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Coal Waste Dumping, Mine Reclamation and Pit Lake Management in the Open Cast Mines of Tikak and Tirap Colliery, Tinsukia District, Assam, India

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ABSTRACT

Coal or black gold usually occurs in layers known as coal seams. The coal reserves of India are of tertiary origin and are of peat, sub-bituminous and bituminous nature. The Tirap and Tikak coalfields are the largest coalfields of Ledo-Margherita area in the District of Tinsukia. While Tikak coalfield is operational, Tirap has been closed on environmental grounds. Both the coalfields have undergone the activity of mine reclamation and pit lake formation. Coal waste mountains extensively mark the landscape. The Rat-Hole mining is also operational in the area resulting in illegal mining and unpredictable fires due to oxidation and release of poisonous gases. Deliberate efforts by the mining authorities have been seen in the management of the mines. The process of mine reclamation has already begun in both the coalfields and there has been a significant transformation after the plantations took place. The barren lands are planted once the mining gets completed for the zone. A unique feature of surface mine is the presence of pit lakes. They are the lakes formed in the depressions caused by mining and often coincide with the level of the ground water table. These lakes are filled with ground water, precipitation, water from mountains and other surface run-off. They have high potential in serving the aquatic needs of nearby communities, recreation and provides home to flora and fauna if taken utmost care of. Case study approach has been chosen to understand the sustainability efforts of the mines. The effectiveness of mine reclamation has been studied to understand its present and future benefits. Pit lakes and its role in aquatic sustainability have been analyzed as they are basically created and regulated to mitigate environmental impacts from mining operations. Pit lakes are being seen as an important site to have its inclusion in the Ramsar list in India. These efforts are leading its way towards green mines and sustainability.

Key words: *Tikak and Tirap coalfields, Mine reclamation, Pit lakes, Coal waste dumping, Rat-Hole mining.*

Introduction

Coal is one of the most abundant fossil fuel and has been known and used as a primary fuel for thousands of years marking its significant place in the period of Industrial Revolution. Coal occurs in layers known as coal seams or coal beds. It is a piece of history that is being utilised in the present. Like other conventional forms of energy, coal is finite but still it holds an important position in the energy market. Even though renewable clean energy sources like solar power, wind energy, hydropower

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etc; are taken as alternatives and are competing against the conventional sources to meet the growing demands cutting soaring carbon emissions, the bigger proportion of a country's energy requirements are met by coal as it is one of the relatively cheapest, plentiful and dependable long-term resource. Developing countries rely on this primary resource as need for energy manifolds and it is geographically covered and available domestically in many countries. Coal is unlikely to lose its significance due to its abundance and proximity to markets globally, also mining forms the economic foundation of many countries. One of the key goals of economic growth is access to affordable energy, hence mining operations are inevitable. However, mining has a hazardous impact on surroundings and livelihood of people. Mining tends to make a notable impact on the environment, the impacts varying in severity depending on whether the mine is working or abandoned, the mining methods used and the geological conditions (Bell *et al.,* 2001).

The extraction of this mineral is a tedious and risky task involving manpower in tunnelling, digging, and manually extracting the coal from deep and dark underground mines or a surface also called open cast mines. Open cast mining or surface mining is a technique that extracts rocks or minerals deposits found relatively close to the surface of the earth. Miners determine the information on the ore, collect information on the vertical extent of the layer and then it requires a tunnelling into the earth and drilling of open pits on the ground. These pits are typically enlarged, progressively wider until the resource is exhausted in the site. Even though coal extraction has a challenging impact on environment and livelihood, it also exerts a long lasting impact on landscape, ecosystem and ecological degradation of the mining area. Large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands are some of the conspicuous environmental implications of coal mining (Swer and Singh, 2004). Open cast coal mine spoils are deficient in plant nutrients due to biologically rich top soil being removed and cause a serious problem for revegetation and restoration (Maharana *et al.,* 2015). Coal mine drainage affects the channel of water flow in the area , also disturbing the natural drainage pattern.

