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Impact of Coal Mining on Ambient Air in Respect of Global Warming: A Critical Approach

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ABSTRACT

Coal mining is the prime reason behind climate change and has a great impact on global warming as coal produces 39% global CO_2 emissions. At the same time, coal production is the chief factor of 40% of the world's electricity including economic development. The purpose of the present study is to the worldwide, national & endemic impact of coal mining on ambient air in respect of global warming. A number of peer-reviewed, research articles, reviews, and reports were collected from 1970 to 2022 employing a keyword-based search. The articles compiled were analyzed globally & indigenously and assorted according to the selected browsers addressed & the methodological approach adopted. Coal mining activities emit toxic gases into the atmosphere and hence decline the ambient air quality. The crucial Greenhouse gases contribute to the overall warming of the earth. Coal continues to be the distinctive and long-term resource of the world energy supply hence its mining-related pollution mitigation and the reclaiming of the environment are necessary. In present circumstances, it is obligatory to implement Clean Coal Technologies i.e. sustainability in energy production & its utility. Abandoned mine wasteland restored and converted into vegetative land may also solve numerous major issues like lessening GHGs, GW, and prevention of degraded wasteland.

INTRODUCTION

In the world coal is the most plentiful fossil fuel. It is a crucial resource that secures energy security & sustainable development as well as the quality of life. Next to fuel oil it is the second that is utilized to generate about 40% of the world's electricity and economic resource of energy (Holdren et al., 2000; Pudasainee et al., 2020). The first industrial revolution, urbanization, and economic growth were initiated in the coal industry at the end of the 18th century. But, its excavating and utilization are related to significant environmental impacts. Since the 19^{th} century, the growth of coal mining has recognized the negative impact on the environment. In coal mines, air pollution is mainly due to fugitive emissions of gases including CO_2, CH_4, NO_x, etc., and Particulate Matter (airborne respirable dust) and surface-cut coal mining and its related activities are primary contributors to particulate pollution. Aside from coal mining activities, the devious multiple sources such as open coal burning, mine fires, garbage burning, vehicle exhaust fumes, and diesel generators are responsible for air pollution (Ghose, 2002; Roy et al., 2016).

Hence coal creates environmental problems at various stages of mining as stockpiling, coal preparation, transportation, and utilization stages of operations. GW is determined as the rise in the average surface temperature of the earth because of the increase in the concentration of GHGs like water vapor, CO_2, CH_4, Chlorofluorocarbons, O_3, NO_x etc. Water vapor in the atmosphere is causing an increase in the average surface temperature of the Earth (Venkataramanan, 2011). The atmosphere consists of nitrogen, oxygen, argon mainly, and other gases in few quantities including GHGs. The % of the permanent gases like oxygen, nitrogen, and argon does not change while the % of the trace gases, CO_2, CH_4, CFCs, O_3, and NO_x changes daily, seasonally, and annually (Khandekar et al., 2005; Composition of the Atmosphere, 2018). Water vapor and CO_2 are responsible for two-thirds and controlling factors of GW respectively. To be specific, GW would not have happened if the concentration of CO_2 did not increase.

Scientists profess that in the atmosphere doubling or halving the CO_2 causes the change in the average surface temperature of the earth by +3.8 °C or −3.6 °C respectively. However, this amount of alteration depends on the alteration in the humidity of the air which in return turns on the atmospheric temperature. Consequently, even though the other GHGs like CH_4 and N_2O produced in mining have a stronger ability to absorb the radiation, they contribute to GW (Oktyabrskiy, 2016; Al-Ghussain, 2019).

Essentially, anthropogenic GHGs are released actively during mining and passively emitted by the energy-intensive activities associated with mining equipment, ore transport, and the processing industry (Liu et al., 2021). Surface-cut coal mines represent the spontaneous combustion and low-temperature oxidation of waste coal which is a potentially large source of GHGs emissions (Carras et al., 2009). In coal mining activities either from the coal seam itself or from other gassy formations, underground Coal Mine Methane gas is emitted. The amount of CMM produced at a specific operation depends on the productiveness of the coal mine, the coal seam gassiness, and any underlying and overlying formations, geological conditions, and operational variables (Karacan et al., 2011). The constant increases in global energy demand for coal lead to subsequent increases in emissions of GHGs in the atmosphere. In the coal mining industry controlling the air pollutants including GHGs in the atmosphere puts forth a substantial challenge. For the management of GW, carbon emissions as well as GHGs mitigation from the coal mining industry is a necessary step. The present review article aims at the indigenous and worldwide impact of coal mining on ambient air in respect of GW.

