Geo-sustainability Challenges and Remediation Strategies: A GIS-based Assessment of Sripur Coalmine Areas, West Bengal, India

Abstract:

This study examines the health, risk, and safety aspects of coal mining in the Sripur area, focusing on the Bhanora West Block, Asansol, West Bengal, India as one of the 14 operational mines of Eastern Coalfields Limited in Asansol. The study addresses the increasing risks of accidents, fires, and subsidence in active, ageing, and closed mines and storage yards. The study's incorporation of field surveys, satellite imagery, and environmental data ensures that the findings are based on a well-rounded and multi-faceted dataset.

The satellite imagery data (GIS and Remote Sensing)are perceived along with available literature and environmental impact compliance reports from time to time, with particular interest in the Bhanora West coal mine, both open cast and underground. The aspect, Hill shade, LULC and stream order maps of the Damodar are generated using Q-GIS, 3.28.7.

The environmental clearance data, accident data, subsidence area, and landslide data are analysed. A vast area in Sripur is observed to be under subsidence, with cracks appearing even near residential areas. The flow of the Nunia nallah is nearby, and old closed mines are not adequately backfilled, so the chance of seepage cannot be neglected though regularly attended.

Pneumoconiosis (CWP), a lung disease (black lung), chronic obstructive pulmonary disease (COPD), and silicosis are common in Sripur due to dust and substandard water. Effective and riskless mining extractions using proper technologies can avoid mining hazards, such as subsidence, the influx of water in underground mines, health hazards, air/water pollution, mine fire, and intact physical landscape and observing criteria of sustainable Development Goal SDG-1 SDG-3, SDG-6, SDG 12, SDG-13, and SDG 16.

Keywords: Coalmines, Environment, GIS/RS, Subsidence, SDGs

Introduction:

Coal is a heterogeneous sedimentary rock material, black, comprising a high rate of carbon and hydrocarbons. Coal remained the primary energy source for India's energy sector after the plying of steam locomotives in 1853. However, East India Company absorbed coal from mines in the Raniganj area by summer and hearty in 1774 (Ministry of Coal; https://coal.gov.in/en/about-us/history-background). However, many advances have been made in solid fossil fuels in the thermal energy sector. Hydropower, solar, geothermal, and hydrogen as sources of energy emerged later in the 20th century. Coal storage is more susceptible to fire hazards. The extraction and storage of coal are always risky. However, there is always a gap between the demand and supply of coal Never the Coal (the black diamond) production growth is economical and also availability is assured (Min. of Coal, 4th Mar 2024, https://coal.nic.in/sites/default/files/2024-03/PIB2011252.pdf.

Many collieries have been housed in the Asansol area in the central part of Raniganj Coalfield of Eastern Coal Field Limited (ECL), along with the study area at Sripur. Bhanora West Block Colliery in Paschim Bardhhaman District, West Bengal, India, connected with Asansol by

Grand Trunk Road (NH-2) at Kalla More (Do Mohani) (Fig 1).

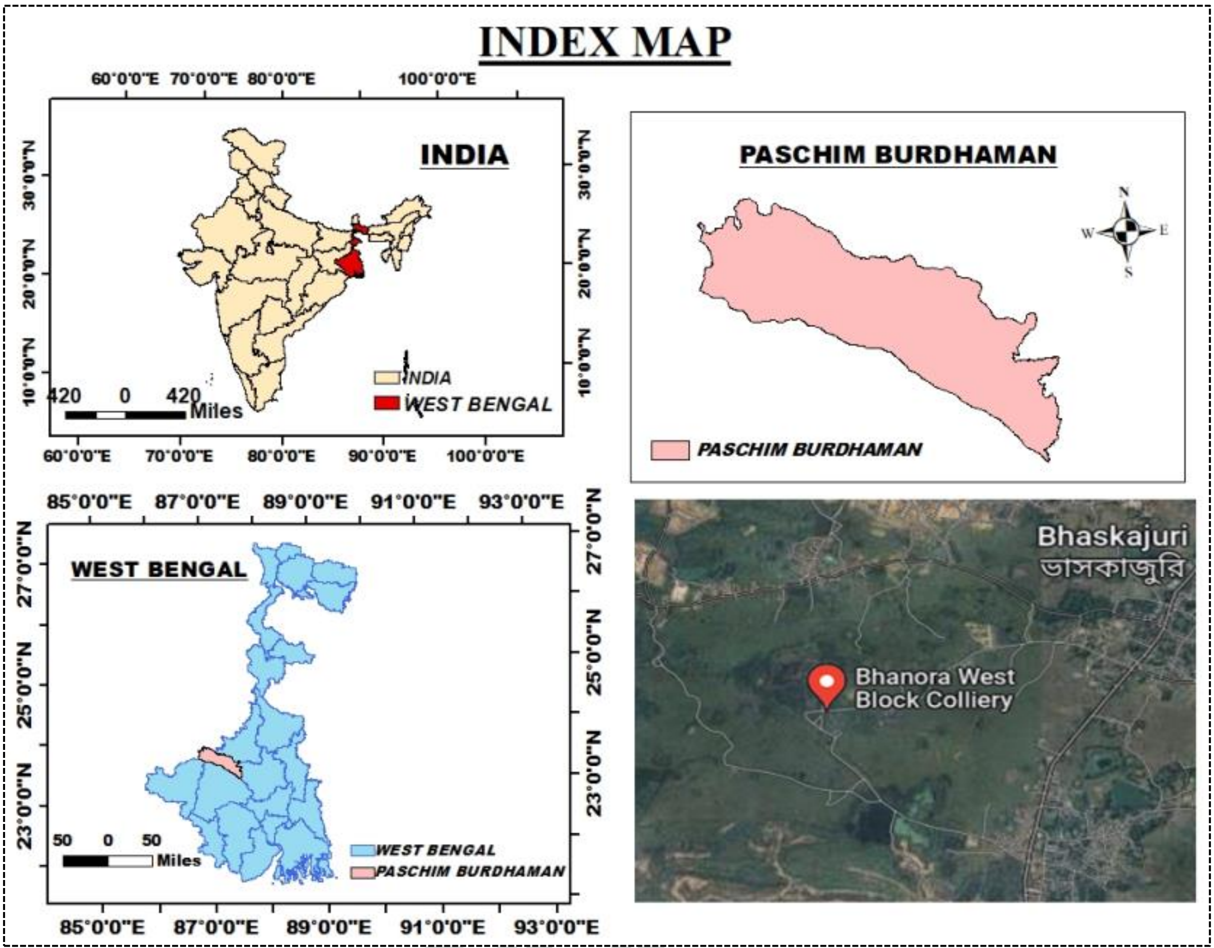


Fig 1: The index map of Bhanora colliery in the Sripur (Raniganj coalfield) area

The DG of mine safety opined that the human health issues associated with miners are silicosis, Pneumoconiosis, cancer of the lungs, Sickle cell diseases stomach, pleura and peritoneum malignancy (Mesothelioma) IQ_222_14032011_U1956_p216_p218.pdf. Coal miners are unprotected from coal dust and crystalline silica dust, causing various pulmonary (respiratory tract) diseases, including coal workers' pneumoconiosis (CWP), chronic obstructive pulmonary disease (COPD), ischemic heart disease, heart failure, and cancer.