Coal is one of the vital resource of industrialisation and developmental activities in India. Open cast mining is still prevalent in many of these mining states. North-east India much to the significance with the rest of the states in India, has a rich repository of natural resources from coal to crude oil, limestone etc. North Eastern coalfields, operating under parent organisation Coal India ltd has its headquarters in Margherita, Tinsukia in Assam. Based on geological formations, the north-eastern mines have a distribution of younger tertiary coal reserves. This variety of coal has low carbon content and a high percentage of moisture and sulphur. These coalfields bear peat, sub-bituminous and bituminous nature of coal. These north-eastern coals are characterised by high sulphur content and occur in the states of Assam, Meghalaya, Sikkim, Nagaland and Arunachal Pradesh (Saikia *et al.,* 2015a). The major collieries functioning in the region are Tikak colliery, Ledo OCP, Tirap colliery, Tipong colliery, Borgolai colliery.

Tikak and Tirap colliery mines comes under Ledo-Margherita coalfields where surface mining takes place for mining operations. The Tirap and Tikak coalfields are the largest coalfields of Ledo-Margherita area in the district of Tinsukia. Tirap colliery has been operating since 1983 and Tikak colliery since 1986. While the underground coal mining is a more environment friendly method, the open cast mining operations cause major damage to the environment. In the Ledo colliery in Assam, open cast mining is the main method being used (Dutta *et al.,* 2017). The topical study on the two mines is an attempt to understand the after processes of mining. While Tikak coal field is operational, Tirap has been closed on environmental grounds. Both the coalfields have undergone the activity of mine reclamation and pit lake formation. The old age practice of coal waste dumping has worsened the situation but a new dawn of light can be seen through the practice of mine reclamation in these area's post-mining activities. A unique feature of these two surface mines is the presence of pit lakes. These lakes are filled with ground water, precipitation, water from mountains and other surface run-off. They have high potential in serving the aquatic needs of nearby communities, recreation and can provide home to flora and fauna if taken utmost care of. The dangerous practice of digging deep narrow tunnels to illegally enter and extract coal from unoperational mining grounds, often known as Rat-Hole Mining has become a flourishing business in these areas. Often, it becomes a treasure-hunt for poverty ridden people to earn daily bread.

They employ young children into this dirty business as it involves less investment and bring good returns. Such unskilled theft leads to many deaths due to suffocation, hunger, cave flooding which are kept aloof from the ears of the people, and benefitting only a section of coal mafias. Inspite of site inspections, recording instances of illegal mining in Tirap, there is a continuance of such activities for a long time. Satellite surveillance of the coalfields can help to trace the extent of such ongoing underground practices to prevent coal theft.

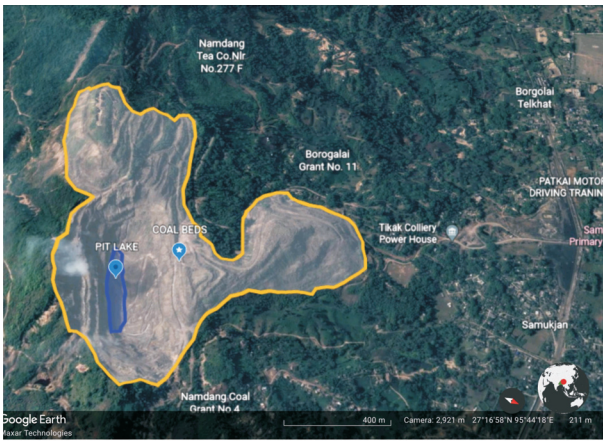


Fig. 1. Map of the study area

Source: Google Earth

Monitoring Location Details:

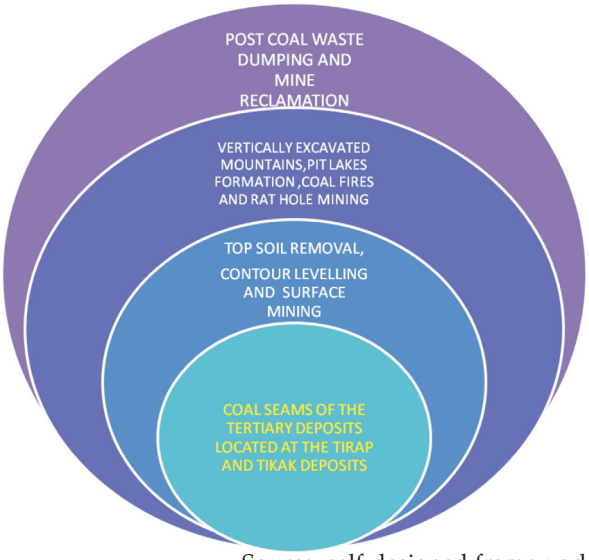
LOCATION	COORDINATES	
Tikak colliery	27°16′58″N	95°44′18″E

Objectives of the study

1. To understand the effectiveness of mine land reclamation measures carried out by the coalfield authority.
2. To understand and analyse the causes of pit lake formation and its importance in the ecosystem.
3. To understand the relationship between mine reclamation and rat-hole mining.

Methodology

This study is a result of assessing and interpretation of secondary data source. Necessary data has been gathered from the Northeast Coal Department and later other effective methods like the observation, photography and interview method has been adopted to get an in-depth view of the mining operations, environmental degradation and environmental planning. For identification of the mining sites and pit lakes satellite images from Google Earth has been extracted. Descriptive statistical graphs are drawn for better visual representation. Focus group interview has been carried out with a total of 10 members asking about their perceptions and opinion about the impact of pre and post mining processes.



Source: self-designed framework

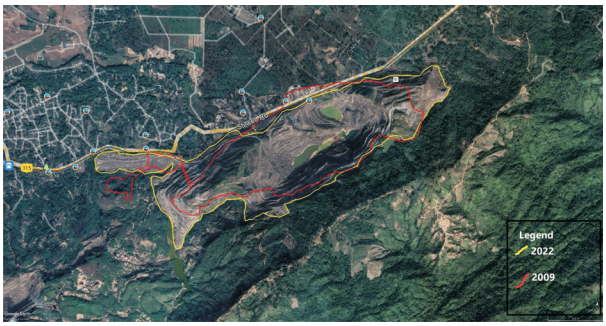
Fig. 2. Conceptual Framework to Explain the processes Involved in Tikak and Tirap Coal Mining

Findings and Discussion

- Mine reclamation and mine water quality data of Tirap colliery has been extracted from the official website of North-eastern coalfields as well as its Regional Department located at Margherita.
- Tirap mines have been operational for more than 30 years and the major coal seams located at 60ft and 20ft are extensively exploited over these years. The use of mechanised drill and blasting in the area has led to greenhouse gas emissions, coal fires, chemical leaching, waste dump containing radioactive or toxic metals like lead, nickel, cyanide and arsenic compounds.
- The continuous surface mining has led to the water stress in the region. Acidic discharges and run-off has dissolved heavy metals in water which has penetrated into local aquifers. There has been seen a rise in skin diseases and diges-

tive illnesses in the vicinity areas.

- The river courses of Namdang, Ledopani,and Tirap are exposed to the coal bearing section of Tikak parbat formations. This is the reason for high arsenic, copper, iron and lead in the water. This has caused the reddishness of clothes and nails of the netizens.
- Therefore, Environmental Impact Assessment of mining areas should follow stringent land reclamation codes to mitigate environmental impacts.



