

## Underground and Opencast Coal Mining Methods in India: A Comparative Assessment

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### Abstract

Coal is one of the most essential resources of a country. It is widely used for power generation and as a raw material in the industries. India ranks third in coal production. However, the country has to import coal in order to meet the rising demand for coal. In India, coal mining is conducted using two methods: underground and opencast methods. The underground method is suitable for extraction of deeper coal seams, whereas opencast method is suitable for shallow coal seams. However, due to less production cost, mechanisation, and less wastage, opencast method dominates in India (93.26% of the total production in the financial year 2016-17). Underground coal production in India shows a declining trend, and several underground mines are closed every year. However, 60% of the total coal production in the world is from underground mines, whereas in India it constitutes only 6.74% in the financial year 2016-17. Thus, underground coal production in India is declining. Due to the large scale extraction of near-surface coal resources by opencast mining, near-surface coal resources will be depleted in future.

Moreover, opencast mining has several environmental impacts, which is ignored keeping in view the colossal coal demand of the country. Thus, coal production in India is facing a crisis concerning the production method, environmental impacts and future demand for coal. With this background, this paper has been prepared on the basis of data collected from reports, research papers, and articles. Here, we make an attempt to compare both the mining methods with respect to advantages, disadvantages, environmental impact and feasibility. We also discuss the current and future trends of coal production using both the mining methods. Measures to sustain coal production in India are discussed in the conclusion part.

**Keywords:** Coal Mining, Underground Mining, Opencast Mining, Environmental Impact, Coal Demand, India

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## Introduction

Coal, as a conventional source of energy, plays a very vital role in the overall economic development of a country. Coal plays a critical role in our economy, as 45% of the total energy consumption in India is met by coal (Energy Statistics, 2017). Indian economy is facing massive energy demand due to the rising growth of population, industry and other infrastructures. Coal-based power plants meet a major portion of this total energy demand in the country. It is also a major driving force for the industrial revolution, and still, it contributes to the industrial sector as a significant source of energy and raw material. A major consumer of coal in India is the thermal power sector, steel, cement, sponge-iron, aluminium, fly ash bricks, paper, textile, and other small industries. Development of an industrial unit or industrial agglomeration depends on the availability of coal to a large extent. Coal is also used as a source of fuel in households. Countries like India, where the availability of petroleum is deficient and confined, coal plays a vital role in overall economic development. The importance of coal is not only confined in the energy sector but the more significant role it plays in the economy of the country (Coal Vision, 2030a).

The Government of India targeted 1.5 BT of coal production by financial year (FY) 2020 (Tongia, 2016a). Demand for coal in power plants in India is increasing at a faster rate since the 1970s (Chikkatur, 2008a). India ranks third in coal production with a total production of 657.868 million tonnes (Coal Directory of India, 2016-17a). Though India ranks third in coal production, the gap between demand and supply is so vast that, India has to import coal to meet the rising demand. The gap between supply and demand for coal was 89.913 million tonnes during the FY 2016-17 (Coal Directory of India, 2016-17b). Demand for coal in India as a source of energy will increase up to 2030 and maybe beyond that (Coal Vision, 2030b). In FY 2016-17, India imported 41.644 million tonnes of coking coal and 149.309 million tonnes of non-coking coal. Thus, coal production in India

witnessed a massive demand, and domestic production is not sufficient to meet the rising demand. Against this background, the central objective of this research is:

- To present a conceptual background about the OC and UG mining methods in India.
- To make a comparative assessment of significant advantages, disadvantages and environmental impacts of both UG and OC mining methods in the Indian scenario.
- To analyse the overall problems, and suggest suitable measures.

## Methodology

As far as the methodology of this research is concerned, it is mainly based on various secondary data sources such as reports, papers, and articles. Reports about coal production in India were collected from online sources. To analyse the impacts of OC and UG mining methods on the environment, different papers and articles were studied. Past production and current trend of coal production in India was obtained from Provisional Coal Statistics (2012-13 to 2016-17), Coal Directory of India (2007-08 to 2016-17d), Coal Vision 2030 by Stakeholders' consultation and Indian Coal and Lignite Resources-2017, published by Geological Survey of India have been used to analyse the scenario of coal mining in India.