Coal extraction and storage are inherently risky. Despite these risks, coal production has continued to grow to meet the demand, ensuring its availability remains economical." Similarly, in the statement, "The present study is conducted to a. Reporting geology, petrology, and stratigraphy of the area," the language can be improved too, "This study aims to report on the area's geology, petrology, and stratigraphy.

Review of literature:

In the scientific industrial revolution of the 1850s, coal energy was the frontline player in societal, industrial, and economic growth Carvalho et al.,(2024). Until 2024 (June), the total thermal installed capacity in the thermal sector is 242.99 GW, out of which 210.96 GW is based on Coal. The power industry for coal-based thermal power generation in India is 52.4% (private), States (24.1%), and the Centre 23.4%, respectively, as per Amit Manohar from Invest India 2024, https://www.investindia.gov.in/sector/thermal-power. The power generation from coal has surged from 71% in 2019-2020 to 75% in 2023-24. The coal production in India was 997.25 MT during 2023-24, with a growth rate of +11.65%. Coal India Limited (CIL) yielded extracted 622.63 MT in 2021-22, whereas 703.20 MT of coal during 2022-23 showed a growth of +12.94%. (Ministry of Coal 2024[1]).

The quality of life (QoL) and ecosystem for project-affected people (PAPs) in coal mining areas may deteriorate if not adequately addressed during the production stage. If not adequately cared for during the project in the production stage, it may make their lives worse. Revegetation in defunct but reclaimed OB dumped areas of coal mines is suitable land for plantation growth. (NITI Aayog report 2015[2], Paltasingh et al., 2021[3], Sinha et al., 2023[4]). QoL of the rehabilitated and resettled people of the coal mines area must be provided with adequate WASH facilities, job opportunities, Income prospects, Housing affordability, Health Security, Infrastructure, and social and religious bonding without any occupational hazards Han et al., (2018)[5], Li et al., 2024[6].

Overburden (OB) is a bottleneck for the coal mine area's environment, ecosystem and habitats. The ecosystem can be better repaired, and sustainability can be approached in externally dumped areas rather than internally. Das et al., 2020[7], Wang et al., 2023[8].

Coal mining activities There is a heavy release of suspended particulate matter (e.g., PM10 and PM2.5). These dusts enter the lungs and cause circulatory and respiratory diseases. The dust includes metals, which are carcinogens and fine particles, bounded by polycyclic aromatic hydrocarbons (PAHs) that have effects on respiratory organs Dubey et al., 2012[9]; Su et al., 2020[10]; Cortes-Ramirez et al., 2022[11].

Study area:

Bhanora is a census town belonging to the CD block Bara Bani in the Asansol Sadar subdivision of the Paschim Bardhhaman district in West Bengal, India. The Bhanora West Block open cast patch of Bhanora West Block Colliery is housed in Eastern Coalfield Limited and lies east of Nunia Nallah and Salma Dyke. The Bhanora WB, Open Cast Colliery area, is in Sripur (Lat 23.729521, Long 86.993622), 12 km north of Asansol Rly station part to Paschim Burdwan district of West Bengal. Asansol City accommodates more than 0.12 million in the south per the 2011 census. In the south, the area is connected to G.T. Road (now NH 19) at Do Mohani via Kalla More. The Asansol Railway Junction is the nearest. The Bhanora mines in the Sripur area have open-cast (OC) and underground (UG) mines, Fig 2(a-b).

About 23 seams are found in the Raniganj (11) seams and 12 in the Barakar area. Some are 1-2m thick on the surface, and the rest are underground. Major coal seams are found at Taltor, Halnal Koithi, Sanctoria-Ponihati, Bara Dhemo-Raghhunathbati-Rana-Pariharpur-Satgram Sonpur, Dishergarh-Salma, Sripur-Topsi, Kenda, Chora-Purushottampur, Kajora-Jamad-Bankola, Gopalpur-UperDhadka-Ghusik-Upper Kajora. Bhanora West OC patch and Underground extraction is considered for the study (Fig 3).

Present study: This study aims to:

a. Report on the area's geology, petrology, and stratigraphy.
b. The quest for a sustainable ecosystem for the mothballed and defunct coal mines.
c. A GIS study of the Sripur coalmines and generation of the area's Aspect, Hill shade, drainage, and LULC maps.

d. Since there is vast land subsidence in the vicinity of the mines, the causes of subsidence are discussed.

Fig 2: The insight of Bhanora WB Colliery (U/G) mines in Bhanora (Sripur), West Bengal

Methods and methodology:

In the coal production projection analysis, GIS/RS technology proved to be one of the best methods through spatial analysis, estimating exposition, and 3-D knowledge can lighten the location, size of seams, geometry of deposit and status of the deposited coal strata, by the generation/analysis of geospatial data, the planning, operational, health, and environmental management of the mining area of interest. The GIS analysis results are used for the selection of coal deposit sites, mining-induced risk and hazard assessment, Topographic slope analysis, proximity factors, slope maps,

The field survey will be conducted on the subsidence areas, OC/ UG coal mines, health data collection, and interaction with the miners and local people to assess the production, risk and safety measures with environmental distraction. The surface water samples are collected and tested in laboratories to determine the water's minerals, toxicity, biochemistry, and probable solutions to the contamination issues.

In the present study, applied methodology involves data acquisition of primary/ secondary data acquisition, mapping, georeferencing, analysis, interpretation, picturisation and communication. These maps help monitor different species' natural resources, soil, water resources, vegetation and habitat. Mining activities like ore reserve assessment, Opencast (OC)/ Underground (UG) coal reserve estimation, mine infrastructure design, and potential conflict region analysis Choi et al. (2020)[12], Fig 3 (a and b).

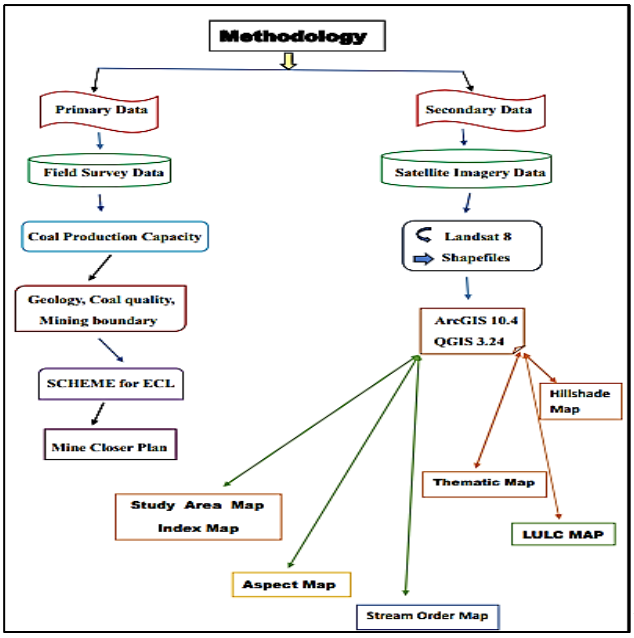
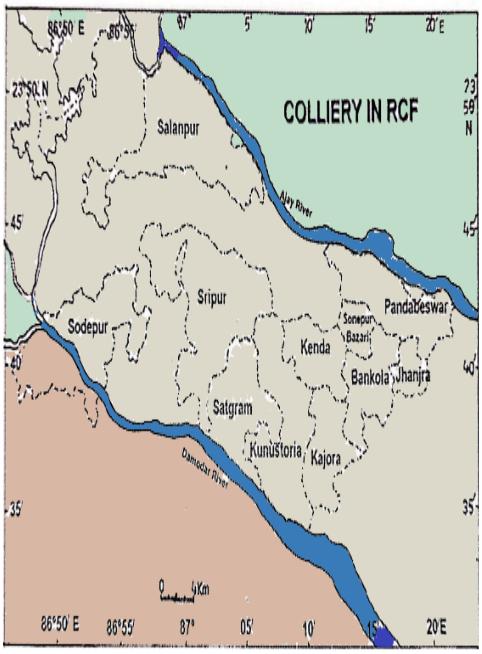
(a)  b. 