MATERIALS AND METHODS

A specific keyword-based explore methodology was adopted so that all the papers collected were typical, significant, and indicative. Google Scholar was selected as a browser and a custom search was done. In the beginning search terms used were 'coal', 'coal mining', 'coal mining and its impacts, 'impact of coal mining, 'coal mining and GW' 'coal mining and GHGs', etc. The pages of Google Scholar were searched and the relevant papers were downloaded and collected. The deriving literature that had relevance to the overall review was incorporated into the paper count and distribution. The papers congregated from keyword searches were studied, analyzed, and assorted. The sub-references of all the papers were also utilized (Upgupta and Singh, 2017; Odell et al., 2018).

RESULTS AND DISCUSSION

Global perspective

The coal mining industry has a long history of significant adverse environmental impacts on regional ecosystems, local communities' health, and workers. China has the hugest coal production in the globe as abundant resource requirements for economic growth and in recent times, the proportion of surface-cut coal mine production has increased significantly. Opencast coal mining can lead to lots of environmental issues, including air pollution also. The Yimin surface-cut coal mine, in China, was chosen to conduct a case study by the authors. In the production of coal in the following stages, there are lots of environmental risks such as stripping, mining, conveying, processing, and reclamation. There are 6 environmental effects i.e., resource consumption, acidification, solid waste, eutrophication, dust, and GW are mostly noticed. Dust was an extremely serious environmental effect and its contribution rate was 36.81% followed by GW in China (Zhang et al., 2018).

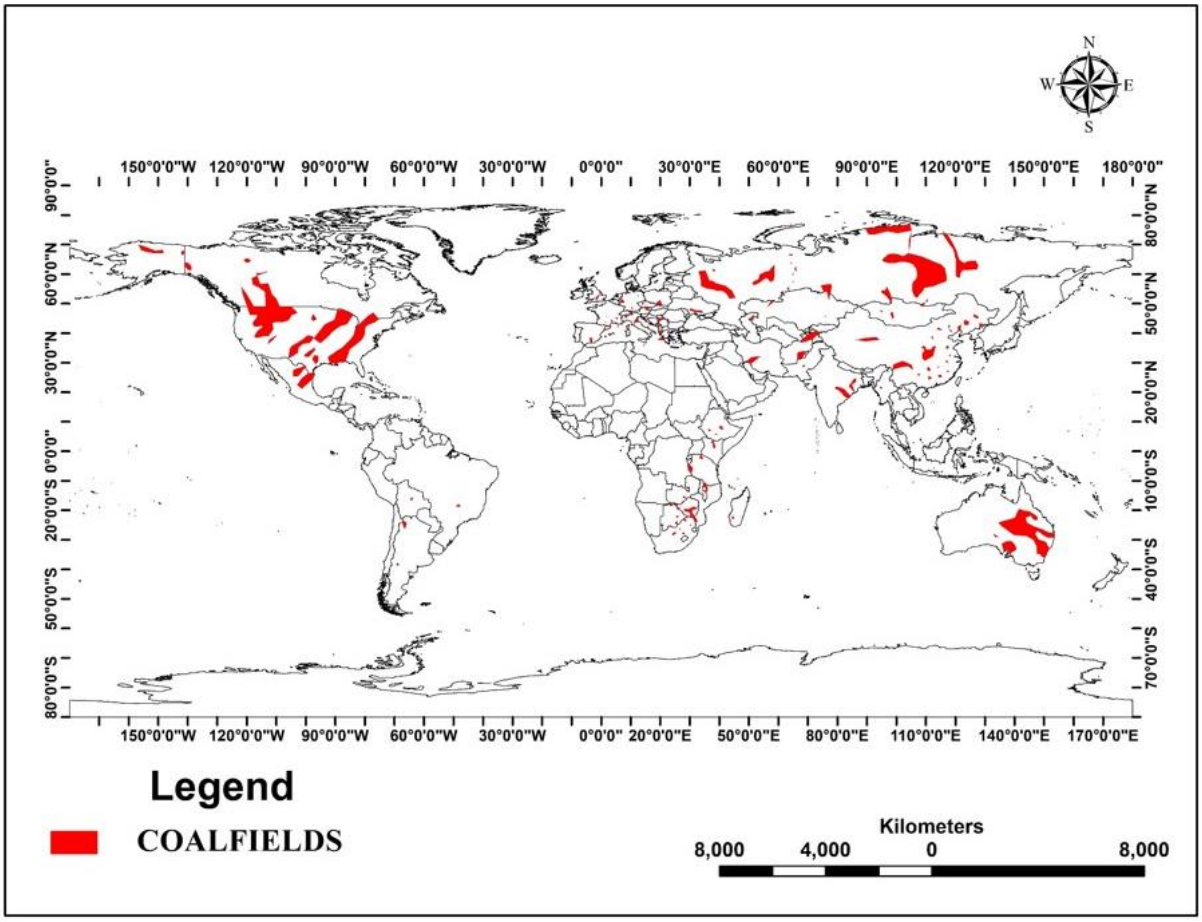

Figure 1. Dispersal of coal mines in the World

The figure represents the distribution of coal mines in more than 50 countries in the world. Coal is quarried commercially in over 50 countries of the world. In the US surface-cut mines were the source of about 64% of the coal mined in 2020. The biggest surface-cut mines are in Wyoming's Powder River Basin in the US, where coal accumulates near the surface and are approximately 70ft thick. Here several principal emissions consequences of coal combustion are noticed.

