n(n-1)}{N(N-1)} \right)$$

n = the total number of organisms of a particular species
N = the total number of organisms of all species

The value of Simpson's index **D** ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.



Faunal Assessment

The study of fauna takes substantial amount of time to understand the specific faunal characteristics of the area. The assessment of fauna was done by extensive field survey of the area and secondary literature. During survey, Line Transect method was used for the study of mammals and Transact & Patch sampling was used for Amphibians, visual encountered methods was used for reptiles, Aerial net was used for butterflies. The presence of wildlife was also confirmed from animal call, foot marks, excreta and from the local inhabitants depending on the animal sightings and the frequency of their visits in the project area which was later confirmed from different government offices like forest department, wildlife department etc.

Status of Flora in the Existing Kedla Nala:

The existing Kedla Nala is flowing to an approximate distance of 15 km and it will be disturbed only in the mine area. In the rest of the area, it will flow and merge with Chotua river. The bund is equal to the ground level in some places. Some places the bund is 3-4 tall and forms a slope. Thick vegetation present in these slopes. The biodiversity index is 0.42. 12 tree species belong to 7 families are identified. Besides several hydrophytic/swamp area plants found in the vicinity of the stream. Usually cattle and sheep herds, birds will come to the stream for drinking water. Often the area is with rich nutrients, plant community is usually rich in the stream area. The tree species found in the bund area of the taller and stout because continuous water availability. Several shrubs, climbers also present in the area. The climbers like Ichnocarpus frutescence are covering the trees densely. Sedges, Typha, Colocasia, Hygrophila, ferns (Marsilea) , filamentous algae used to grow in the stream margin.

Figure: Existing Kedla Nala besides agriculture field and near KOCP OB dump

Status of Flora in the Proposed diversion route of Kedla Nala

The total length of the diverted Nala is approx. 5 KM. Suitable no. of vertical drops of 2 m height each, has been envisaged depending on the actual terrain. The starting point of the stream close to the hillock and a road junction. People moving in the route, staying nearby using the water for taking bath, washing cloth, cleaning the vehicles and contaminate the water. In the proposed diversion route agriculture land, residential area and. Total distance is falling to the extent of 5 km. At the end it merges with another existing stream nearly to a distance of 500m. Finally it confluences with the Bokaro river. In this route 11 species of trees belong to 9 families are observed. Some are cultivated in the residential area and some in agriculture land and 6 species are wild. The Simpson biodiversity index for these trees is coming to be 0.24 which is less when compare with the existing Nala (0.42). Near the Bokaro river where this Nala confluences the biodiversity is rich and it is a reserve forest. It is close to the TATA steel residential colony. Tree species such as Kullu (Firmiana simplex), Kala siris (Albizia odoratissima), Kurrah (Holarrhena pubescence) Daura (Anogeisus latifolia), Polash (Butea monosperma), Sal (Shorea robusta), lendia (Lagerstroemia parviflora) etc. are present.

Figure: Quadrate Survey in the proposed route

Status of Faunal Species in the Study Area:

The faunal species data were mainly collected through secondary means via local community consultation, discussion with forest officials and secondary literature. It was found that no rare, endangered or threatened species is found in the study area.

S. No.	Common Name	Scientific Name	Family	Status as per WPA-1972	IUCN status
Mammals					
1.	Jungle cat	Fellis chaus	Felidae	Schedule II	Not evaluated
2.	Five striped palm squirrel	Funambulus pennanti	Sciuridae	Schedule IV	Least Concern
3.	Indian Fulvous Fruit- Bat	Rousettus leschenaultia	Pteropodidae	Schedule-V	Least Concern
4.	Indian Field Mouse	Mus booduga	Muridae	Schedule-V	Least Concern
5.	Common House Rat	Rattus rattus	Muridae	Schedule-V	Least Concern
6.	Indian Jackal	Canis aureus	Canidae	Sch II	Not evaluated
7.	Bandicoot Rat	Bandicotabengalensis	Muridae	Schedule-V	Least Concern
8.	Indian Grey Mongoose	Herpestes edwardsi	Herpestidae	Schedule II	Least Concern
Reptiles & Amphibians					
9.	Garden lizard	Calotes versicolor	Agamidae	Schedule-IV	Not evaluated
10.	Common skink	Eutropis carinata	Scincidae	Schedule-IV	Least Concern
11.	King cobra	Ophiophagus hannah	Elapidae	Schedule II	Least Concern
12.	Cobra	Naja naja	Elapidae	Schedule II	Least Concern
13.	Pit viper	Crotolus sp	Viperadae	Schedule – II	Least concern
14.	Garden lizard	Calotes versicolor	Agamidae	Schedule-IV	Not evaluated
15.	House Gecko	Hemidactylus flaviviridis	Gekkonidae	--	
BIRDS SPECIES					
16.	Crow	Corvus splendens	Corvidae	Schedule V	Least concern
17.	Little brown dove	Spilopelia senegalensis	Columbidae	Schedule-IV	Least concern
18.	Black drango	Dicrurus adsimilis	Dicruridae	Schedule-IV	Least concern
19.	Pigeon	Columba livia	Columbidae	Schedule IV	Least concern
20.	Myna	Acridotheres tristis	Sturnidae	Schedule IV	Least concern
21.	Red-vented bulbul	Pycnonotus cafer	Pycnonotidae	Schedule-IV	Least concern

Conclusion:

Most parts of this study area are full of forests and stones. The forest of the district comprises of tropical deciduous vegetation due to high temperature and humidity. The buffer zone mainly consists of Protected Forest and open mixed jungle. The main species found in the study area are Sal, Palash and Mahua, Cassia, Tendu & Mango etc.