Fig 3: The methodology of making various GIS maps in the study(b) study area

In the present work, various maps made from various data are prepared. Index, Aspect, Hill shade, Stream order, and LULC maps are created. These maps are analysed, and the subsidence risk assessment of health, accidents and the change in vegetation in the area is ascertained. Water quality tests and ameliorating measures are discussed from field visits to the risk areas.

History and Statistics Coal mines in India:

The incorporated company was named Coal Mines Authority Limited in the year 1973-74 and later renamed Coal India Limited (CIL), incorporating Central Mine Planning & Design Institute Limited (CMPDIL), Eastern Coalfields Limited (ECL), and Western Coal Field Limited (WCL), and formation of Bharat Cooking Coal Limited (BCCL), Coal India Limited (CCL), etc. was formed during 1975-76. The Singareni Collieries Company Limited (SCCL) was a coal-exploiting Deccan company established in 1886 (in the Yellandu area) and was taken over by GOI in 1956.

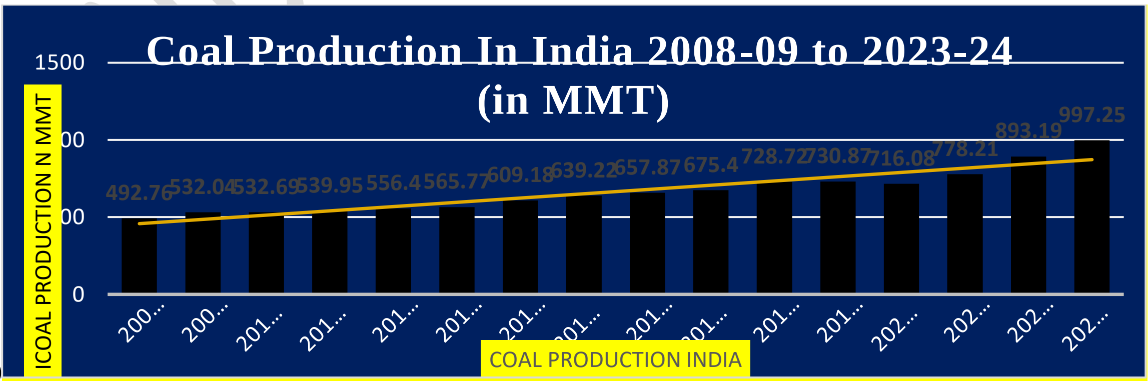
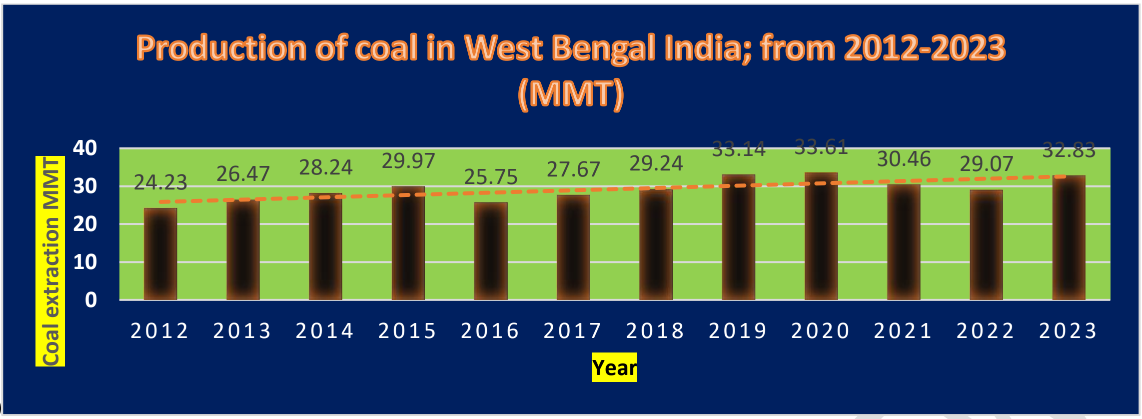
(a) 

Fig 4(a): The production of coal (India) from 2008-09 to 2023-24 (Data: Min of Coal 2024)

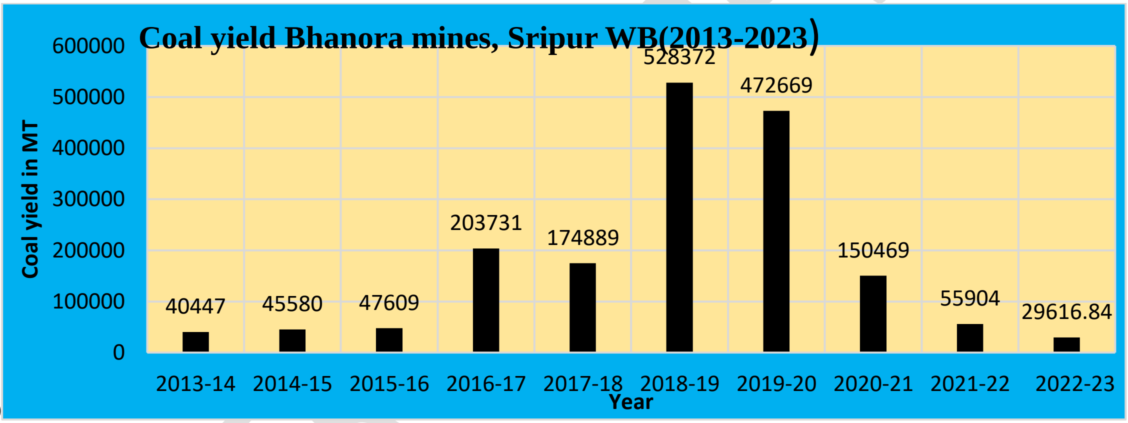
In 2004-05, the coal exploitation was (382.62 MMT)) in the year 2004-05, it surged to 893.19 MMT, and it surged to 997.25 MMT during 2023-24 with a growth of 11.65% (+ve). The rising demand in the energy sector has created a demand for coal, which has reached 1000MMT during 2023-24. The coal production in India from 2008-09 to 2023-24 is in Fig4. (a, b, c).