## Coal Mining Methods in Major Coal Producing Countries

Presently, 60% of the total coal production in the world is extracted through the UG method (The Coal Resource: A Comprehensive Overview of Coal, 2009)

In the United States, surface mining contributed 66% of the total production in 2015 (Coal Mining in the United States, 2018). Further, in Australia, 77% of the total black coal production is extracted by surface mining (Mitra and Saydam, 2012a). The scenario of coal mining for Russia is not very different, where opencast mining contributes 60% of the total production (Sliviyak

& Podosenova, 2013). Further, 90% of the total hard coal production in Poland continues to come from Longwall mining.<sup>1</sup> In Ukraine, underground mining accounts for 99% of the total coal production (Coal Mine Methane Recovery in Ukraine, 2002).

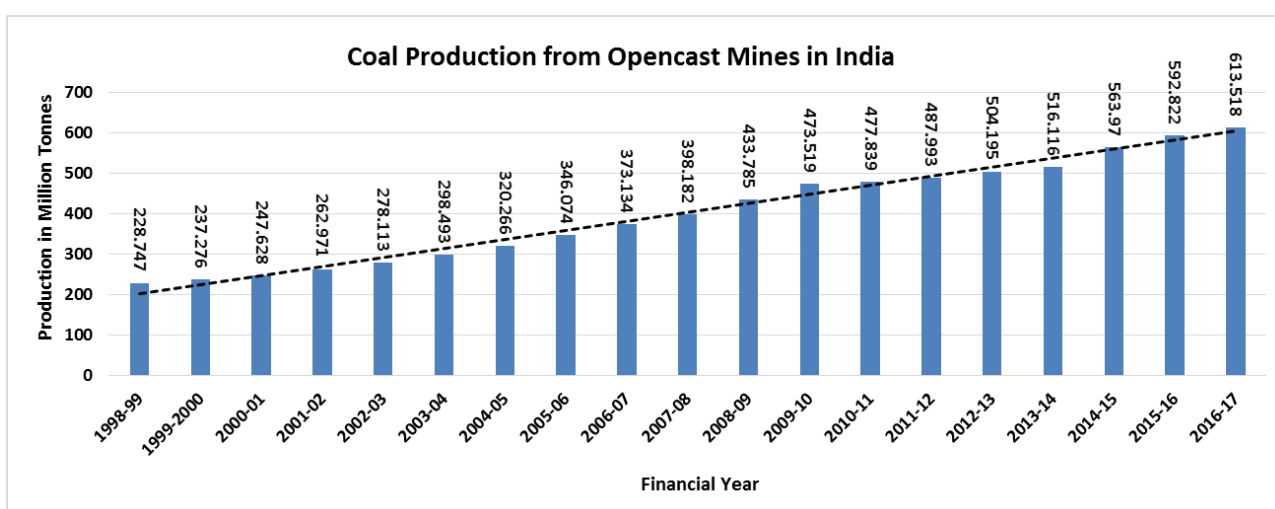
In developed countries, using advanced technologies majority of the coal is extracted by UG method except for Australia, where advanced technology and low-cost environment-friendly production method helps to increase the OC productivity (Mitra and Saydam, 2012b).

In developing countries opencast method is more popular due to high productivity, lower cost of production and application of large mining equipment. Coal production in Kazakhstan through surface mining was 73% in 1990, which increased to 89% in the year 2000 (Kazakhstani GHG Emissions Inventory from Coal Mining and Road Transportation, 2002). However, in the current times, the total extraction of coal in Kazakhstan is estimated at 85%, which is retrieved through the OC method (Oprisan, 2011). Most of the mines in Brazil are opencast.<sup>2</sup> In China, 95% of the total coal production is extracted through the UG method. (Kishore, 2018a). Skilled human resource and

advanced technology along with the investment in the underground mining sector are the reasons behind the large UG coal production in China (Kishore, 2018b) In South Africa OC and UG method contributes 49 % and 51% of the total production (Munnik, 2010). Thus, the OC method of production is dominating in most of the developing countries like Kazakhstan, Brazil and India.