1. NO_x render to smog and respiratory illnesses
2. SO_2 renders to acid rain and respiratory illnesses
3. Particulates render to smog, haze and respiratory illnesses, and lung disease
4. CO_2 is the primary GHG generated from burning fossil fuels.
5. Mercury and other potentially toxic metals are exposed during mining and they link to both neurological and developmental damage in humans and other animals.
6. Fly ash and bottom ash are residues created in power plants when burning coal and have countless negative effects on humans (CECE, 2021).

Air pollution & GW are two of the greatest hazards to human & animal health and political stability. Energy insecurity and increasing prices of conventional energy sources are also major warnings to economic and political stability. Hendryx et al., analyzed National Pollutant Inventory data for the years 2008-2018 to evaluate the air pollutants (metals, nitrogen oxides, PM10, and PM2.5) derived from coal mines in Queensland and New South Wales, Australia. Outcomes denoted that over the study period, tons of coal mined increased significantly the levels of PM, metals, and NO_x. Coal mines accounted for PM10, PM2.5, metals & NO_x 42.1%, 19.5%, 12.1% & 10.1% respectively of national air emissions from NPI sites. Emissions of all said pollutants were notably higher from coal mining sites than from other types of NPI sites (Jacobson, 2009; Hendryx et al., 2020).

In South Africa, the primary impacts arise from mining, especially subsurface mining, largely because coal mines are comparably shallow. Coal washing gives rise to large waste dumps that may explode spontaneously and result in air pollution. On the other hand, the environmental impact of underground mining is CH_4. CH_4 is a greenhouse gas that is 21 times more potent & a faster rate of greenhouse effect & growth in the atmosphere respectively than CO_2. A higher amount of CH_4 is generated from the deeper coal mine. The CH_4 is liberated into the mine air and in due course discharged into the atmosphere. Presently South Africa emits about 7 million tons of CO_2 annually from underground coal mines. In surface mining, huge overburden dumps are frequently contaminated with waste coal that spread across the horizon. Spontaneously the coal dumps may combust and emit sulfurous fumes & smoke (Lloyd, 2002).

The mining sectors of 12 European countries were evaluated. During quarry PM and CO_2, CO, NOx, SOx, PM2.5, PM10, CH_4, NMVOCs, and NH_3 are principally emitted and they have lots of environmental impacts and damage the categories as GHGs emission, photochemical smog & PM formation, terrestrial acidification, damage to ecosystem quality & human health (Figure 2). It is noticed that in the mining and quarrying sector, the highest particulate and gas emission occurs in the United Kingdom and the lowest occurs in Bulgaria. Basically, The UK is a coal mining country where coal mining began on a systematic basis during the 17^{th} century which led to the industrial revolution and coal mining reached its peak in 1900. The environmental indices in all of the impact and damage categories from the mining and quarrying sectors are the topmost in Great Britain, Germany, Poland, and Norway. It is detected that GHGs emissions are quite diverse in this sector in each country for the time horizons of 20, 100, and 500 years, advocated by the Global-warming potential factor for methane emission (Mamurekli, 2010; Fugiel et al., 2017).

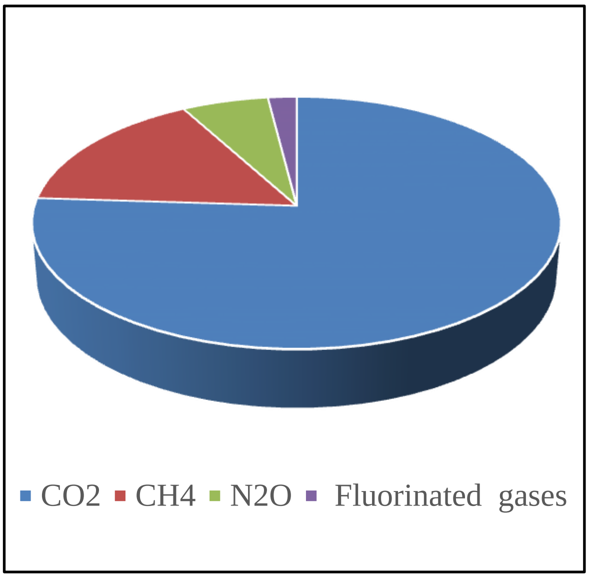

Figure 2. Global mining GHG emissions (in wt%) (Source: Hiraishi et al., 2014, Liu et al., 2021)