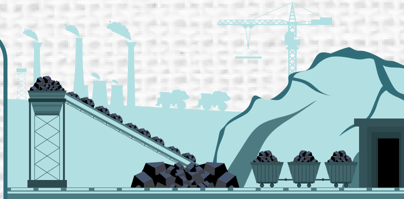
The existing Nala area has trees like Peepal(Ficus religiosa), Shisam(Dalbergia sisoo), Polash(Butea monosperma), Kaim (Mytragyna parviflora) Seemal(Bombax ceiba), Hara pan(Ehretia laevis), Ber(Zizyphus mauritana) in its bund area, hydrophytic plants like Typha angustata, Colocasia esculenta, Hygrophila phlomoides, Perscaria glabra, Mimosa pudica, Saccaharum spontaneum, Ipomoea carnea etc. are growing along the stream. The proposed diversion root passes through agriculture land (encroached) and a small village and then it mingles with small stream then both streams together confluences in Bokaro river. In the new route villagers planted trees like Tamarind (Tamarindus indica), Mango (Mangifera indica), the forest stretch has Polash (Butea monosperma), Kurrah (Holarrhena pubescence), Lendia (Lagerstroemia parviflora), Neem (Azadirachta indica), Babul (Vachilla nilotica), Climbers like Malkangni(Celastrus paniculatus) associated with the trees. Simpson's bio diversity in the existing nala and the proposed diversion route has been found to be 0.42 and 0.24 respectively.

Impact of Nala Diversion on Flora & Fauna

The dust is the major pollutant which will be generated from different mining activities such as blasting including drilling holes, operation of machinery as excavator and movement of dumpers/trucks can have impact in terms of disturbance due to noise; interference in movement etc. Mining activities leads to a dusty environment which is responsible for deposition of dust on foliage of all green plants in the area. The effect of particulate matter on plugging of stomata, and loss of chlorophyll and reduction of photosynthesis process. Disturbance in plant metabolism due to deposition of dust particles on foliar surfaces leads to reduction in plant growth.

Riparian ecology of the existing Kedla Nala in the coal bearing area will be damaged due to coal mining operations coupled with lack of water source. The infrastructure development for the purpose of Nala diversion would lead to the temporary loss of bio-diversity in the proposed diversion sites. The spawning/breeding grounds for aquatic species, avifaunal species may be affected due to Nala diversion, as a result the population of the species may be affected temporarily. But, since Kedla Nala is a seasonal stream and water flow is almost negligible most of the time in a year, the impact on flora & fauna species in the existing Nala route will be limited and new riparian ecosystem will be developed in the proposed Nala diversion route.

The impact on the fauna of the buffer zone due to the mining activity will be marginal. During operation phase nesting sites of different bird species will be affected due to tree cutting. The other major impact on the fauna in and around the proposed project area would be due to increased level of human interferences. The workers may also cut trees to meet their requirements for construction of houses and other needs. During construction phase, a large number of machinery and construction labour will have to be mobilized. This activity may create some disturbance to sensitive species of reptiles, small mammals, and birds to the surrounding similar habitat. The operation of various construction equipment is likely to generate significant noise. The noise may scare the fauna in the region and force them to migrate to other areas. However, the impacts of Nala diversion on fauna would be temporarily event and after diversion similar habitats will be developed.



Introduction of 5G for real time applications in coal mines

Santosh Kumar Mahto[1], Praveen Kumar[1], Rahul Kumar[2],

Abstract

The mining sector in India has experienced remarkable development in the past few years and its contribution are very crucial in the growth of Indian economy. Coal mining is considered the most strenuous and hazardous task in the mining business. The growth in coal production mining sector can be enhance by utilizing 5G technology and offers good connectivity, ensuring safety, high reliability, efficient and large data transmission capacity and seamless communications with low latency. The private 5G network is implemented for real-time communication between autonomous mining vehicles, improving fleet management and coordination while reducing human intervention. 5G-enabled IoT sensors and analytics were deployed in underground mines, providing early detection of potential risks and ensuring worker safety through real-time monitoring of structural integrity. Remote operations in mining leverage advanced technologies such as IoT and automation, offering benefits such as improved safety, increased productivity, enhanced efficiency, and cost savings through reduced on-site staffing and logistics. By implementing remote operations, mining companies can optimize operations, reduce personnel exposure to hazardous environments, make data-driven decisions, and achieve higher levels of safety, productivity, and sustainability in their mining operations. Real-time monitoring of mining operations powered by 5G technology enables continuous data collection, analysis, and decision-making, leading to improved operational efficiency, predictive maintenance, and enhanced safety measures in the mining industry. 5G-powered mining demonstrates the potential for real-time monitoring, including remote equipment tracking, environmental monitoring, and worker safety monitoring, enabling mining companies to optimize operations, mitigate risks, and ensure regulatory compliance.

I. Introduction

The advanced mobile telephony system (AMPS), which was the first commercialized wireless telephone system in the United States, became operational in late 1983. Around once in ten years, an updated set of mobile communications technologies has been released, with the initial version (1G) being deployed in the 1980s. During 1G to 3G, cellular voice communication was the primary application driving the evolution of cell phone technologies. Mobile broadband data applications have emerged as the driving force behind the continued development of wireless communication systems since the advent of 3G. At present, the fourth generation (4G) wireless

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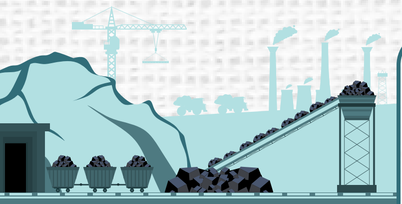


networks, also known as the Long-Term Evolution (LTE), are being extensively implemented in order to provide mobile high-speed data services. The advancement from 4G to 5G will facilitate a wider range of applications and utilization circumstances. Three domains of utilization and implementation have been designated by the International Telecommunication Union's radiocommunication sector for the 5G era: enhanced mobile broadband, low-latency, massive machine-type communications, and ultra-reliable communications [1] as shown in Figure 1. In order to facilitate an extensive variety of scenarios for use and applications in the era of 5G, it is imperative to develop mobile communications systems for the next generation that integrate more sophisticated technological solutions. Such systems should strive for increased data speed, decreased delay, expanded capacity, and improved efficient spectrum use [2]. The next generation of wireless access technology is outfitted with these more sophisticated features.