### Present Status of Coal Mining in India

As stated above in India, coal is mined using both the methods: UG and OC method. However, the majority of the coal extracted in India is through the OC method, and it constitutes, 93.26% of the total coal production in the country (Coal Directory of India, 2016-17c). The share of the OC method of coal production has increased over the years. Less expenditure and wastage is the reason behind the dominance of OC mining technique. During the time of nationalisation of the coal mining industry in 1973, the total coal production was only 75 million tonnes per year, and the share of OC mining was only 20 % (Ghose & Majee, 2001a). In the FY 1998-99, the production of coal in India was 228.747 million tonnes (77.15%) from OC mines whereas, 67.761 million tonne (22.85%) from UG mines (Coal Directory of India, 1998-99c).

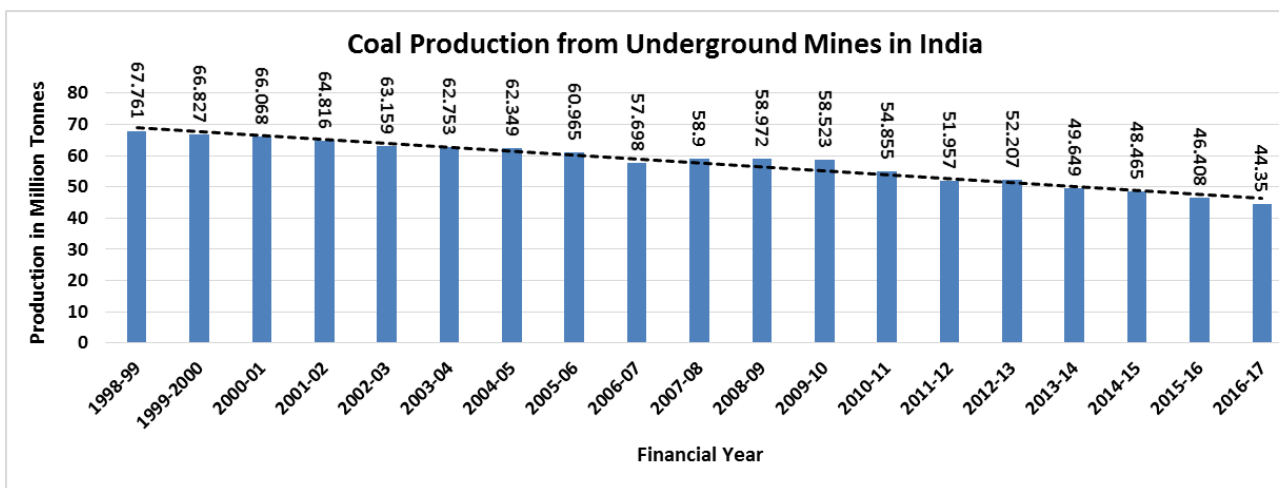


**Figure 1: Coal Production from opencast mines in India (FY 1998-99 to 2016-17)**

**Source: Coal Directory of India, FY 1998-99 to 2016-17**

<sup>1</sup> Eurocoal. Available at: <https://eurocoal.eu/info/country-profiles/poland/> (accessed on 02 September 2018)

<sup>2</sup> Source: BRAZIL Market Overview: Mining Equipment and Supplies. Available at <https://build.export.gov/build/> (accessed on 2 September 2018)

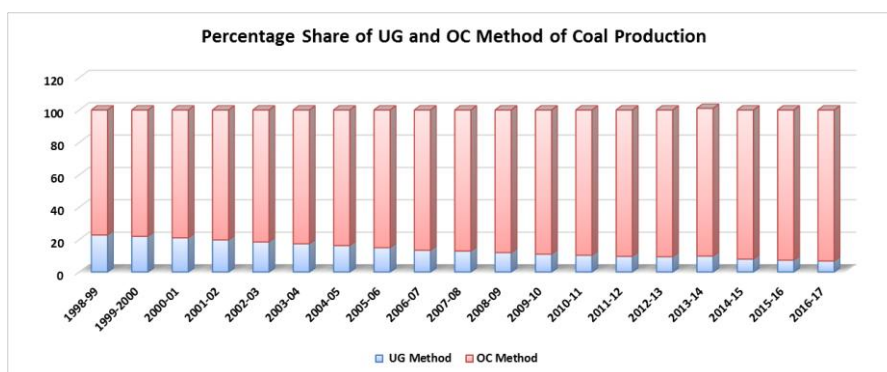


**Figure 2: Coal Production from UG mines in India (FY 1998-99 to 2016-17)**  
**Source: Coal Directory of India, FY 1998-99 to 2016-17**