Figure represents the global mining GHGs include CO_2: 76wt%, CH_4: 16wt%, N_2O: 6wt%, & Fluorinated gases: 2wt%. The aftermath of the mining GHGs emission into the atmosphere has drawn the petite attention of researchers. Thus the collaboration betwixt the economically advanced countries of the globe to combat climate variability and to dedicate themselves to cease global heating that annually rises at $<2°C$ was initiated by the Paris Agreement (Meinshausen et al., 2009).

Indian Perspective

Permian and Oligocene are two distinct geological periods that the coalfields of India represent. Most of the coalfields are created during the Permian period and are confined mostly to the Gondwana basin of Peninsular India while Tertiary coalfields created during the Oligocene period are scattered in Jammu Kashmir, Rajasthan, Gujarat, and Tamil Nadu and mainly in the Northeast states like Nagaland, Arunachal Pradesh Meghalaya, and Assam (Figure 3). But Coal mining and its exploitation are connected with considerable environmental challenges as it generates notable and often irreversible impacts on the atmosphere (Figure 4) (Tiwary, 2001; Chabukdhara and Singh, 2016; CMPDI, 2021).

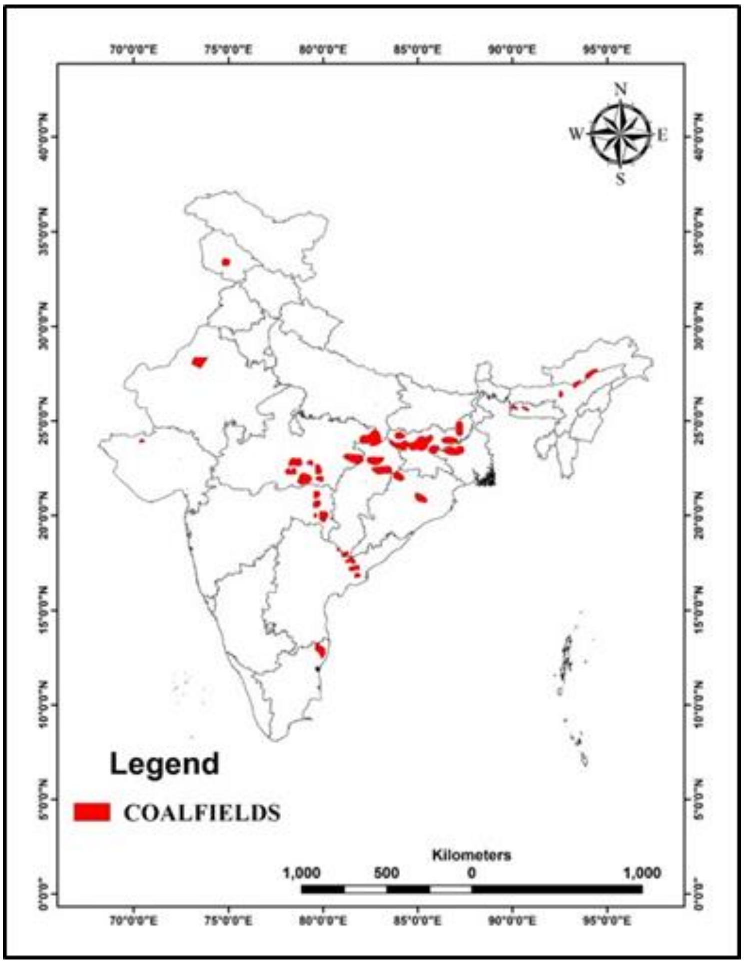

Figure 3. Distribution of coal mines in India

The red dots represent the coalfield in India. There are around 50 coalfields, varying from a few square kms to more than 1500 km^2.