Source: Google Earth Pro software

Fig. 3. Map of Tirap colliery demarcating extensive coal exploration boundary from the year 2009 to 2022

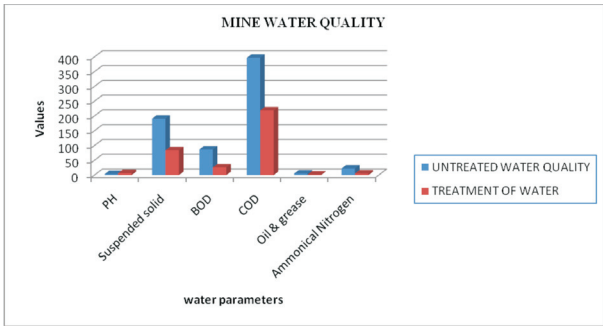
Mining area

The above image depicts a significant increase in mining area since 2009. The effects of it was seen as increasing pollution in the local inland waters, structural changes to physiography, change in colour of the water due to the increasing content of sulphuric acid in it. The loss of biodiversity is pretty evident in the images along with the contamination of soil. The aves of the area have totally abandoned it as per the

Picture showing mining practice of Tikak colliery

Source: Author camera photograph, September, 2022

prevailing conditions. This increase in the total mining area is quite controversial as well. The locals claim it to be encroachment of their habitat to some extent. The approximate increase in area is from 2.15 sq.km in 2009 to 2.83 sq.km in 2022.



Source: Data collected from the Northeast Coal Department, Margherita

Fig. 4. Measuring water quality parameters before and after treatment in Tirap Colliery (2015)

Water quality of mines

The above graph depicts some of the notable parameters of water and measuring its considerable limits in mine water . The water discharging out of mining sites flows and falls into the local streams of the area which might lead to the contamination of water bodies in the area. The levels of BOD, COD is excessively high crossing the permissible limits i.e; BOD is 87 and COD is 397. The PH lies 3.3 highly acidic in nature. The water is moderately turbid due to the concentration of total suspended solids in it. These suspended particles absorbs more heat than water molecules leading to rise in water temperature and decreases dissolved oxygen in it . The concentration of oily particles also raises water temperature, and a rise in BOD levels. Such high level of contamination affects aquatic ecosystem and health hazards if used for consumption. A significant change has been observed in the quality of water after its treatment as an effect on the rising levels of pollution. This shows a positive result in reducing pollution of nearby water bodies around the mining area as it has a direct impact on it.

Analyzing Mine Water Quality and its Treatment Efforts

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- The concentration of oily particles also raises water temperature, and a rise in BOD levels. Such high level of contamination affects aquatic ecosystem and health hazards if used for consumption.
- A significant change has been observed in the quality of water after its treatment as an effect on the rising levels of pollution.
- An effluent treatment plant works effectively in the area maintaining and treating mine drainage water with lime and soda ash with further sedimentation method before its discharged into ledopani drains.
- North-eastern coalfields limited has initiated tender in 2018 for tree plantation drive at Tikak colliery, Tirap colliery with 5 years maintenance.

Mine Reclamation and Afforestation Measures

Mining activities near the sites involves large scale displacement of soil, rock, and vegetation disturbing the natural setting of the topography. Any sort of developmental activity in forest usually initiate a series of changes in the status quo and disrupt the natural forest dynamics (Yadav *et al.,* 2018). This actively operating mines results in varying degrees of degradation, deforestation, erosion of top soil, acid mine drainage. Intense and invasive mine exploration, drilling, operation and extraction often leave large environmental impacts on the local surroundings, pollution from air-borne rock dust, release of toxic, radioactive substances such as cyanide, mercury or arsenic compounds contributes to contamination of water quality. Mining also leads to water stress in the area due to its heavy dependence on water supplies for carrying out mining operation. The vicinity of mines witnesses' loss of biodiversity, formation of sinkholes, waste dump,chemical leaching, coal fire, acidic discharges containing potential toxic metals like nickel, manganese, lead etc affects nearby streams such as Burhi-Dihing river along with its adjoining rivulet. Many aquatic vertebrates cannot tolerate the pollution, eutrophication can be observed around the sites.