During the FY 2007-08, the coal production through the OC method was only 398.182 million tonnes, which increased to 613.518 million tonnes with a total increase of 54.07% in the FY 2016-17 (Figure 1). Furthermore, the coal production through the UG method was only 58.90 million tonnes in the FY 2007-08, and it further, decreased to 44.350 million tonnes in the FY 2016-17 with a total 24.70% decrease. Thus, the UG method of coal production is decreasing in share, and the production through OC coal mining method has increased over the years (Figures 1 & 2).

A worldwide average of coal production from OC mining is 40%.<sup>3</sup> However, in India, OC method of coal mining constitute more than 90% of the total production, and the share is increasing at a faster rate over the years (Figure 3).

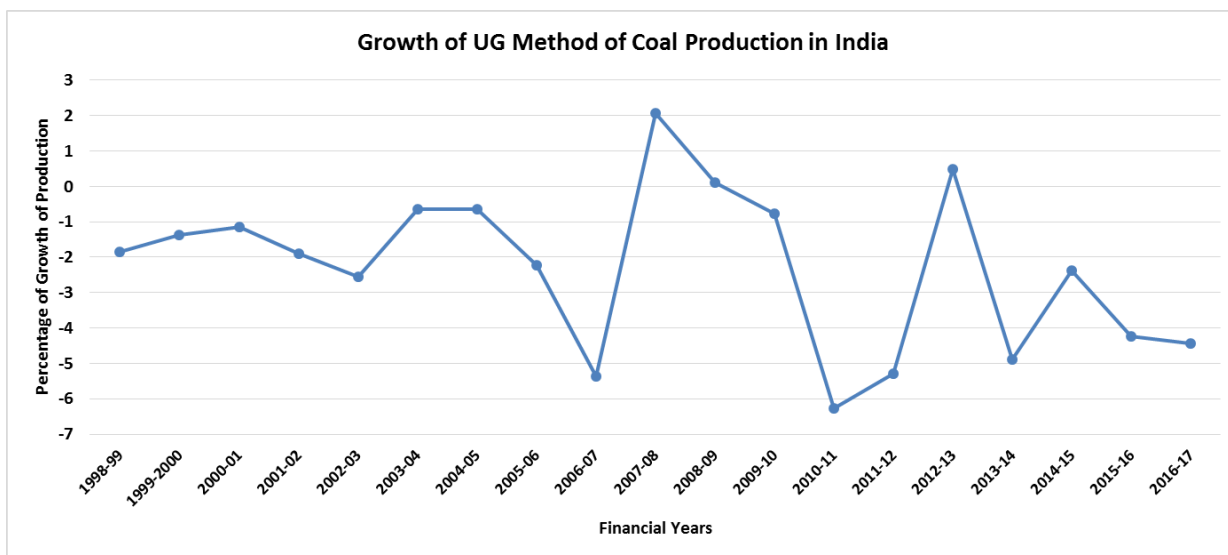
Choice of mining method depends on various factors such as geological condition (depth, size, type, and quality of deposit), technological development and level of mechanisation. Besides these factors, production cost along with selling price, environmental and social aspects are also significant that should be taken into consideration before mining. These factors indeed determine the differences between resources and reserve of coal (Zehirov, 2017a). OC method is generally chosen for shallow coal seams, while UG method is chosen for deeper coal seams. It is apparent from Figures 4 and 5, that production from the OC coal mines demonstrates rapid growth over the years, whereas production from the UG mines shows negative growth over the years (Figure 1).