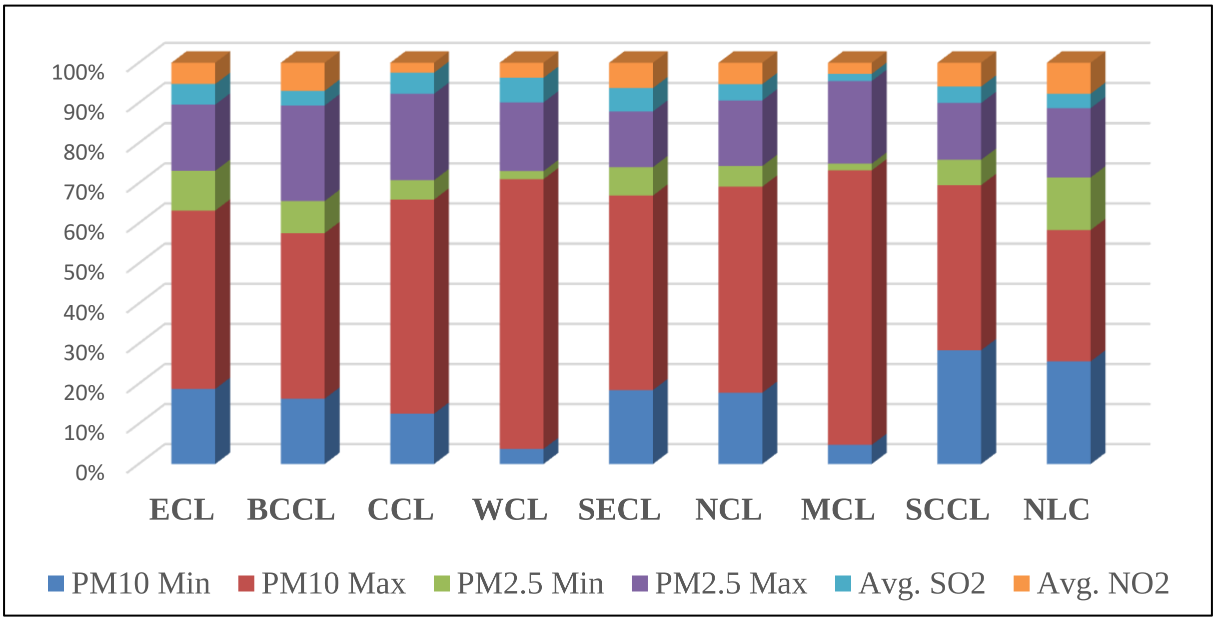

Figure 4. Status of air quality [pollutants measured (µg/m^3)] for projects considered of subsidiaries of Coal India Ltd during Ambient Air Quality Monitoring in FY 2019-20 (data collected from Tiwary, 2001)

The figure represents the status of air quality for each of the projects of subsidiaries of Coal India Ltd. has been cited based on the Ambient Air Quality Monitoring.

In coal production, India ranks among the top 10 countries. Indian coal utilization is around 5.5% of the world and the share of coal as energy has resulted in about 66%. The Indian reserve of coking coal is largely located in Jharia Coalfield, Dhanbad district of Jharkhand. The coalfield is subjected to rigorous mining activities and accounts for 30% of the total coal production in India. In JCF the emphasis on extensive mechanization of surface mining has appeared in widespread concern about the degradation of environmental quality, particularly the increase in the concentration of Suspended particulate matter or dust particles within and adjoining the mining site. Vehicular traffic on the haul road of the mines site, loading, unloading for transportation, and drilling operations have been recognized as the most prolific source of fugitive dust. The dust particles act as core catalysis for many chemical reactions that take place in the atmosphere. Then the burning of coal emits about 60% of all SO_2. Additionally, mine fire and spontaneous heating of coal in waste dumps release a substantial amount of SO_2, NO, CO, CO_2, NO_2, NO_x & H_2O, huge temperatures that all are responsible for the greenhouse effect (Cowherd, 1979; Ghose and Majee, 2000).

Talcher Coalfield is one of the oldermost coalfields in India with huge deposits. Here also Particulate pollution is considered an important environmental problem. The PM not only distressed mine workers' health & the nearby residents' health but also degrade the adjacent vegetation and the nearby ecological environment in many ways. The movement and spread of PM in the atmosphere depend on size, shape density, nature of particles as well local meteorology. The chief emissions during coal mining and its burning are the PM of different size ranges and trace metals. The particulate matter also carries toxic contaminants such as Potentially toxic metals and toxic organic compounds. Seasonal variations of PM concentration approved in the winter season high concentration of PM as compared to the summer season. A total of 10 PTMs were analyzed and selected for root apportionment of PM and PTMs. After investigation, authors cited that the highest mean concentration was Cd followed by Fe, Cr, Zn, Pb, Cu, Ni, Se, Hg, and As. The range of average Pb concentrations were detected between 0.05 to 0.13 µg/m3 i.e. below the National Ambient Air Quality Standards limit of 0.5 $\mu g/m^3$ (Wheeler et al., 2000; Vesovic et al., 2001; Park and Kim, 2005; Shah et al., 2006; Gunawardana et al., 2011; Tripathy and Dash, 2018; Omer, 2021).