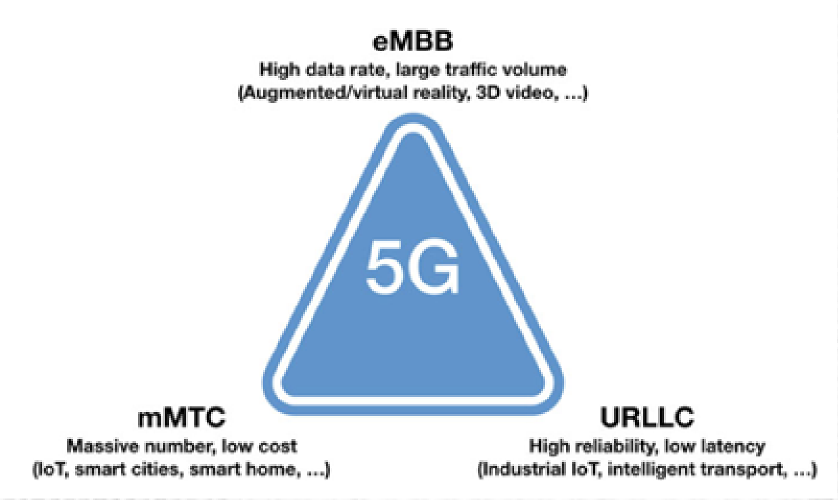


Figure 1: 5G usage scenarios [3]

The forthcoming version of communication technology is outfitted with these more sophisticated features. Although wireless services for data and wireless voice telephony continue to be the main uses for wireless communication systems, new uses for the Internet of Things (IoT) and the industrial revolution are beginning to propel the industry's upcoming expansion. To attain faster data speeds, reduced delay, higher capacity, and more effective spectrum application, 5G communication systems will require an updated mobile communications system that combine more sophisticated technological explanations. The subsequent generation of wireless access technology is the crucial allowing skill for facilitating the various usage scenarios and applications that are anticipated for the 5G period. At the core of 5G lies a collection of essential technologies that enhance network efficiency and facilitate the introduction of novel services, ecosystems, and revenue streams.

The coal-mining sector has experienced an important change in paradigm in recent times, largely driven by enhancements in technology. One significant development is the integration of 5G wireless technology, which has the potential to greatly change operations in coal mines worldwide. Due to the ongoing demand for coal in many industries including power generation and manufacturing, there is a pressing need for mining methods that are efficient, safe, and environmentally friendly. However, traditional communication infrastructure often does not meet the evolving needs of modern mining operations. Implementing 5G infrastructure provides a ground-breaking opportunity to overcome limitations and create new possibilities for the coal mining industry.

II. 5G applications in coal mines:

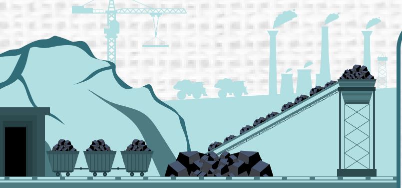
1. Real time dump slope monitoring in opencast mines:

Significant amounts of decomposed waste rock and scattered topsoil are extracted and deposited at a particular site during the mining process, leading to the development of several substantial man-made landfills that exceed a height of one hundred meters [4]. Some landfills have a capacity of tens of millions of cubic meters, while others can accommodate hundreds of millions. The local safety is jeopardized by the slope instability caused by the unsecured structures of the disposal sites, which increase the likelihood of landslides or debris flows, particularly in the aftermath of heavy rainfall [5]. Consequently, it is critical to track the stability of landfills in order to safeguard the assets and lives of those who work and live nearby.

The landfill site consists primarily of loose topsoil and fragmented rock. Ancient blended granites and metamorphic rocks from the archaea to the early proterozoic era compose the rock. The landfill contains both hard and soft rocks stacked thereon. The hard-rock mass comprises mixed granite, granulite, amphibolite, and low-grade magnetite quartzite. The soft rock consists of phyllite, quartz schist, and chlorite schist. Due to the resistance of the hard granite formations to significant shear forces without deformation, landslides transpire infrequently in this area. Conversely, malleable rocks are predominantly flexible, characterized by low fracture capacity and susceptibility to deformation.

China makes extensive use of mapping techniques such as GPS measurements, total station measurements, and prism leveling as a result of the ongoing progress of technological and scientific advancements. Nevertheless, the ability of ground measurement technology to precisely measure distortion at a limited number of locations renders. It challenging to extract distortion patterns for an entire area. For large area displacement monitoring, synthetic aperture radar interferometry (InSAR) has gained significant traction by way of a supplementary method to conventional ground survey methods. This is particularly true due to the swift advancements in time series InSAR (TS-InSAR) computations, including small baseline subset (SBAS) analysis and permanent scatters interferometry (PSI) [6-8]. Despite its extensive utility and promising accuracy in measuring distortion, overcoming the inherent side-looking topology of SAR sensors, which introduces constraints to 1-D line-of-sight (LOS) measurements, continues to be a formidable challenge [7]. The effective implementation of TS-InSAR expertise is significantly hindered by the challenge of accurately converting 1-D LOS measurements to the actual dislocations of ground marks, given that ground displacements typically occur in both vertical and horizontal directions.