(b)

Fig 4(b): Production of coal in different mines of West Bengal (Data: https://www.ceicdata .com/en/india/coal-production-by-major-states/coal-production-west-bengal)

West Bengal in India extracted 32.83 MMT of coal in 2023, an increase of the previous year's production of 29.069 MMT for 2022. Fig 4(b)



(c)

Fig 4(C): The production of coal from the Bhanora, Sripur area, near Asansol, West Bengal,

Environmental clearance:

The Sripur coal mines area (8281ha) falls under Cluster 8 (7mines), comprising 1.53-2.75 MTPA in mines MOEF&CC of GOI has accorded leased M/S regions Eastern Coalfield Ltd (ECL), (Order no J11015/107/2011 – I9A) and II-M dt March 19, 2015. The life span of the seven mines is in Table 1;

Table 1: The mines in Sripur area in cluster 8, with production capacities, area and life span

The mines (cluster 8)	Production capacity fixed (MTPA)		Mines lease area	Life span (yrs)
	Normal	Maximum	(ha)	Years
Bhanora UG/ mines	0.2	0.3	1330	>20
Ningah UG mine	0.04	0.10	1072	>50
Girmint UG mines	0.04	0.65	1981	>50
Sripur Seam incline (UG)	0.105	0.136	279	>25
Sripur UG mines	0.014	0.024	2338	>20
Satgram UG mine	0.85	1.20	754	>30
Mitahpur OC patch	0.25	0.30	29.2	2years
Mithapur West UG	0.03	0.04	527	>50yrs

Topography:

The land is barren with gently undulating terrain. The Bhanora West Block Colliery of Sripur M/s ECL area is about 05 sq. km as per Sec 76 of Mines Act 1952. The block belongs to the lower and middle Raniganj formation. The Bhanora West block works on three seams, where the extraction is in progress from Poniati (R-II) to the Kalla seam. Some mines may be explored Underground (UG), and others are open-cast (OC) mines. The Bhanora O/C west patch is a mothballed coal mine where extraction is suspended but can be recommenced. Mineable coal reserves were 2.3MMT; OB was 24.1MMT, with an average stripping ratio of 10.48 Cum/MT.

The Over Burden (OB):

The Bhanora Colliery has two seams, R-V-Rana and R-VI-Sripur, which are functional. R-V-Rana has a maximum and minimum working depth of 230m and 129m, respectively. R-V and R-VI-Sripur coalmine are 230m and 88m, respectively, Fig 5(a-d) & Table 2.

Fig 5(a): The project area Bhanora OC patch (b) The drainage system (c)The coal mines / the OB area (d) Waterlogged area in Sripur e. Loading source of air pollution (f) Transportation

Company	2020-21 Over Burden Removal	Production (Open Cast)	Stripping Ratio	2021-22 Over Burden Removal	Production (Open Cast)	Stripping Ratio	2022-23 Over Burden Removal	Production (Open Cast)	Stripping Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ECL	139.585	35.695	3.91	118.989	23.432	5.08	133.128	26.050	5.11
CIL	1244.731	569.768	2.18	1335.590	597.008	2.24	1646.575	677.717	2.43

Fig 5(b): The stripping ratio is the OB removal ratio (OBR) in (M.cum) to Coal produced and production in MT in open-cast(OC) mining.

The last three years of OB removal from Eastern Coal Field Limited (ECL) and the stripping ratio is given in Table 2(a). The average stripping ratio of Coalfield India Limited (CIL) is 2.43, much less than the ECL. This shows that more OB must be extracted to yield the coal. The high volume of OB yield needs a suitable disposal area and the spread of toxicity, fire risk, and groundwater pollution.

Table 2: The seam status, thickness, and Parting in the Bhanora West O/C patch

#	Seams/GCV grade	Thickness in seams (m)		Parting(m)	Present status
		GPR	BH NCRB-11	28.15 (prev)	
1	Kushdanga (Local)/G-7	2.22-4.12	3.7	17.66	Mostly Virgin and Illegal mining pits
	R-VIII (T)/G7	0.97-1.87	1.18		Virgin
	R-VIII (B)/G-7	0.69-1.88	1.38	14.14	Virgin
	R-VII	0.30-2.71	1.05	63.41	Virgin
	R-VI	2.20-5.51	4.50	63.03	UG/ OC on Pillars.
	R-V	0.98-2.06	1.70	33.18	Developed in a small area

GCV: Bross calorific value; GPR: Ground penetrating radar; BH :Bore hole; OC: opencast

Since many illegal pits are made by the community in the crop zone of Kushadanga seam and few old excavated pits, there is a chance of exhaust of 0verall reserve, which may be about 20% from the UG mines and OC patch about 10%.

Geology of the Study Area

The Paschim(west) Bardhhaman dist. is shaped as Archaean (Precambrian origin) rocks comprising sedimentary or metasedimentary rocks (granites, Basalts schists, etc.). The volcanic eruptions in the Rajmahal basin and the deposition and mediation of ashes to the formation of coals and deposits in traps are the sources for coal mines in the west Bardhhaman district and so also the emergence in the Bhanora west coal mines in the Sripur area. The area of Ironstone shales is 113 Km2, and the thickness is 365 meters. The Raniganj measures crop out along the southern half of the famous Raniganj area (Gaz, Burd. 1994:33). The area of Supra Panchayat is 13 Km2, and its thickness is 300-600 m. Mishra et al., (2022)[13] (Table 3).

Table 3: In the last decade (2013-23), the coal extraction from the Bhanora West Coal mine

Sl. No.	Financial Year	Output (in Metric Tons)			Average OMS (in Metric Tons)			Avg. monthly output(u/g)
		(U/G)	Overcast (OC)	TOTAL	U/g	OC	Total	
1	2013-14	40447	NA	40447	0.32	NA	0.32	3370.7
2	2014-15	45580	NA	45580	0.36	NA	0.36	3798.33
3	2015-16	47609	NA	47609	0.38	NA	0.38	3967.4
4	2016-17	43850	159881	203731	0.42	NA	0.42	3654.16
5	2017-18	30364	144525	174889	0.24	NA	0.24	2530.33
6	2018-19	28375	499997	528372	0.21	NA	0.21	2364.58
7	2019-20	29695	442974	472669	0.19	NA	0.19	2474.58
8	2020-21	29471	120998	150469	0.22	NA	0.22	2455.91
9	2021-22	31466	24438	55904	0.24	NA	0.24	2622.16
10	2022-23	29616.84	NA	29616.84	0.21	NA	0.21	2468.07

The drainage system:

The area is located between rivers Ajay (North), Damodar (south) and Barakar (West). The Ajay – Damodar interconnective drainage channels and several drains in Paschim Bardhhaman. A drainage channel from the Sripur area joins Punta Khal/Jore, a tributary nallah running NE-SW, and joins the Nunia River (4th order). Garui Jore (3rd order) flows west to east and joins Nunia River flows SW-outskirt of Cluster-8. Nunia River runs NE to SE debouch in the Damodar River. (CMPDI piezometric report Job No. 111609[14]), Fig 5-d.

Stratigraphy:

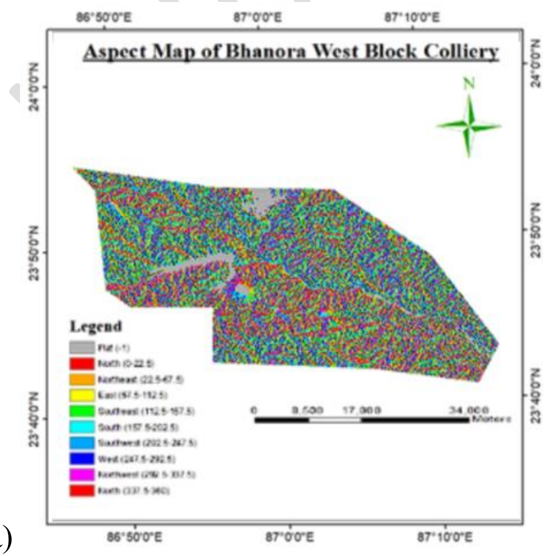
The GSI has reported that the Raniganj coal seams are of Upper Permian age, with the height of coal deposits of 1035m in the Raniganj area, and the limnology comprises medium-grained sandstone (grey to greenish), a variety of siltstone, shales and coal seams.