Meghalaya, Assam, and Arunachal Pradesh in northeast India contain around 79% of the total tertiary coal reserves thus good deposits of sub-bituminous tertiary coal. The northeast Indian coals have surprising physicochemical features such as high sulfur, vitrinite content & volatile matter, low ash content, and numerous environmentally sensitive elements such as Fe, Cu, Mg, Pb, Mn Al, Bi, V, Cd, Ni, etc. remain enriched in these coals. Organic sulfur was more abundant among the different sulfur species composing an average of 62% of organic sulfur of the total sulfur content of 4.59 % in Bapung coals of Jaintia Hills, Meghalaya. The primitive & unscientific rat-hole & related mining activities have been adopted by private agencies, causing large-scale environmental destruction & severe ecosystem damage in Meghalaya. Based on reports the ambient air quality around north-eastern coalmines in Margherita, Assam the highest daily average values of SPM, Respirable particulate matter, SO_2, and NOx were found to be 214, 60, 25 & 52 µg/m3 respectively. All values were within CPCB guidelines except SPM. In Tirap colliery, Margherita, Assam from the mining activities in open cast mine area atmospheric concentration of gaseous NH_3, SO_2, and NO_2 released 4.7–40.03, 1.47–6.14, and 1.92–2.40 $\mu g/m^3$ respectively whereas particulate NH_4^+ in PM10 and PM2.5 varied between 0.02–0.07 and 0.008–0.03 $\mu g/m^3$ respectively (Ahmed and Rahim, 1996; Rajarathnam et al., 1996; Swer and Singh, 2003, 2004; Sarma, 2005; Khare and Baruah, 2010; Sarmah et al., 2012).

Ambient air quality monitoring regarding SPM, RPM, SO_2, NO_x, and CO was executed in two mining areas in western parts of Kachchh district in Gujarat, India. As of 1 April 2021, the estimated lignite reserves in Gujarat are 2.722 metric tons. This area has 2 crucial mine complexes and several large-scale industrial projects with pipelines. Ambient air sampling was evaluated in 4 sites each within a 5 km radial distance from 2 major mine sites these are Panandhro and Mata-na-Madh. Air Quality Index of the mining sites ranged from 25-50 i.e. Light Air Pollution category, while the adjoining rural areas in the region (AQI 10-25) had relatively better air quality and fell under the clean category (Prusty, 2012; ESI, 2022).

A study for the evaluation of the air quality was carried out at Neyveli coal mines in Cuddalore district, Tamilnadu. The 24h average concentrations of total SPM, RPM, SO_2, NO_2, PM10, and PM2.5 were observed. Samplings were done constantly all around the year at 6 monitoring stations. The 24hr average SPM and RPM concentrations varied from 123.2 to 141.80mg and 60.6 to 69.8mg respectively. During this time the annual average SPM and RPM concentrations were within the permissible limits of the respective standards set in the NAAQS protocol in most areas. Even so, in the study areas 24-hr and annual average concentrations of SO_2 and NO_2 both were also within the prescribed limit of NAAQS, these varied from 13.2 to 14.10 mg, average 13.65 mg and 12.5 mg to 13.2and average is 12.76 mg respectively. The temporal variation and its concentration variation trends of SPM, RPM, SO_4, and NO_2 are ambient. The highest concentration of PM10 and PM2.5 in a core zone is detected i.e. 484 $\mu g/m^3$ and 131 $\mu g/m^3$ whereas in the buffer zone 112 $\mu g/m^3$ & 63 $\mu g/m^3$ respectively. These values of PM10 is exceeding the defined limits as per Indian Coal Mines Standards and the highest concentration of PM2.5 is crossing the prescribed limit (Pati et al., 2021).

West Bengal, India perspective

Raniganj in West Bengal, India an important coalfield is susceptible to mining subsidence (Figure 5), and emission of toxicants into the environment.