Currently, there are three distinct approaches to resolving three-dimensional surface displacements [7]. One approach involves the integration of azimuth measurements and multi-pass LOS derived from SAR examinations. As an illustration, 3-D dislocations can be obtained through the integration of InSAR LOS measurements obtained from a minimum of three viewing angles [7,9]. Alternatively, one can accomplish this by merging InSAR LOS with azimuth measurements obtained from multi-aperture interferometry (MAI) or offset tracking (OT). The second method involves the integration of GPS data with InSAR measurements. However, meeting the aforementioned approaches' requirements is frequently challenging. Each of the aforementioned strategies has its own limitations and is only applicable under specific conditions. To illustrate, fused multi-pass InSAR LOS measurements are restricted to regions characterized by the availability of numerous stacks of data, and their ability to provide precise orientations is primarily observed at high latitudes [9]. The accuracy of combining azimuth measurements from OT or MAI with InSAR LOS



measurements for displacements is compromised due to the OT and MAI's relative insensitivity to sluggish displacements. The extent to which InSAR measurements and GPS data are integrated is highly contingent on the quantity and dispersion of GPS examination. Opportunely, there exists a third approach to alleviate the criteria for TS-InSAR examines; it merely entails the translation of the InSAR measurements using pre-existing information. Investigating the collapsing of a large area, for instance, it is possible to disregard horizontal deformation under the assumption that dislocations happen exclusively in a similar line to the ground surface; this also applies to glacial movements and landslides. In addition to TS-InSAR, supplementary technologies for remote sensing are required to conduct a comprehensive investigation of ground displacement. Real-time dump slope monitoring in opencast mines is a critical aspect of ensuring the safety and stability of mining operations.

A singular radar monitoring system utilized at the mine for highwall or low wall surveillance is illustrated in Figure 2. Azimuthal panning capability of the radar enables surveillance of structures at considerable strike distance. Due to the radar's sensitivity being constrained by line-of-sight (LOS) deformation, this method is ineffective, especially when monitoring obliquely. The implementation of numerous radar systems to surveillance a solitary wall is infrequent at this and similar coal mine locations owing to the exorbitant expenses linked to such infrastructure.

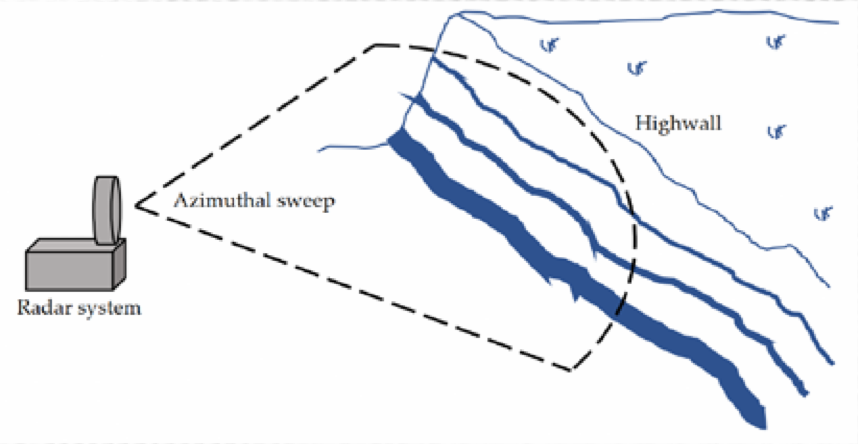


Figure 2. Single radar-based monitoring system [8].

2. Remote controlled Blasting

Blasting is an essential procedure in the mining process, utilized in both underground and open cast mining operations to break the solid surface bed into pieces that can be managed by mining machinery. Figure 3 illustrate the blasting site of coal mines. The variety of rock sizes generated from blasting has significant effects on subsequent processes, such as the energy usage and efficiency of grinding and crushing systems. The fragmentation procedure caused by the blast is influenced by the dimensions of the blocks in the natural block mass, known as the in-situ block size distribution (IBSD). Block masses with a reduced initial block size distribution generally result in a smaller final block size distribution when the blast design remains constant. Obtaining a desired Blasting, Burden, Spacing, and Distribution (BBSD) needs a thorough quality control/quality assurance (QC/QA) process to verify the appropriate implementation of blasting parameters in the field. This involves overseeing the explosion site and evaluating whether the explosion pattern adheres to the intended design. Current blast inspection typically involves measuring the blast specifications and the resulting rock pile. Mining enterprises have to put much effort into monitoring blast dynamics, such as blast scheduling and identifying reasons for discrepancies between the anticipated blast result and the real waste heap.

Terrestrial high-speed cameras are commonly employed for observing blast behavior in open cast mines. It is crucial to limit disruption to the final pit walls while obtaining the intended disintegration. The mining process can accomplish the appropriate final wall structure and steepen the pit angle of slope by minimizing damage to the final pit walls. Minimizing over break has safety and economic ramifications by enhancing structure integrity, stability, and reducing waste rock removal. The existing methods for monitoring and evaluating the blasting procedure in open cast mines needs to be upgraded.

Figure 3: Coal mines blasting site [CMPDI brochure 2023]

The utilization of unmanned aerial vehicles (UAVs) in several open cast mining operations has witnessed a significant increase [10–15]. Terrestrial remote sensing methods like photogrammetry and LiDAR have become more common in the past ten years. However, a significant challenge with terrestrial remote detecting is the occurrence of occlusions [16]. Occlusions are regions that are not visible to remote detecting, either because of the geometric configuration or because of obstructing materials. Furthermore, by minimizing the amount of hazardous field environments that mine workers are exposed to, remote sensing helps allay a number of the security worries related to architectural modeling and fragmentation assessment. Utilizing UAVs can help to overcome obstructions though ensuring protection. Moreover, UAV systems provide improved proximity to the blasted rock piles or rock mass, which enhances the potential resolution of the created models. By combining top-notch aerial sensing data like 2D photos and high-speed video footage with digital photogrammetry and image analysis techniques, a sophisticated monitoring system may be developed for overseeing the blasting procedure in mining operations.

Emissions of toxic substances, including the increase in greenhouse gases, are among the primary contributors of environmental changes. Worldwide temperature of the earth and the amount of greenhouse gases in the environment have increased dramatically since the onset of the industrial revolution in the 18th century [17]. This is due to the discovery and widespread use of fossil fuels as the primary energy source. The natural greenhouse effect established the conditions that are essential for the emergence and maintenance of life on earth. However, as its magnitude escalates, it disrupts the equilibrium of ecosystem operations on a global and regional scale [18,19].