The Petrology and Hydrology of the area

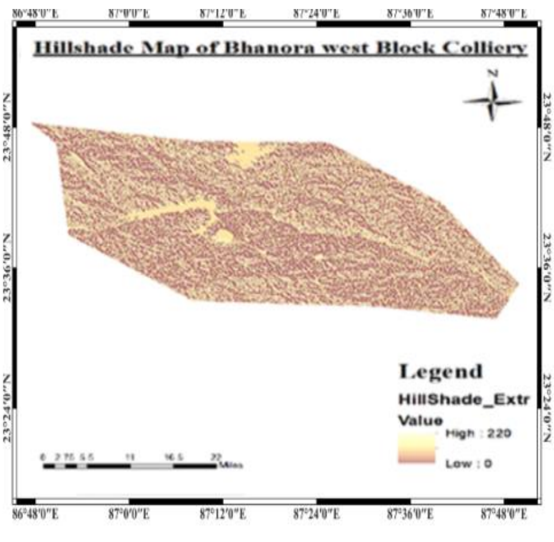
The area is positioned over the lower Chattan of Chhota Nagpur Plateau. The 60m thick Salma dyke at the western boundary is comparable to Rajmahal basalt. Rajmahal Basalt formation is 65Ma, but the Salma dyke is less than the 114 Ma Ca. years of age, but similar to Decan Volcanic rock, it might have formed due to post-Decan volcanic bustle. The dyke is a critical mafic intrusive in the Raniganj basin of tholeiitic in composition and MgO abundance. The dyke is mediated by ultramafic-ultrapotassic (minette, lamproite and orangeite) and mafic (dolerite) rocks, Paul DK, 2005[15], Banerjee et al., 2024[16]. The direction of the dip of the seams of coal is Sx4^{0}W, the dipping rate is 1 in 6.5, and the average thickness ranges from 1.81m (Koithee) and at Sripur 4.03m.

Geography of the area:

Raniganj area is part of the Gondwana Supergroup. This group is identified to have large coal seams throughout India. They are datable from the Late Palaeozoic to the Mesozoic era. The Sripur area lies between the transitional zone between the Chota Nagpur Plateau (peninsular shield) in the west and the Ganga-Brahmaputra alluvial plain (north and east). The land is of undulating rocky topography, sporadic laterite soil, dolerite, and basalt rocks towards the west with coal seams, carbonaceous shales, and fine greyish sandstones, Fig 6.



(a)



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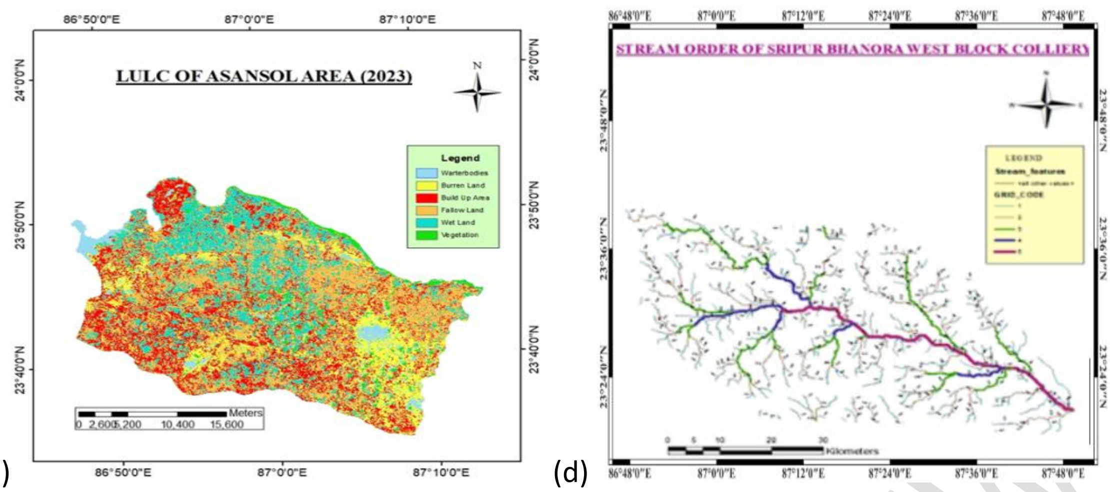


(c) (d)

Fig 6 (a-b): The aspect Map, (b) the hill shade map of Bhanora west Block, Asansol, (c) The Land-use /Land cover map of Asansol area, (d) the Stream order map of Asansol 2023

The Coal in Asansol District:

Rich and abundant with coal seams, the Asansol area has huge and the best type of non-coking coal reserves, spreading over 443.50 sq. km; mining activities are datable to 1774 by the Britishers. Systematic coal extraction started in the mid-19th century. The coal was extracted using two methods: Raniganj and Barkar. The present study area is part of Raniganj measures and under Eastern Coalfield Ltd. Covering areas Raniganj, Pandaveswar, Jhanjra, Kajora, Kenda, Bankola, , Satgram, Sonapur, Sodepur Kunustoria, Sripur and part of Salanpur.

The Demography of the area:

Before the advent of coal mining, the entire region was a low-productive rice crop area in what was once a part of the Jungle Mahals. Before mining started, land ownership passed from local Adivasis to agricultural castes. However, the Santhals and the Bauris, referred to by the colonial administrators as "traditional coal cutters of Raniganj, " remained attached to their lost land and left the mines for agricultural-related work, which was also more remunerative. It forced the mine owners to bring in outside labour, mainly from Bihar, Odisha and Uttar Pradesh. In time, migrants dominated the mining and industrial sectors. The pauperisation and alienation of the Adivasis has been a significant point of social concern.

The climate:

The climate of the Sripur area falls under the Köppen climate type, which is Aw: Tropical savanna, wet, with summer from Mar. to June and a rainy season from June to Sept.. With a moderate climate, the temperature range is 24°C to 44°C during Summer months and 6°C to 26°C in Winter, with av. rainfall is ≈ 1300mm/yr., paschimbardhaman.gov.in/agriculture/.

Study of vegetative changes:

The study involves detecting mining ecosystem changes and conducting reclamation activities using GIS/RS, including visual interpretation, discrimination of vegetation index, sorting and time-series analysis. The standard method in earth science is the change detection (CD) method, which compares remote sensing (RS) images of different years by visual interpretation Wang et al., 2023[8]. Many areas have been deforested and turned infertile due to the dumping of OB. ECL has taken up plantations and afforestation of 105.00 Ha over the inside OB Dump/Backfilled Area (52.5 Ha), outside the OB Dump (10.0 Ha), fallow lands (41.0 Ha) and other plain lands transportation stockyards (1.5 Ha) with about 262500 nos of saplings have been created or purchased from the Forest Department of Jharkhand and West Bengal. In Sripur seam incline-8 areas, about 20 ha of land has been taken up in the subsided areas for plantation, https://easterncoal.nic.in/corpinfo/environmeasures.aspx.

Safety in coal mine activities:

Safety administration in coal mine areas is vital to reduce and improve risk management. The mothballed or defunct closure of coal mines with poor mining left-out conditions accelerates risk and the safety status quo of the mines and the miners without proper planning and a well-judged closure proposal. The method of working in Sripur mines is the board and pillar method, with a board width and pillar size of 30mx30m and a gallery height of 2.8m. On 9.10.1979, there was a significant accident in Bhanora Mines, killing five persons and seriously traumatising two persons due to the fall of the roof (Sarkar et al., 2017[17]). An eight-year study of various accidents from 2012 to 2019 was undertaken. The fatalities/Trauma/ reportable cases of mine accidents while in operation in the Bhanora west OC patch are in Table 4.