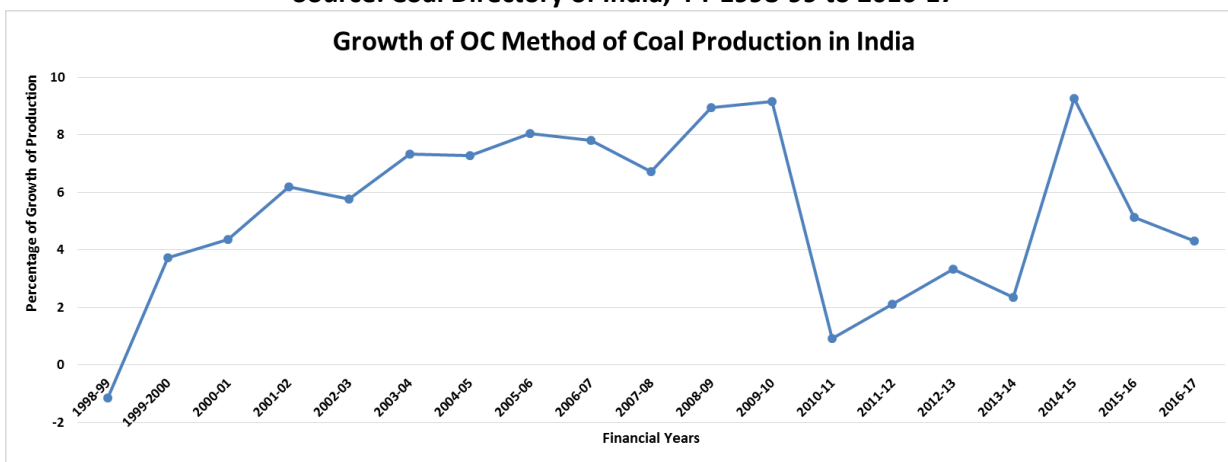
**Figure 3: Percentage of a Share of OC and UG Mines in India.**  
**Source: Coal Directory of India, FY 1998-99 to 2016-17**

<sup>3</sup> Will privatisation help the cause of coal industry? *The Asian Age*. Available at

<https://www.asianage.com> (accessed on 2 September 2018).



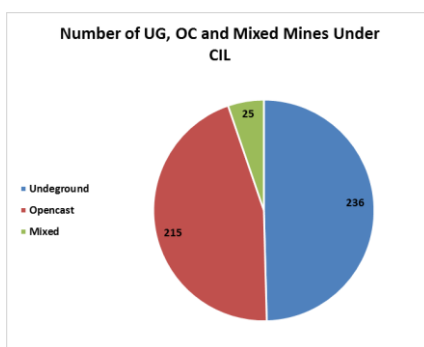
**Figure 4: Percentage of Growth of UG Method of Coal Production in India.**  
 Source: Coal Directory of India, FY 1998-99 to 2016-17



**Figure 5: Percentage of Growth of OC Method of Coal Production in India.**  
 Source: Coal Directory of India, FY 1998-99 to 2016-17

Currently, India has 476 mines in operation, among which, 236 are UG mines, 215 are OC, and 25 mines are mixed in nature (Figure 6). However, the percentage of a number of OC mines is only 45.16%, whereas it accounts for

93.26 % of the total production (Coal India Directory, 2016-17). 70% of the total coal resource in India is extractable by UG mining method, whereas UG mines constitute less than 10% of the overall production (Raghavan, 2014).



**Figure 6: Type and Number of Mines under CIL.**  
 Source: Coal Directory of India, FY 2016-17

## Underground Method of Coal Mining

UG mining method is the oldest method of coal mining, where coal is extracted by making a tunnel into the earth surface. Tunnels and horizontal shafts are made in order to extract the coal. Thus, a network of tunnels is formed in the underground. As already stated, UG coal mining method is dominating over the OC method in the world, as more than 60% of the total coal production in the world is extracted from UG mines. However, in India, only 6.74 % of the overall coal production is from UG mines (Coal Directory of India, 2016-17e).