The aggregate of all greenhouse gas emissions that are generated by anthropogenic activity, whether directly or indirectly, is widely known as the carbon footprint [20,21]. The measure of carbon footprint is denoted as carbon dioxide equivalent (CO2e). The equivalence of a particular greenhouse gas to carbon dioxide is determined by multiplying its mass by its global warming potential [22,23]. Although there are variations in the methodologies employed by different nations (e.g., France, the United Kingdom, and the United States) and international organizations (e.g., the World Bank, the United Nations, the World Resources Institute, and the International Organization for Standardization), the overarching objective remains the mitigation of the adverse consequences associated with greenhouse gases [24,25]. These problems can be overcome with the help of multiple 5G enable sensors.

3. Safety Enhancements:

Certainly, coal mines are recognized as essential energy suppliers, and their smooth functioning is crucial for the worldwide economic structure. However, the complex nature and risks present in coal mines make them prone to regular safety problems. These dangers endanger miners and also interrupt the flow of mining operations. The significance of real-time monitoring methods for these dangers in coal mines has been emphasized. Digitalization may significantly enhance safety in mines by providing operators with comprehensive insights into all aspects of operations, including monitoring crucial parameters such as air quality and tunnel stability. An efficiently designed mine, particularly one equipped with cutting-edge 5G-enabled private networks, can provide miners with vital seconds that could potentially prevent accidents and save lives.

I. **Real-time Hazard Detection:** Developing a real-time comprehensive surveillance and threat forecasting system for coal-mines has been challenging due to their extremely complicated and constantly changing environmental conditions. Various toxic, combustible, and dangerous gases found in underground mines can negatively impact miners' health and lead to natural hazards such as mine fires and explosions [26], resulting in significant casualties and financial losses. Figure 4 displays the framework of the tracking and forecasting system. The system comprises two modules: MHQI for the working face and gas concentration in the goaf area. 5G enables the utilization of cameras and sensors based IoT for immediate monitoring of safety circumstances. This aids in promptly identifying threats, leading to a faster response to emergencies.

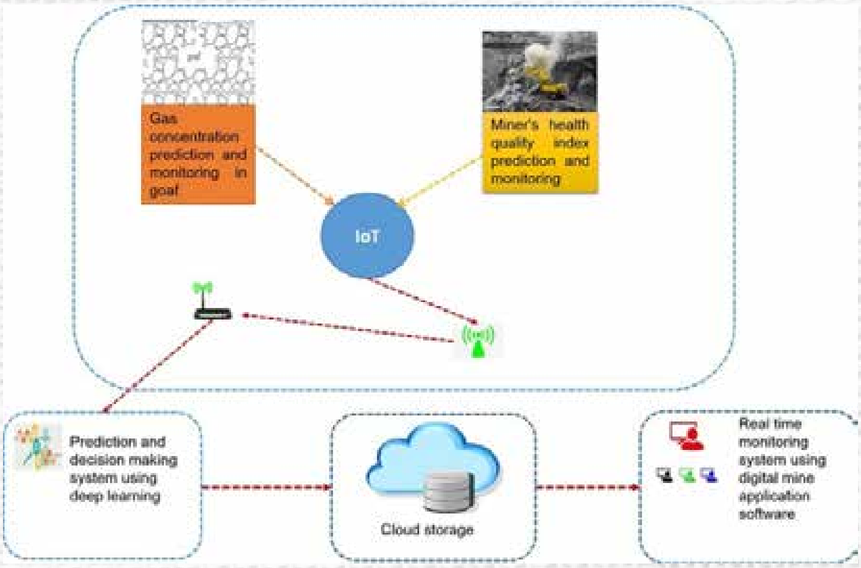


Figure 4. System architecture for real-time monitoring and prediction of mine hazard [27].

II. **Wearable Technology:** Wearable gadgets have quickly become important in the consumer electronics market and are seen as a new way to meet the needs of various businesses. The coal mines have researched the application of wearable gadgets in the workplace to manage health and safety through proximity detection and physiological monitoring of construction workers. Miners can utilize wearable devices connected via 5G for immediate health tracking and emergency communication. A wearable safety management system for miners to enhance safety by offering wearable equipment for mine workers as shown in Figure 5. The system incorporates multiple wearables to enhance safety, enable hands-free operation, and monitor employee wellness. The system comprises a sensor-equipped protection vest, smart spectacles, a smart helmet, and a smart watch as shown in Figure 6.

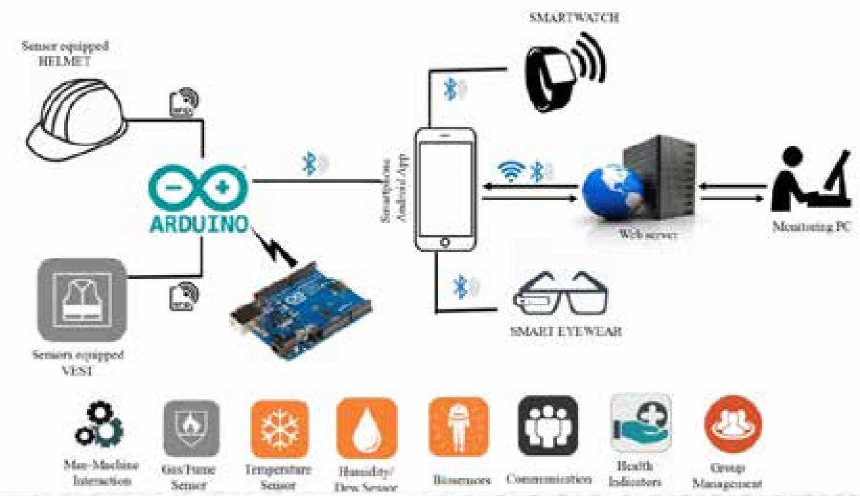


Figure 5. Wearable technology-integrated safety communication system [28].