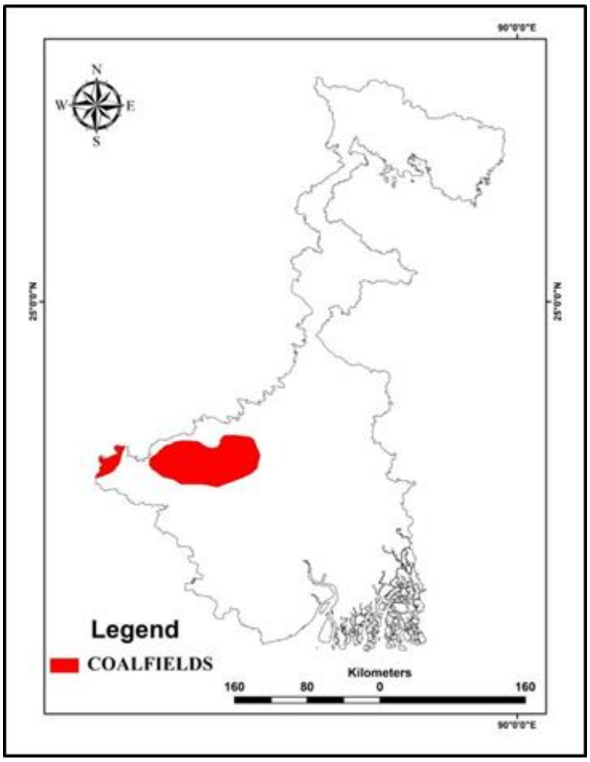

Figure 5. Distribution of coal mines in Weast Bengal, India

The figure represents the dispersal of coal mines in West Bengal, India. In West Bengal has been allocated 8 coal blocks out of which 6 are being grown through the Public Private Participation method by 2 by Damodar Valley Corporation with West Bengal Mineral Development & Trading Corporation Ltd (Mining Industry, 2022).

In Raniganj Coalfield, West Bengal ambient air quality monitoring for SPM, SO_2, and NO_2 was executed over a period of one year to study diurnal & seasonal variations and spatial distribution of cited contaminants. Studies specify that mining and related activities have raised the framework levels of SPM pollution in the coalfield. The coal handling plant and deteriorated dilapidated roads, the consequence of the transport of coal dust by means of wind, are identified as the sources of SPM contamination. Coal burning and transportation exercises appear to be crucial sources of SO_2 and NO_x in RCF. Produced GHGs from coalmines effect due to trace amounts of water vapor, CO_2, SO_2, CH_4, and NO_2 in the atmosphere. These gases let the solar radiation arrive at the Earth's surface yet they absorb infrared radiation discharged by the Planet and thereby lead to the heating of the surface of the

Orb (Singh and Sharma, 1992; Rehman et al., 2020).

RCF has a historical document of substantial fire activity owing to spontaneous combustion since 1865. These fires impart a vital challenge to the safety, environment, and productivity of these operations. Spontaneous combustion of coal and subsequent mine fires fabricate combustion products including, CH_4, SO_2, CO_2, CO, and other gases which led to GHG emissions. Methane generated due to heating is different from the mechanical release of the seam gas confined in the coal due to mining activities. In the course of coal combustion, H_2S & SO_x are generated and that can react with O_2 & H_2O to produce H_2SO_3, H_2SO_4, or H_2S. Thus, sulfur releases an effect on the ecosystem (Dhar, 1996; Zutshi et al., 2001, Gopinathan et al., 2022).

In RCF Coal mining activity harmfully affects the human health of the quarry area. In the coalfield, the discharge rate of greenhouse gas is rising moderately (0.4% per annum) to a frightening level and has become detrimental to locals. The air quality in the locality of the coalfield, moreover in the mine's ambiance is very much negatively modified, judged by the yardstick of the World Health Organization. Normally, it is noted that the locals & mining workers are affected by asthma, bronchitis, breathlessness, COPD, black lung disease, cardiovascular disorders, irritation to the skin, eye, nose, and throat, diabetes, hypertension, kidney problems, liver problems, poor visibility, etc. (Schins and Borm, 1999; Goswami, 2014; Samanta, 2015; Neogi et al., 2018; Dash et al., 2020; Saha et al., 2022).

For exploration of the ambient air quality with respect to SPM, SO_2, and NO_X at the coal mine adjoining area in the Raniganj-Asansol, West Bengal, India, ambient air was observed with a sampling frequency of twenty-four hours on every alternate day (3 days a week) covering a period of a year. Samples were collected from the study sites.

Figure 6. Mining activities (a-e) emit PMs & toxic GHGs gases in RCF, West Bengal, India

The figure represents instances of environmental pollution caused by mining activities in RCF, West Bengal, India. Temperature, humidity, wind speed, and wind direction i.e. meteorological parameters were also recorded at the same time during the sampling period. In this way, monthly and seasonal variation of these pollutants has been noted and recorded. The yearly average & range values have also been estimated. Outcomes of the study indicate that the 95th percentile values of SPM levels transcend the limits whereas the 95^{th} percentile values of SO_2 and NO_X levels did not transcend the reference level. Additionally, it has been noticed that the pollutants' concentrations are excessive in winter in contrast to the summer & the monsoon seasons. The outcome of the study shows that coal mining activities, combustion of coal in the open air, vehicular traffic, etc. are accountable for the high concentration of pollutants in this area (Figure 6). The burning of coal, fossil fuel for electricity, vehicles, and other anthropogenic activities was the wide source of global greenhouse gas emissions in the coalfield adjoining areas (Reddy & Ruj, 2003; Yaseen et al., 2017).