UG mining has evolved from the pick and shovel method to the modern mechanised Longwall

technology. In India, 90% of the total UG coal production is produced by the Board and Pillar's method, and the rest is extracted by the Longwall mining method. (Mishra et al., 2013b).

Board and Pillar's method is the most common method of UG mining. In this method, a series of pillars are made to support the roof while the coal is extracted between these pillars. Board and Pillar's mining method is more suitable for shallower coal seams, where the pressure of overlying materials are low so that the pillars are able to support the roof. However, the recovery of coal is low (60%) compared to the Longwall method (Das Sharma, 2009a).

**Table 1: Production in UG Coal Production in India by Different Methods**

Mining Methods	Conventional Board and Pillar's	Mechanical Board and Pillar's	Conventional Longwall Method	Mechanical Longwall Method	Other Methods	Total
Production in Million Tonnes	1.123	34.241	0.126	2.616	6.244	44.350
Percentage	2.5	77.2	0.3	5.9	14.1	100

Source: Coal Directory of India, FY 2016-17

In Longwall mining method, self-advancing hydraulic roof supporters, coal shearing machine, and a conveyor, which is parallel to the face of coal are used to extract the coal. In this method, within a long corridor in one side, steel supporters support the roof, while the other side involves in coal cutting. With each cutting, the coal cutter is forwarded to the excavated space. After the full removal of coal, the roof is allowed to collapse.

Longwall mining method has an advantage over the Board and Pillar's method because it allows greater extraction of coal, and it also requires less human resource compared to the Board and Pillar's method. The main drawback of the Longwall mining method is that the cost for installing machinery used in Longwall method is very high, which is not feasible for small UG mines. In India, as the majority of the UG mines are small in size, so the application of Longwall

mining technology is not economically profitable.

The total coal production from UG mines in India is only 79.7 % by Board and Pillar's method, whereas it is 6.2 % by Longwall method (Table 1). Thus, most of the UG mines in India operated by Board and Pillar's method have low productivity. Therefore the production from UG mining is steadily decreasing over the years compared to the OC mining (Figure 4).

Recently, CIL has closed 40 UG mines because these mines had failed to make profits and contributed only 10 % of the total output by Coal India Limited (CIL) but employees a huge labour force (The Economic Times, March 30, 2018). Most of the UG mines in India belongs to the colonial period. Due to inadequate technology and lesser mechanisation, most of the UG mines in India operates in a traditional manner involving more labour force.

## Major Advantages of Underground Coal Mining Method

**Lesser Environmental Impacts:** UG mines are operated over a smaller area, and it affects a small area compared to the OC method. Thus, it causes less deforestation, less topsoil removal, lesser impact on the ecosystem of surrounding areas than the OC method. In UG mines, generation of dust is limited within the UG environment; and in the surface, it emits a lesser amount of dust compared to the OC mines. Thus, UG mines have a lesser environmental impact when compared to that of the OC method. This observation bears resonance to the observation as reported by Banerjee and Mistri (2019) in their research on the impact of Barjora colliery area of Bankura district, West Bengal on diversification of rural livelihoods. UG method is useful for densely populated areas or ecologically sensitive areas, where the extraction of coal by the OC method can seriously affect the environment. UG mining is also suitable for forest areas, where the OC method requires the conversion of forest land. Thus, the environmental impact is much lower in UG mining when compared to OC mining.

**Extraction of Deeper Coal Seams:** Extraction of coal seams with greater depth is more suitable with the UG method. Rapid and large-scale extraction of shallow coal seams by OC mining method causes depletion of near-surface coal resources of India. Thus to maintain the current rate of production and to meet the future coal demand extraction of deep coal seams is necessary. Extraction of coal seams with greater depth is more suitable and economically feasible with UG mining method.

**Can Avoid the Problem of Land Acquisition:** UG mining method is operated over a smaller area as compared to the OC method. Thus, the land requirement in UG mining is much smaller when compared to OC mining. UG mining also has a lesser impact on the surrounding environment as it is operated within a smaller area. Thus, problems of land acquisition, displacement, etc. can be avoided through UG method. After the extraction is over, the productivity of land can be maintained through UG mining method.