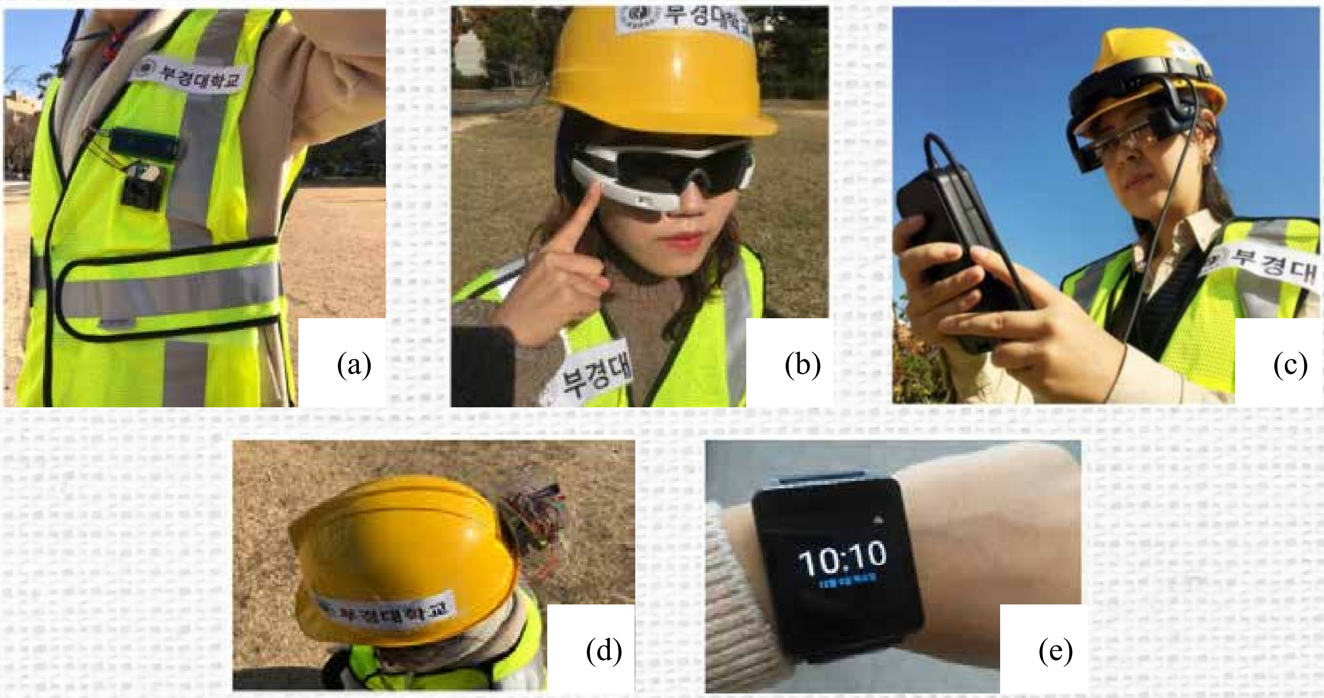


Figure 6. Proposed embedded wearable system shown at a mining site: (a) sensor-equipped mine safety vest; (b) miner wearing Recon Jet Smart Eyewear; (c) miner using Epson Moverio BT-2200; (d) sensor-equipped safety helmet; (e) smartwatch [28].

III. Smart Sensors and IoT: 5G allows for the implementation of a network consisting of intelligent sensors and Internet of Things (IoT) devices across the mine. Multiple sensors are utilized in IoT-based coal mine safety monitoring to provide alerts when a specific parameter exceeds predetermined threshold levels as shown in Figure 7. The sensors may gather data on characteristics like temperature, pressure, vibration detection, harmful gas detection, and humidity, offering insights into the general working conditions.

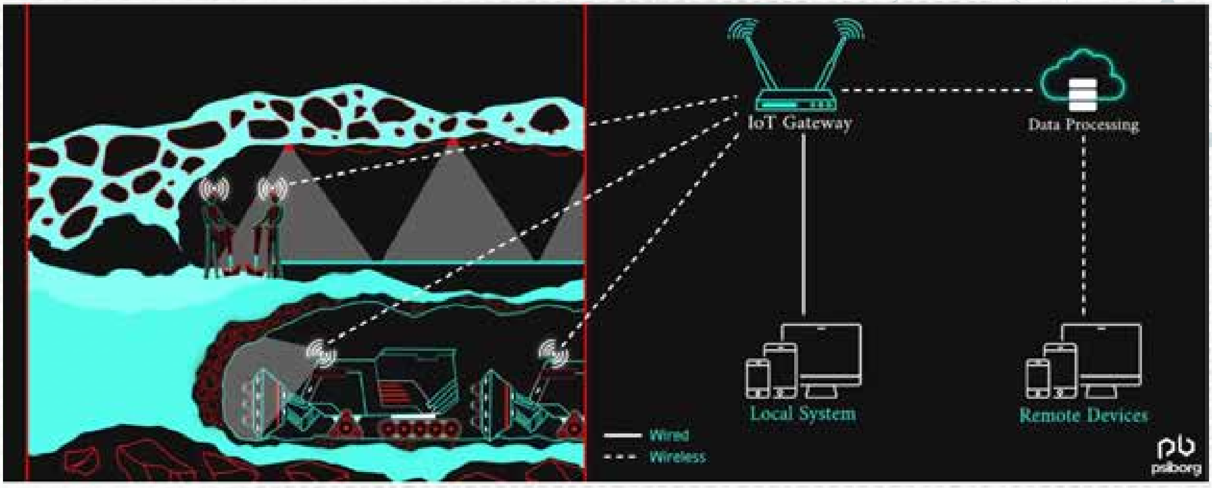


Figure 7: IoT dashboard for monitoring coal mines [https://psiborg.in/iot-based-coal-mine-safety-monitoring/]

4. Communication Infrastructure:

Millimeter waves (mm Wave), are used in 5G networks and have the capacity to transmit more data more quickly but only within a very small, unhindered communication range. These upper band radio frequencies can be sent and received by small cell antennas. The automation system and communication network's architecture are shown in Figure 8.

i. **Improved Connectivity:** 5G enhances communication networks within the mine, providing reliable connectivity for voice and data communication. This is crucial for coordinating activities and ensuring efficient communication among workers.

ii. **Reliable Connectivity:** 5G networks offer greater reliability compared to previous generations of wireless technology. In coalmines, where communication breakdowns can be life-threatening, reliable connectivity ensures continuous communication between miners, supervisors, and rescue teams.