Table 4: The accident statistics of the Bhanora West coal mine from 2012 to 2019

Year	Fatalities	Trauma (serious)	Minor but reportable	Total
2012	Nil	Nil	08	08
2013	Nil	Nil	08	08
2014	01(non-mining)	Nil	05	06
2015	Nil	Nil	09	09
2016	Nil	01	03	04
2017	Nil	Nil	01	01
2018	Nil	Nil	Nil	Nil
2019	Nil	Nil	nil	nil

Fire Accidents:

Coal left behind as safety pillars and ribs during mining can catch fire, and open cracks and fissures can allow oxygen in to make the problem worse and become unfit for human habitation. These related issues can make mining areas uninhabitable. Amongst the major accidents in Indian coal mines in the post-independence period, only one has occurred in what is now the Sripur Area; on 14 March 1954, 10 persons were killed in an explosion of firedamp at Damra Colliery, then owned by Kali Pahari Coal Company.

Preventing Environmental degradation:

Coal mine areas are storehouses of contamination, conducive to environmental degradation, including greenhouse gas emissions, air/water pollution, soil degradation, etc. These activities can lead to health adversities, biodiversity deterioration, and climate change. To avoid/ ameliorate environmental pollution, optimisation of coal extraction, regular use of dust masks, periodical lung disease testing, and development of green belts within the canopy are needed. Grading of subsided areas and planting The Re-handling of overburden (OB) needs re-handling and the final dumping of the residual OB dump in unusable lands. Some pillars must be constructed below the land during agricultural production. No coal production should be below the lacustrine areas, settlement, H.T. lines, roads and habitation areas. The drainage/ storm/ sewage water disposal is direct to the Nunia nallah and must not be done after the STP plant. A slow sand filter and chlorination must be treated for further use.

Human Health

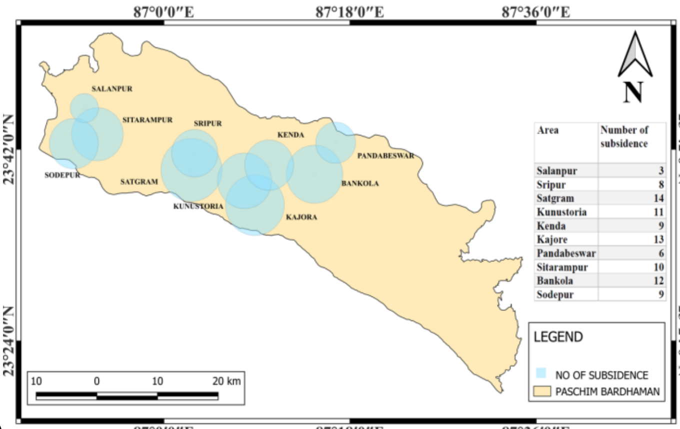
Coal miners' health is vital in mining areas and is wide-ranging. Coal mining operations expose them to detrimental chemicals, heavy metals, and suspended particulate matter (SPM). Acute respiratory, cardiac, and lung problems are more common. Substantial incidences of diabetes, cardiovascular diseases, and hypertension are health issues, along with higher rates of skin infections, lung disorders, and breathing-related illnesses. States like Chhattisgarh, Jharkhand, and Odisha have more coal mine areas. Accumulating trace metals like mercury, arsenic, cadmium, lead, and chromium are also present in Choudhury et al., 2022[18]; Mishra et al., 2020[19]; Cortes et al., 2022[20]; Gopinath et al., 2023[21].

Subsidence hazard:

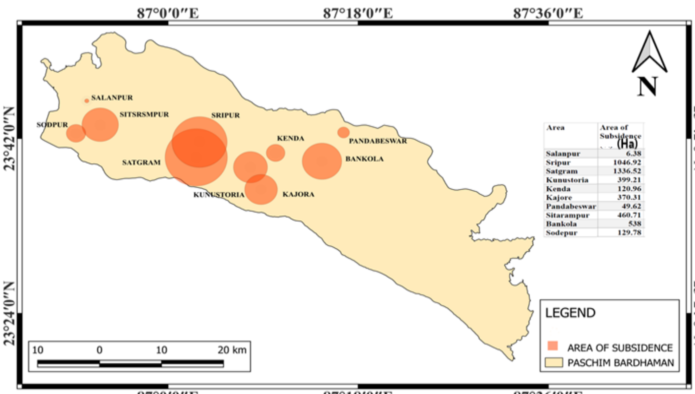
The coal-extracted areas must be backfilled to avoid subsidence of overlying layers and conserve shallow water. Backfilling can also stabilise old and abandoned underground workings. The underground coal mine must be backfilled with coal ash, overburden (OB) materials, slag from nearby factories, and sand for stowing by designing pipeline reticulation. Extraction accompanying backfilling and ground soil stabilisation or UG dam design are preferred. The coal is locked up, and standing pillars or panels should be prioritised to avoid sinking and subsidence. Ground study of the Sripur area has shown eight such subsidence areas over the coal mines (Roy et al., 2023[22]),

The Bhanora West Block Colliery lies in the east of Nunia Nallah and a dyke named Salma. This patch of the Raniganj area is prone to the threat of land subsidence, causing ecological deterioration. Toxic runoff to the biome and drains has polluted the aquifers, and seepage to the underfill has lowered the water table along the flow path of the UG reservoir. The coal mines have sporadic fire hazards.

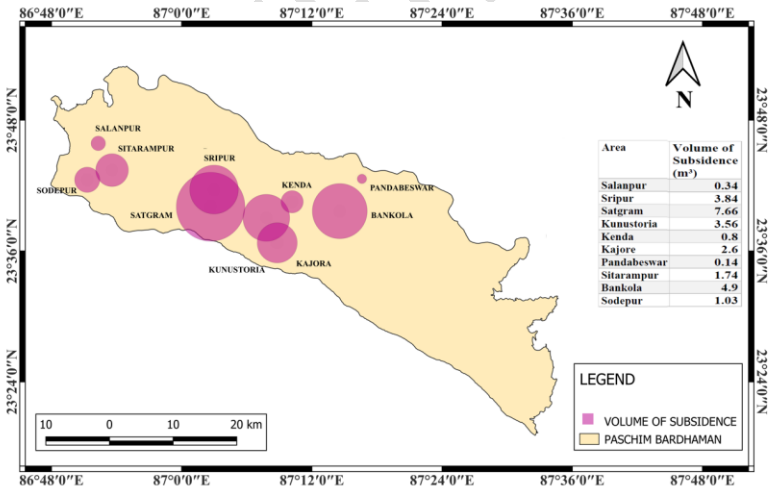
The number of sinking and subsiding areas found is at eight locations in the Satgram area. CMPDIL-2019 has reported in its Feedback report that the Satgram mines area is more susceptible to landslide and subsidence. The landslide and subsidence exist in the Kajora area in Jambad Colliery, Sripur Satgram area, Kalipahara Colliery, Kalla Hospital ECL Quarter area, Giri Mint Colliery in the upper Dhowdha Quarter area, Mahabir Colliery (Raniganj) etc.