**Lesser Waste Generation:** UG mines generate a lesser amount of waste materials compared to the OC mines. It has a lesser impact on the surface than the OC method. It does not create any anthropogenic landforms such as mine pit and mine dump like OC mining. The only deformation that takes place due to UG mining is subsidence. UG mines have a much smaller footprint on surface land as compared to the OC mines.

**Involve Greater Manpower:** In developing countries, UG mines involve more labour force than OC mines due to lesser mechanisation. As a result, it creates more job opportunities for the local people than the OC mines.

## Adverse Environmental impact of Underground Coal Mining Method

UG mines affect the environment in various ways. UG coal mines are exposed to the risk of roof subsidence, mine fire, explosion, emission of toxic gases (Mkpuma et al., 2015). The impact of UG mines on the surrounding area is following: changes in land use and land cover; seismicity due to blasting; emission of dust into the atmosphere, and other socio-economic problems like illegal coal mining and unsocial activities within coal mining region (Goswami, 2013a).

In the UG mines, after the extraction is over the strata is allowed to collapse, which puts a severe impact on surface topography (Wagner & Schumann, 1991). With subsidence in subsurface, surface land also subsides. Subsidence affects the surrounding structures like the ground, agricultural land, irrigation network, transport lines and others (Li et al., 2016). Land subsidence and damages of property and other infrastructures is the significant impact of UG mining.

UG coal mines also affect the groundwater of the mining area. Over exploitation of groundwater and dewatering within the UG mines affect the groundwater regime (Table 2). Subsidence of land also damaged the aquifer (Goswami, 2013b). Thus, water contained within the aquifer may penetrate deep below as a result of subsidence. Sometimes, the water that

discharged from UG mines has high hardness due to the presence of Sulphate and Chloride, which are not suitable for drinking or bathing (Tiwary, 2001a). Thus, the quality of both surface and subsurface water gets degraded by wastewater discharged from the UG mines.

Emission of Methane gas from UG coal mines is another impact of UG mining on the environment. The deeper the mine, the higher the amount of methane emission. Methane is also responsible for underground mine fire.

UG mines are prone to accidents, and most of them take place due to two main reasons; either

faulty engineering structure within tunnels or due to the exposure to flammable methane or coal dust (Das Sharma, 2009b).

Workers of UG coal mines are also exposed to the risk of lungs disease due to the exposure to underground coal dust. A study by Bhelkar et al., (2015a) shows that the moribund condition is prevalent more in UG coal mines (65.7%) when compared to OC mines (54.4%). Their study also reveals that coal miners in UG mines also open to the risk of various respiratory diseases, and backache, skin disease, tuberculosis and others.

**Table 2: Impact of UG Mining**

Activity within the UG mines	Impact
Depillaring and Blasting.	Land Subsidence and Damages to Property and Infrastructures.
Dewatering	Over exploitation of Groundwater.
Subsidence in Surface and sub-surface.	Damages to the Aquifer.
Drilling, Blasting, Loading, and Transportation.	Pollution of Land, Water, and Atmosphere.
Unhealthy Underground Environment and Dust Generation during Blasting and Extraction.	Health Issues to Mine Workers.
Flooding, Subsidence, and Outgassing within the UG Mines	Accidents and Deaths of Mine Workers
<b>Source: Prepared by the Authors</b>	

### Opencast Method of Coal Mining

Choosing the appropriate mining method for extraction of coal depends on several factors, and the OC method is generally chosen when the coal deposit is large, and the seams are located near the surface. OC mining or open pit mining is a surface mining technique where overlying rock and soil materials (overburdens) are removed to extract the underlying coal strata. As, the overlying materials also called as overburden piled up near the mining site hence, overburden dump, spoil tips and other anthropogenic landforms are formed. Excavated area formed a pit, which is known as mine pit. Thus, the OC mining method is liable for the change in topography. OC mining method is dominating in India because of its more accessible mode of extraction, a higher rate of production, safety concern and the higher scope for applying

modern technology for augmented production (Ghose & Majee, 2001b).