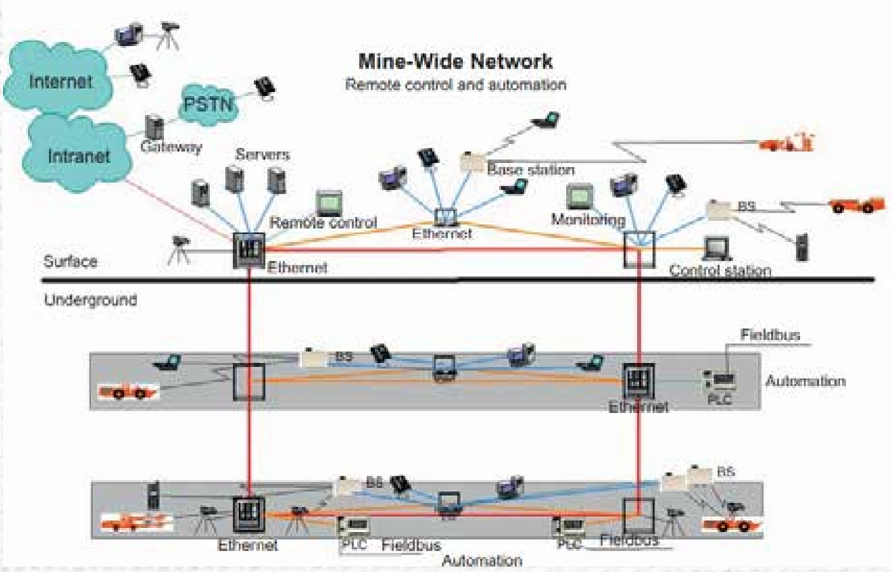


Figure 8: Communication and automation system [29].

iii. **High-speed Data Transmission:** 5G offers ultra-fast data transmission speeds, allowing miners to access and transmit large amounts of data quickly. This enables real-time monitoring of equipment, environmental conditions, and personnel safety.

5. Security and Surveillance:

With the transition from 4G to 5G mobile technology, video surveillance applications are positioned to experience a performance revolution. Presently, surveillance cameras are equipped with cellular connectivity, primarily due to the inability of 4G networks to provide the requisite rates for efficient video transmission. In contrast to 4G networks, which may experience bottlenecks when dozens of cameras are integrated into a system, 5G technology permits the deployment of thousands of cameras, all of which can broadcast UHD video in real time. The ability of a 5G network to transmit vast quantities of data across vast distances at lightning-fast velocities. 5G networks are capable of delivering latency rates of 1-4 milliseconds. The near-total elimination of latency will facilitate real-time surveillance, allowing security personnel to identify suspects and address events and emergencies with greater agility. Automation potential is significantly increased when real-time analysis is integrated; cameras can now communicate with other systems to instigate responses, such as sending an alert or activating an alarm, in response to detected events.

iv. **Low Latency:** 5G technology provides low latency, reducing the time it takes for data to travel between devices and servers. This is critical for applications like remote control of machinery and real-time monitoring of underground conditions.

i. **Camera Surveillance:** High-definition camera systems are supported by 5G for enhanced security and surveillance. This can aid in mine security monitoring and prevent unauthorized access to critical areas.

ii. **Drone Surveillance:** By deploying drones equipped with cameras and sensors, aerial surveillance of the mine can be conducted as shown in Figure 9. Real-time transmission of high-quality video and data is made possible by 5G connectivity, providing a comprehensive view of the mining area for monitoring and security purposes. Subsidiary of Coal India, Mahanadi Coalfields Limited (MCL) has implemented drone technology in coal mines for photogrammetric, volume measurement, and mapping environmental monitoring of mines to digitize the mining process, as depicted in Figure 9. The technology was introduced by launching a web-based site called 'VIHANGAM' together with a drone and ground control system.

Figure 9: Drone technology in coal mines [CMPDI brochure 2023].

III. Conclusion:

Since the beginning of the twenty-first century, the coal enterprises have advanced to a new phase focused on building inherently safe, smart, and environmentally friendly mines. Intelligence is essential for the advancement of coal-mines. It is a scientific and methodical idea that involves a dynamic and ongoing process. 5G technology will play a crucial role in advancing the development of smart coal mines. Smart coal mining and the integration of 5G technology in the coal mining industry have demonstrated the potential to enhance the information and intelligence capabilities of coal mining firms. The use of 5G networks for research and communication in coal mines is covered in this paper. In order to aid in the deployment and promotion of the coal mine communication field more successfully, it examines in detail the application of 5G key technology in conjunction with the benefits and features of 5G networks. 5G-powered mining demonstrates the potential for real-time monitoring, including remote equipment tracking, environmental monitoring, and worker safety monitoring, enabling mining companies to optimize operations, mitigate risks, and ensure regulatory compliance.

References:

[1] ITU-R, IMT vision–framework and overall objectives of the future development of IMT for 2020 and beyond, Recommendation ITU-R M.2083, Sept 2015.

[2] X. Lin, J. Li, R. Baldemair, T. Cheng, S. Parkvall, D. Larsson, H. Koorapaty, M. Frenne, S. Falahati, A. Grövlen et al., 5G new radio: unveiling the essentials of the next generation wireless access technology. IEEE Commun. Stand. Mag., 3(3), 30–37 (2019)

[3] Lin, Xingqin, and Namyoon Lee. "Introduction to 5G and Beyond." 5G and Beyond: Fundamentals and Standards 1-25 (2021)

[4] Cho, Y.C.; Song, Y.S. Deformation measurements and a stability analysis of the slope at a coal mine waste dump. Ecol. Eng. 2014, 68, 189–199.

[5] Steiakakis, E.; Kavouridis, K.; Monopolis, D. Large scale failure of the external waste dump at the “South Field” lignite mine, Northern Greece. Eng. Geol. 2009, 104, 269–279.