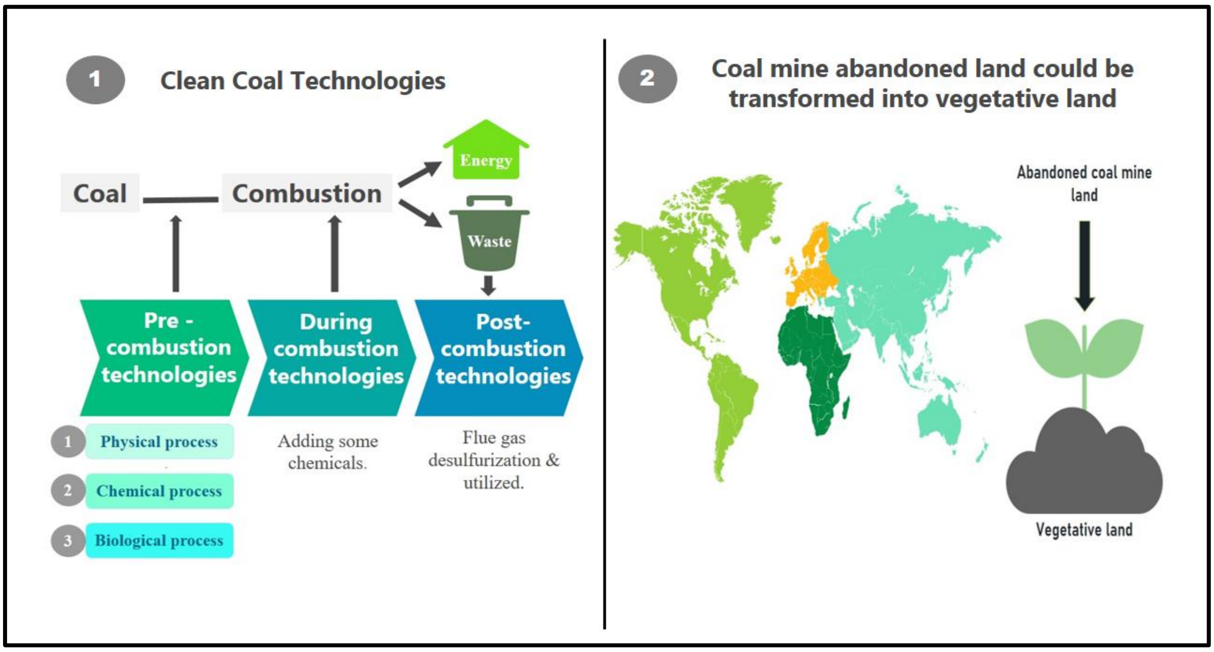

Figure 7. Around the world the strategies to remove coal mine pollution in ambient air

The figure represents the model strategies equanimity between mineral developments and the reimposition of the environment. In this situation, it is necessary to pursue a discussion on CCT i.e. sustainability in energy production and its utility, safety, and environmental concerns. CCT can be organized into 3 categories: a) Pre-combustion technologies b) During combustion technologies c) Post-combustion technologies. To apprehend SO_2 through sulfonation of CaO Calcium carbonate is added to coal in the combustion chamber. These processes may be classified as Physical, Chemical, and Biological. In the biological process, the research managed by using isolated cultures of *Acidithiobacillus ferrooxidans* with various coal types exhibited that the highest yield was achieved in lignite-type coals of removal for pyritic sulfur (Acharya et al., 2001; Soleimani et al., 2007; Aksoy et al., 2010; Celik et al., 2019).

There is a possibility of vegetation being a key sink for gaseous pollutants & GHGs from ambient air and also alleviating global warming. On the other hand for PM in the atmosphere the only possible practice for sponging ambient air is through vegetation, acting as a biological filter for pollutants. Abandoned coal mine land could be transformed into vegetative land to fulfill the strategies (Figure 7) (Hill, 2012; Przybysz et at., 2019; Burkhardt and Pariyar, 2014; Leung et at., 2011).

Conclusion

Owing to the fact that the growing demand for coal in the world results in enhanced coal mining consequently there is concern over its environmental impacts. The potency of mining effects largely depends on the size, stage, and mining method of the operation. The adverse effects of mining can be diminished by heedful planning and execution of mining. It is necessary for equanimity between mineral developments and the reimposition of the environment. Eliminating GHGs including atmospheric carbon & PM is an expensive option. In recent times, studies on improving the efficiency of CCT emphasized sustainability in energy production and its utilization, safety, and environmental issues. All around the world, there are huge areas of abandoned mine land. If reinstated and converted into vegetative land, they can solve major issues like lessening GHGs, GW, prohibition of degraded wasteland etc. This article reviewed how GHGs are emitted by the mining industry globally and indigenously and the majority of the studies were engrossed on the GW that are directly impacted by mining. In the end, it is concluded that fundamental issues and outcomes require to be navigated by the mining industry to satisfy policymakers, authorities, administrators & environmentalists and produce needed primal matter in a sustainable and eco-friendly way.

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