(a)



(b)



(c)

Fig 7 (a-c) : The subsidence area maps (no, volume and area) of different coal mines in west Bardhhaman (Source updated: CMPDIL-2019; Feedback report)

An assessment was made 2008 that 22 unstable areas in and around Sripur areas are likely to affect about 71000 people of 10600 unstable houses, even in the few quarter areas. Subsidence in different collieries of Eastern Coalfields up to 2008. Source: Feedback Report. CMPDIL (8) and (https://coal.gov.in/sites/default/files/2024-06/PIB2027083.), Fig 8 (A-D)

Fig 8 (A-D): A&B: fire hazards in the Sripur area C&D: landslide and subsidence hazards in coal mines in and around the Asansol area.

The subsidence has become alarming near the newly constructed NH from Kalipahari Railway gate leading to Neamat Pur (subsided 2.6 -4 m depth X length ≈1500 m in 2006-7. The more susceptible landslide-prone areas are Banksimulia, Bhanora, Rana, Adjoy II, Sheebpur, Bhanora, Charan Pur East, Bhanora, D. Bright's Rana, Kalapahari, Sripur, Grimint, Dhadka, Sripur no.3 incline, Bhutdoba, Kalipahari, sheebpur, Jamuria 5, 6, 110 & 11 and Damodarpur, and Akhalpur 1 & 2 pits, Central Jamuria, Poniati, New Ghusick. The villages around are unstable and hang over a hollow and void coal seam, and Kuccha houses are overlain by Mishra et al. (2023[23]).

Actions taken for environmental Impact:

i. **Effluent treatment**: For debouching the mine effluent, an STP (slow Pressure Filter of 5000 GPH) has been installed by CMPDIL to treat the effluent of Bhanora colliery at Sripur and discharged finally to Nunia nallah (As per norms of MoEF Schedule VI).

ii. **Air quality:** To sustain PM 2.5 and PM 10, the coal is transported to Rly siding by tarpaulin-covered trucks from Bhanora or other mines to Asansol.

iii. **Water quality:** The water quality of the aquifers in the Sripur mines area along with the Nunia nallah has been tested in the laboratory by ECL and Nunia nala water by Joshi et al. (2017)[24], Mukherjee et al. (2023)[25] Table-5

Table 5: water quality of UG water at Bhanora and Ningah and drain water off Seopur nallah

Sl	Parameters	Unit	Underground water **(Bhanora)**	Underground water **(Ningah)**	Drain (Nunia Nallah)	Permissible limit	Acceptable
1	Colour	Hazen unit	4	3		5	15
2	Turbidity	NTU	2	2		1	5
3	Total Hardness		192	232	238	300	600
4	pH		7.5	8.66	7.1	6.5-8.5	6.5-8.5
5	Chlorides	mg/lit	34	43		250	1000
6	Fluoride (F)	mg/lit	0.79	0.28		1	1.5
7	TDS		474	546	403	500	2000
8	Alkalinity	mg/lit	320	148	352	200	600
	Metals/Nonmetals	NB					
9	Calcium (Ca)	mg/lit	56	72	86	75	200
10	Manganese (Mn)	mg/lit	0.02	0.02		0.1	0.3
11	Copper (Cu)	mg/lit	<0.03	<0.03		0.05	1.5
12	Selenium (Se)	mg/lit	<0.002	<0.002		0.01	0.01
13	Iron	mg/lit	<0.06	<0.06		0.3	0.3
14	Arsenic (As)	mg/lit	<0.002	<0.002		0.01	0.05
15	Lead (Pb)	mg/lit	<0.005	<0.005		0.01	0.01
16	Zinc (Zn)	mg/lit	0.04	0.03		5	15
17	Chromium (Hex Cr)	mg/lit	<0.1	<0.01		0.05	0.05
18	Boron (B)	mg/lit	<0.2	<0.02		0.5	1
19	Cadmium (Cd)	mg/lit	<0.0005	<0.005		0.003	0.003
20	**Biological parameters**						
21	Coliform (MPN)	mg/lit	Nil	Nil			
22	Phenolics	mg/lit	<0.001	<0.001		0.001	0.002

Source: Environmental Monitoring report ECL (P-11) Job No – 110310 and

Recommendations:

It is essential to conduct regular awareness campaigns by appropriate mentors from time to time about water contamination in the area. The liquid wastes from the mine/ market area must be addressed before being disposed of in the adjacent Garui Nallah and Nunia Nallah. Since mine workers need frequent bathing, the water of nearby Nallahs must be of standard Class-B, i.e. minimum fit for open bathing as per Water Quality Standards (as per (IS 2296) – CWAS. The senior management must be aware of maintaining the quality of groundwater and surface runoff to decrease water pollution by enhancing the drain's perennial water flow, Mishra et al., (2016)[26].

Since Bhanora OC/ UG coal mines are both active, the production should not exceed 0.74MTPA within the mining leased area (maximum prefixed) to validate the EC norms for the life of the Mine or as specified in Part-II, and Section 3, Sub-section (ii) EIA Notification, 2006, whichever is earlier maintaining all safety norms including well-covered transportation as per DG Mines coal mines regulations (CMR) 2017. The existing three-tier green belt cover should be maintained, including the roadsides and railway sidings, to protect the environment free from dust and noise nexus.

More Piezometers suggestions:

Piezometers (Geotechnical sensors) are used to quantify the degree of pore water pressure in soil, earth and rock fill, foundations, concrete structures, etc. It is constructed to reduce the bearing capacity of soil /rock, assess the level and groundwater flow pattern, and delineate the phreatic line. The Nunia Jore is flowing in the vicinity, and the chances of the influx of water inside the mines cannot be evaded, and the construction of Piezometers is essential. Out of 30 numbers of installations of Piezometers in the ECL command area, two numbers are constructed in the Sripur area, one at the Manager's office campus (Madanmohanpur and Bhanora villages) and the other at Bhakhapara, Shivdanga (Ningha colliery Office campus)),to monitor the pore water pressure of the aquifer between R-IV and R-V seams) CMPDI Report job No 111609[14].

Coal, mining activities and SDG's:

Coal mining activities are directly related to Sustainable Development Goals (SDGs), SDG 1 (No Poverty), SDG-3 (Good Health/Well-being), SDG 6 (Clean Water/Sanitation), SDG 12(Responsible Consumption and Production); SDG 13 (Climate Action) and SDG 15 (Life on Lan). Also, the extraction of coal and its mining activities are indirectly related to SDG 7: Energy Access and Sustainability, SDG 8 (Catalysing economic growth and employment), and SDG 9 (Creating more resilient infrastructure). SDGs 1, 12, and 16 were considered high priority (Omotehinse et al., 2023[27]).

For strict adherence to the norms of the SDGs, a sustainable development cell has been constituted by ECL to formulate plans, concoct guidelines, perform review by monitoring, and appraise various environmental amelioration measures headed by the Director (Tech) P&P chairs the SDC cell and senior management teams. The pedagogy prepared for a better environment for the stakeholders of the environment.

Environmental Sustenance

The corporate environmental policy formulated by ECL for pollution mitigation, natural resources conservation, and Waste Management (Solid, liquid and atmospheric) for sustainable biodiversity). The norms of the Mission SuDESHH (Sustainable Dev. of Environment, Water Safety, Health and Hygiene) are well maintained for the local people. 10 R's (Reduce, Reuse, Recycle, Redesign, Refurbish, Repurpose, Recover, Repair, Refuse and Redeploy) are strictly followed in Bhanora Colliery areas as an adoption of Corporate Environmental Policy (CEP). The area is accorded Environment and Forest Clearance from appropriate government organisations for a conserved ecosystem and biodiversity till 2019. CSR policies must be followed to sustain the environment.