[6] Zebker, H.A.; Goldstein, R.M. Topographic mapping from Interferometric Synthetic Aperture Radar observations. J. Geophys. Res. 1986, 91, 4993–4999.

[7] Zhang, L.; Ding, X.L.; Lu, Z. Modeling PSInSAR time series without phase unwrapping. IEEE Trans. Geosci. Remote Sens. 2011, 49, 547–556.

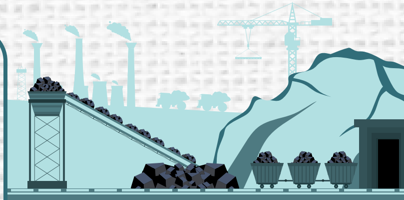
[8] Elmouttie, Marc, and Peter Dean. "Systems engineering approach to slope stability monitoring in the digital mine." Resources 9, no. 4 (2020): 42.

[9] Hu, J.; Li, Z.W.; Ding, X.L.; Zhu, J.J.; Zhang, L.; Sun, Q. Resolving three-dimensional surface displacements from InSAR measurements: A review. Earth-Sci. Rev. 2014, 133, 1–17.

[10] Gray, L. Using multiple RADARSAT InSAR pairs to estimate a full three-dimensional solution for glacial ice movement. Geophys. Res. Lett. 2011, 38, L05502.

[11] ISO 14688-1:2002: Geotechnical Investigation and Testing—Identification and Classification of Soil Part 1: Identification and Description; International Organization for Standardization (ISO): Geneva, Switzerland, 2002.

[12] Binet, S.; Jomard, H.; Lebourg, T.; Guglielmi, Y.; Tric, E.; Bertrand, C.; Mudry, J. Experimental analysis of groundwater flow through a landslide slip surface using



natural and artificial water chemical tracers. Hydrol. Process. 2007, 3472, 3463–3472.

[13] Ronchetti, F.; Borgatti, L.; Cervi, F.; Gorgoni, C.; Piccinini, L.; Vincenzi, V.; Corsini, A. Groundwater processes in a complex landslide, northern Apennines, Italy. Nat. Hazards Earth Syst. Sci. 2009, 9, 895–904.

[14] Nielson, K.; Kristiansen, J. Blast-crushing-grinding: Optimisation of an integrated comminution system. In Proceedings of the International Symposium on Rock Fragmentation by Blasting (Fragblast), Montreal, QC, Canada, 25–29 August 1996; pp. 278–296.

[15] MacKenzie, A.S. Optimum blasting. In Proceedings of the 28th Annual Minnesota Mining Symposium, Duluth, MN, USA, 1967; pp. 181–188.

[16] Adermann, D.; Chalmers, D.; Martin, C.; Wellink, S. High-speed video—An essential blasting tool. In Proceedings of the Fragblast, Sydney, Australia, 24–26 August 2015; pp. 471–476.

[17] Boeker, E.; Van Grondelle, R. Environmental Physics: Sustainable Energy and Climate Change, 3rd ed.; John Wiley & Sons: Hoboken, NJ, USA, 2011; p. 480.

[18] Gamage, D.; Thompson, M.; Sutherland, M.; Hirotsu, N.; Makino, A.; Seneweera, S. New insights into the cellular mechanisms of plant growth at elevated atmospheric carbon dioxide concentrations. Plant Cell Environ. 2018, 41, 1233–1246.

[19] Hertwich, E.G.; Peters, G.P. Carbon Footprint of Nations: A Global, Trade-Linked Analysis Environ. Sci. Technol. 2009, 43, 6414–6420.

[20] Wiedmann, T.; Minx, J. A definition of ‘carbon footprint’. In Ecological Economics Research Trends; Pertsova, C.C., Ed.; Nova Science Publishers: New York, NY, USA, 2007; pp. 1–11.

[21] Fullana, P.; Betz, M.; Hischier, R.; Puig, R. Life Cycle Assessment Applications: Results from COST Action 530; AENOR, Emerald Group Publishing: Madrid, Spain, 2009.

[22] Glossary: Carbon Dioxide Equivalent. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title= Glossary:Carbon_dioxide_equivalent

[23] GOST R ISO 14064-1-2007: Greenhouse Gases. Part 1. Requirements and Guidelines for Quantification and Reporting of Greenhouse Gas Emissions and Removals at the Organization Level. Available online: https://docs.cntd.ru/document/120007 7407 (accessed on 22 October 2022). (In Russian).

[24] Balaguera, A.; Carvajal, G.I.; Albertí, J.; Fullana-i-Palmer, P. Life cycle assessment of road construction alternative materials: A literature review. Resour. Conserv. Recycl. 2018, 132, 37–48.

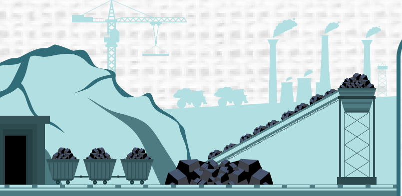
[25] ISO 14040:2006. ISO Environmental Management—Life Cycle Assessment—Principles and Framework. Available online: https://www.iso.org/standard/37456.html

[26] Raheem, S. R. "Remote monitoring of safe and risky regions of toxic gases in underground mines: A preventive safety measures." Postgraduate Diploma Thesis Report, African Institute for Mathematical Sciences (AIMS), South Africa (2011).

[27] Dey, Prasanjit, S. K. Chaulya, and Sanjay Kumar. "Hybrid CNN-LSTM and IoT-based coal mine hazards monitoring and prediction system." Process Safety and Environmental Protection 152 (2021): 249-263.

[28] Mardonova, Mokhinabonu, and Yosoon Choi. "Review of wearable device technology and its applications to the mining industry." Energies 11, no. 3 (2018): 547.

[29] M. Paavola, P. Seppälä, “Wireless networks in underground mines, Electronic and Optical Materials, Industrial Wireless Sensor Networks, 2016, 107-123,



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