Mining targets directly on environmental issues which makes it a significant global threat to climate change, environmental sustainability and carbon footprint. In response to the multifaceted risk involved in mining industry, investments in decarbonisation measures to reduce industry carbon footprint, carbon pricing , taxing on greenhouse gas emissions are becoming popular measure to make mining sustainable. Coal mining activities have caused massive health and environmental hazards over decades. But now, mining operations are taken under sustainability measures to reduce the risk and the industries are required to follow stringent environmental measures and rehabilitation along with land reclamation codes . These regulations follows the practice of environmental impact assessment, environmental monitoring before-during-after mine closure. Reclamation of mining areas restores environmental quality. It involves the process of revegetation, afforestation to balance the ecosystem structure, process and function post mining activities and mine closure. It ensures in reviving the sustainability of land along with its potential for future commercial use and aesthetic value. Reclamation process is carried out through 4 stages: land contouring, replacement of soil cover, planting trees and plant species and monitoring/site assessment over a specified time. Over time, expansion of tree cover and forest land will offer comprehensive benefit and raise the productive capacity of the degraded lands. To establish a stable landscape, mine reclamation efforts plays a central role in landscape planning, physical stabilization and integrated, sustainable post mining land use. The repair and recover of plant loss, regrade of mined land surface estimate the cost and benefit analysis of mining including cost of the emissions or degradation and benefit of reclamation work. The mines of Tirap

Source: Google Earth Pro software

Fig. 5. Land deforestation and the formation of pit lake in the mining ground of Tirap coalfield (image: 2009)

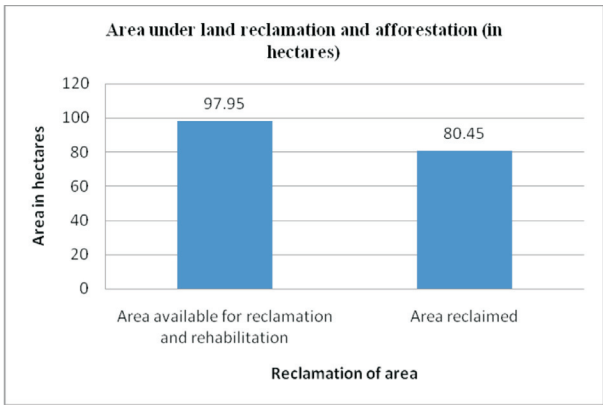
colliery have undergone certain amount of reclamation which marks a considerable sustainable change in the area.

Source: Google Earth Pro software

Fig. 6. Reclamation of the deforestated barren land post mining in Tirap coalfields (Image: 2022)

Land reclamation

Land reclamation after mining was not a firsthand adopted strategy in the Tirap colliery. But since its continuous lash off by the netizens led to the transformation of choice and revival strategies of the post mined areas. The Fig 1.5 depicts a part of Tirap colliery as of year 2009, which appears to be completely barren, void and facing tremendous soil erosion with dying health of the landscape. But the scenario started to change since 2019 when replantation and reclamation activities were adopted before the orders of it closing down. The recent picture shows the top layer being reclaimed in greens and a further close look depicts improved soil strength and health.

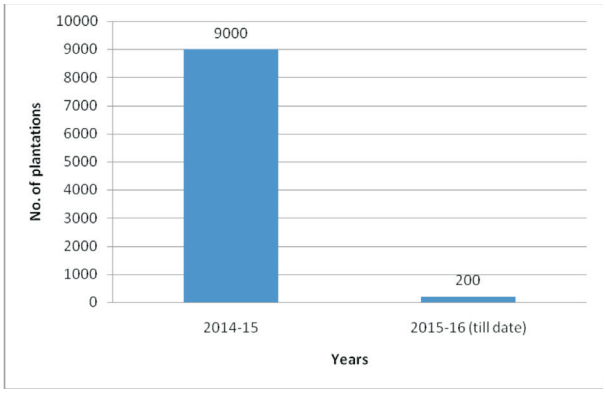


Source: Data collected from the Northeast Coal Department, Margherita

Fig. 7. Tirap colliery – Implementation of land reclamation and afforestation measures in post mining sites (2014-16)

This is one such eminent example which shows that damages cannot be reversed but can be lessened if restoration activities are in practice.

The graph above depicts the area in hectares under reclamation in the Tirap colliery mining site. It shows the area available for reclamation is more than the area reclaimed. This difference in the implementation of reclamation measures calls for a more efficient and inclusive practice.