Adoption of Renewable Energy: Like other mining areas, it should be lit with solar LED street lights and lighten in the other areas by installing solar plants and recent advanced geothermal plants.

Coal illicit trading: After 1980, the coal mines are nationalised. In the Bhanora mines, coal is available at a very shallow depth. The local villagers in the open cast mines area have unauthorised mining extraction practices, either by digging pits or unauthorised boreholes, and extensive malpractice in transporting and selling them elsewhere, which must be checked.

Groundwater Recharge: Groundwater recharge (by rooftop rainwater harvest) for the UG aquifers in the mining areas and irrigation facility must be provided to augment stakeholders'/farmers' needs. STPs must be installed to make the contaminated water portable and fit for human use. Post-mining impacts are hazardous, so proper risk assessment and formulation of judicious management plans by the authorities, policymakers, and planners, even for the mine closed or at geriatric (post-mining) age, Al-Heib et al., (2023)

Subsidence avoidance: Planting stump-rooted trees with deep roots like Neem, Karanch, Seemul, Shisham, Arjun, Babool, Sirish, etc. are needed to prevent soil erosion. The proponent is for additional plantations at various barren lands in clusters, depending upon the readiness of the land. Rivulets/ drains shall be renovated and cleared of Ipomeas and water Hyacinths to bring them back to a functional state. The effluent-carrying channels are to be separated from STPs. For smooth discharge to Nunia nallah, garlanding of drains within the Sripur area after extraction, followed by caving/ stowing, must be done to avoid coal mine hazards, Al Heib et al.(2023)[28]. All structures within the coal mines preferred to be arch type, Li et al. (2022)[6]

Dust suppression

The water sprinkler (Mobile) in the total Coal siding areas by the Water Tanker needs to be geared up with more numbers of machinery. To control particulate emissions, more fixed water sprinklers must be installed in dumping/ sidings.

Waste to wealth

Maintaining a circular economy through waste to wealth has been initiated by recycling the OB instead of dumping/ and stowing and reusing it after refurbishing M-Sand to minimise ecological pollution and constructing a three-tyre green belt Mallick et al., (2020)[29] Fig 9.

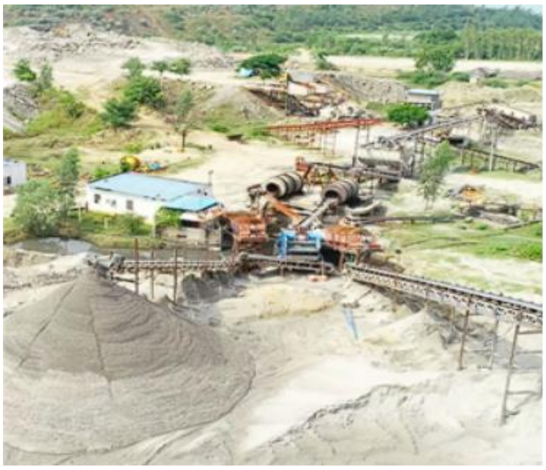
(a)  (b) 

Fig 9(a-b) : (a)The plantation over OB (b) the Processing of OB Plant in Bhanora, Sripur

Coal/Lignite PSUs have been made to order by four OB processing plants and five OB to M-sand Plants at Sripur, Kazora, Gonegaon, Amlhori, etc. Six nos of OB processing/ OB to M-sand plants are in the different stages of installation in the coal/lithium PSUs. MOEFCC proposes to have 1181.2 Ha @1600 trees/ha until the closure of the project.

Precaution to water hazards/ During and After Depillaring:

More allowance and an accurate mine plan are needed to avoid hydrological accidents within the UG mine areas due to water seepage under pressure. Hydrological hazards within mines are estimated to occur in de-pillaring zones within 50-60m of waterlogged areas and omission of boreholes. Depillaring below lacustrine areas, areas under subsidence, landslide areas, rivulets, drains, etc., are not to be taken up. During bottom seam depillaring with stowing, it is needed to start from rise to dip after dewatering boreholes from the bottommost seam after receiving appropriate permission from higher authorities. The caving and stowing activities should be monitored strictly, and backfilling should be prioritised to avoid subsidence. The mines and OB excavated must be returned to their original status and fit for agricultural /plantation purposes.

Risk and Safety Mines areas:

The Coal Mines Regulations (CMR) 2017 has obligatory the Safety Management Plans (SMPs) as a statutory prerequisite for mines. Clause 104 of the CMR 2017 states that the mines should launch a Safety and Health Management System (SHMS) to detect hazards and high risks and apply controls. Implementing mine-specific rules and adequate training for HEMM operators, maintenance teams, and the contractors' staff are essential. The high mast towers should be safe, and lighting should be uninterrupted and of better standards. The coal extraction without blasting, vertical rippers used to excerpt OB and maintaining an eco-friendly working environment is essential. Regularly conduct safety audits for mines in operation to measure safety and rectify any violations. The application of high-tech technology in mining procedures, advanced machinery, and safety monitoring with highly skilled operating personnel should be updated regularly with experienced trainers and mentors.

Constant vigilance, stress amelioration, supervision, and work assistance must be in vogue in the workplace. Mental and physical health, safe drinking water, a conducive workplace environment, and a friendly atmosphere between the management and workforce is essential. Supervision: Providing constant vigilance, constant supervision, and assistance from various sectors are necessities for ameliorating risk and maintaining safety, per comprehensive Safety Management Plans in coal mines.

Health in the Sripur Mines area:

Coal extraction and transportation processes add to environmental pollution. There is a potential risk to people in coal mines with lung diseases, termed Coal Mine Dust Lung (CMDL) diseases. They suffer from pneumoconiosis (CWP), a lung disease (black lung), chronic obstructive pulmonary disease (COPD), and silicosis. lung function impairment, etc. When breathing coal dust, coal miners suffer from symptoms of organic dust toxic syndrome (ODTS) that occur 4 to 12 hours after exposure. Symptoms are fever, weakness, body aches, cough, headache, chills, and shortness of breath. To avoid dust hazards, roads must be planned and appropriately designed, Nayak et al., (2020)[30]

Conclusion:

Fostering sustainability growth and conservational stewardship in the coal mining sector is essential under affordable and clean energy (SDG 7) and climate action (SDG 13). The coal mining activities cause environmental bearings, ecosystem degradation, landscape variation, soil pollution, and surface/ groundwater changes. In addition, toxic compounds such as heavy metals, radioactive elements, polycyclic aromatic hydrocarbons (PAHs), and other organic contaminants are released into the environment, ultimately affecting the health of ecosystems and the general population. All safety procedures must be followed per CMR- 1957 and subsequent Circulars.

Regarding subsidence, specific legislation is lagging in India and is treated as a property act of the country. The formulation and enactment of such laws are evident with a holistic approach to sustain the adjoining ecosystem health. Regularly use Sentinel-1 SAR Data to detect and analyse the emerging subsidence in new areas from poor backfilling and coal mine fires in the Sripur area.

The GIS-based assessment provides valuable insights into the environmental impact of mining activities. It offers practical remediation strategies that can be applied globally in West Bengal and similar regions.

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Details of the AI usage are given below:

1.

2.

3.

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