Source: Data collected from the Northeast Coal Department, Margherita

Fig. 8. Number of saplings planted in the year 2014-15 and 2016 (till date) in Ledo coalfields

Understanding the sustainable benefits of land reclamation

- Tirap coalfields shows a considerable extent of land reclamation (80.45 ha) in the site post mining and exhaustion of resource in the area. Though the area available for reclamation (97.25 ha) is more than the area reclaimed till date. It marks a significant transformation in the landscape but the difference in its implementation calls for a more efficient and inclusive practice.
- The suspension of Tirap colliery under Northeastern coalfields in 2020 was on environmental grounds. Mining operations had surfaced with detrimental environmental hazards due to which its functioning was halted.
- Revegetation and sustainable mining was not committed to maintaining a balance between resource exploitation and natural management leading to its suspension for a brief period.
- Tikak coalfields are actively practicing full-fledged repair and recover of plant loss, regrading of mined surface for a sustainable change in the area. Saplings have been planted in the barren lands to restore environmental quality. The

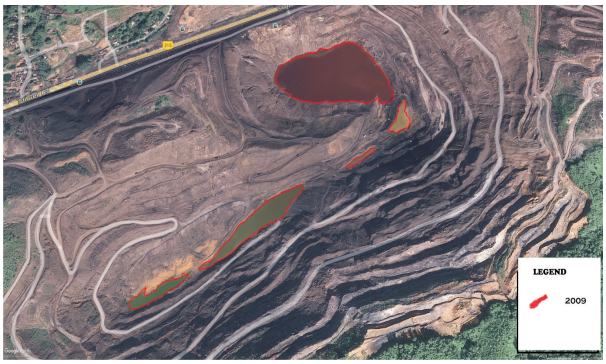
area under reclamation is still in process, requires timely monitoring and assessment to confirm a reclaimed area.

Picture showing the overburden layers,coal beds and the process of mine reclamation

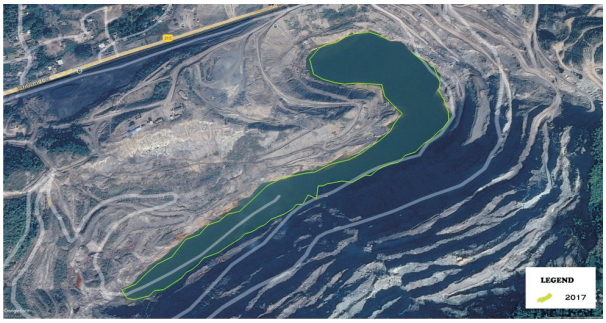
Source: Author camera photograph, September, 2022

Pit lakes of Tirap and Tikak colliery

Pit lakes are those water bodies which are formed by the mining activities. Pit lakes remain as final landforms of the post mining landscape in many instances of open pit mining, also called cut mining and surface mining. Depending on the country and local vernacular, these legacies may also be known as mine pit lakes, mine lakes, void lakes or end pit lakes (Martin *et al.*, 2022). Pit lakes are formed by water filling the open pit left upon the completion of mining operations. The pit lakes of the Tikak and Tirap colliery are coal seam lakes and have their own geology, structure and characteristics. Surface mining is widely practiced in the Tikak coal mines due to the availability of peat, sub-bituminous and bituminous variety of coal. open-pit coal mines (strip mines) on relatively level terrain commonly use area-mining techniques, in which overburden is stripped off and coal is mined along a linear front. As the mine front advances, overburden is used to reclaim mined-out parts of the pit. At the end of the mine life, this commonly leaves a long, narrow linear pit lake, which sometimes is referred to as a "final cut lake." It is common for such a lake to have a steep high wall or cliff along its front side and a more gradual slope on the back side. The depth of the lake is the sum of the thicknesses of the overburden and the coal seam. However, other shapes are possible for coal pits. The Pit lakes of Tikak and Tirap are Terminal in nature which means it receives groundwater from all the directions along with precipitation. These lakes are slightly acidic in nature due to the presence of pyrite in coal which is the main source of sulfur. But, lake management efforts can significantly help in reducing the toxic elements in water and making it suitable for aquatic habitat. The closed mines of Tirap coalfields has a mesmerizing pit lake which has huge potential to be developed as a recreational site. One of the most crucial environmental issues after creating pit lakes is related to their water quality. The role of geological, hydro geological, hydrological and geochemical conditions in the mining areas as principal components for predicting the water quality and the



Source: Google Earth Pro software



Source: Google Earth Pro software

Source: Google Earth Pro software

Fig. 9. Different images of Pit lake boundaries in the year 2009, 2017 and 2022

sustainability of pit lakes needs to be analyzed in correlation with climate changes (Chara *et al.*, 2021). Pit lakes are usually not that intoxicated but the mixing of excessive minerals makes it unfit for human use. Sincere biological and chemical cleaning of the Tirap pit lake can help in making it usable source of water.

Changes in the pit lake size

The pit lakes in the Tirap colliery has been changing not only in its shape but also its size based on turning years. In the year, 2009 the approximate pit lake size is accounted for 57,248 sq.m which grew up to be 118,669.15 sq.m in the year 2017. By the year 2022, it has come down to 66,164 sq.m, fragmenting into several small size pits. This has given a major idea about the ongoing operations at the mining site. In the initial years, the mining was limited, so the pit lakes formed were also smaller in size but with advancing years, the operation at the mining site increased along with increased extraction which has almost doubled the pit size area in 2017. But, after its closing order in the year 2019, the size has noticeably reduced as intrusion into the groundwater has also primarily reduced.

Rat hole mining and mine reclamation

Rat hole mining is the illegal practice of digging holes in the previously operational mines to undertake the coal business under the curtains. Commercial mining demands proper big tunnels with pillars and support, which requires a good sum of money, therefore the investors and the miners find rat-hole mining easy as it calls for less investment and gives out good returns (Sri Nidhi and Lloyd Katiyar Aakansha, 2022). Even though the mine reclamation process has been started in the Tirap coalfields, rat hole mining is still in progress because not all parts of the previously operational mines are covered. This gap gives a chance for the coal mafia to flourish and bloom. This can only be stopped if all the exposed mines are replanted and refilled with top soil.

Rat hole mining in the tirap colliery

Source: Author camera photograph, September, 2022

Conclusion

Mining operations in Tikak and Tirap coalfields aims at obtaining sync with nature, augmenting coal production along with conservation measures. Coal sector of north east India is adopting the path of sustainability and green mines. The coal ministry is making sustained efforts to protect the biodiversity, conservation of pit lakes as breeding ground for avifauna population, recreation purpose, maintaining the ecological and aesthetic character of the landscape. Land reclamation practices in the area are significant features of both the coalfields. The hilly terrains of degraded landmasses are covered with a boundary of green saplings and other vegetation cover to restore the natural resource and conserve soil. It serves to maintain abandoned closed mines making them environmentally stable landscapes. Coal is formed out of dead plant and animal matter with humus beneath the crust undergoing natural processes for millions of years. The vegetation near the mining site will help in regenerating this fossil as a part of the natural cycle of biological processes. Post mining activities followed by afforestation by the Department will help in restoring the natural drainage pattern and ecological balance in the long run. This practice will also bring an end to the dangerous rat hole mining in the area which kills at least an average of 5-10 people annually in Tinsukia District.

The ongoing practices of land reclamation in the closed mines of Tirap region should be taken as a set example to undertake early steps for other operational mines in the area. Although, practices of mine closure planning for land reclamation has come under stringent measures to mining companies as laid down in the Mineral conservation and development rules (MCDR) 2017 for sustainable mining but planning early for mine closure is essential to avoid future environmental challenges. There should be proper resource mapping to go through mine clo-

sure and reclamation to assess environmental and social impact post mining. This might help to make real-time decisions and implementation of unique solutions to restore degraded mining areas.

Conflict of Interest: The authors declare that they have no conflicts of interest.

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