OC mines are operated over a larger area, and it uses modern, efficient and large equipment like overburden is removed by draglines, power shovels, bucket wheel excavators and conveyors are also used in this regard. Large trucks are used for the transportation of coal. Other equipment includes pick-up cars, site-mixing truck, bulldozers, scrapers, graders, water spray trucks and others. Loose and less resistant overburden is removed using bucket wheel excavators (Das Sharma, 2009c).

An essential aspect of OC mining is that the cost associated with the removal of overburden, which determines the profit of the mines. The depth of coal seams controls the amount of overburden to be removed. Coal seams with the greater depth require to remove a large amount of overburden, and the production cost of coal



are higher. Nature of overburden is also crucial because hard and resistant overburden (for example, boulders,) requires blasting using efficient technology, which further increases the production cost. Here, the concept of Stripping Ratio is critical. Stripping Ratio is calculated in the following way:-

Stripping Ratio = Unit Waste/ Unit ore cost of stripping overburden (Coal Directory of India, 2016-17f)

Higher stripping ratio indicates a higher cost for overburden removal. Stripping Ratio for OC mines in India is increasing at a faster rate, and with the increasing Stripping Ratio, the production cost has also been increasing for the OC mines (Coal Vision, 2030c).

**Table 3: Overburden Removal by Subsidiaries under CIL, SCCL and Different Sectors of India.**

Company Name	Overburden Removal (million tonnes)	Production (million tonnes)	Stripping Ratio
Eastern Coalfields Limited	124.637	32.390	3.85
Bharat Coking Coal Limited	131.215	35.358	3.71
Central Coalfields Limited	102.630	66.310	1.55
Northern Coalfields Limited	324.136	84.096	3.85
Western Coalfields Limited	166.142	40.264	4.13
South Eastern Coalfield Limited	174.588	120.131	1.45
Mahanadi Coalfields Limited	123.342	138.193	0.89
North Eastern Coalfields	5.676	0.597	9.51
Total Coal India Limited	1156.569	522.663	2.21
Singareni Collieries Company Limited	312.636	51.821	6.03
Others Public	23.779	9.45	2.51
Private	124.394	29.584	4.56
India	1617.378	613.518	2.65

Source: Coal Directory of India, 2016-17

Stripping ratio of 2:1 to 4:1 is very common in the mines while the stripping ratio greater than 6:1 makes the extraction unprofitable depending on the ore extracted (Das Sharma, 2009d). From Table 3, it is seen that the stripping ratio of India is 2.67 for the year 2016-17, whereas in the FY 1998-99 it was 2.09. This indicates that the stripping ratio is gradually increasing over the years. Stripping ratio is also high for Eastern Coalfield Limited (3.85), Bharat Coking Coal

Limited (3.71), Northern Coalfield Limited (3.85), Western Coalfield Limited (4.13), The Singareni Collieries Company Limited (6.03). This indicates that cost for extraction of coal is high within these subsidiaries of CIL and SCCL. As more the near surface coal resources will be depleted, the stripping ratio will increase in future to extract the deeper coal seams. Thus, waste generation will also increase in future, and after a certain

level, higher stripping ratio will make the extraction unprofitable.

Output Per Man shift (OMS) is another measure which is used to measure the efficiency and productivity of mine or particular mining method. It gives an idea about the efficiency and feasibility of a particular mining method (Coal Directory of India, 2016-17g). This is the simple ratio between input and output of mines). The higher value of OMS indicates the efficiency of mine, whereas the lower value indicates the unprofitable condition in mines. From Figure 6, it is seen that the OMS under CIL for OC mines increases from 5.52 in FY 1998-99 to 15.00 in FY 2016-17 with a three-fold increase, whereas for UG mines, OMS shows prolonged growth: 0.59 in FY 1998-99 into 0.8 in FY 2016-17 (Figure 6).

OMS for SCCL also shows a similar result, OMS for OC mines under SCCL was only 3.92 in FY1998-99, whereas in FY 2016-17 it is 13.85 as compared to the UG mines, which stands at 0.75 in FY 1998-99 to 1.1 in FY 2016-17. Thus, the productivity and efficiency of UG mines are much lower than the OC mines, and the technology or efficiency of UG mines does not show any significant progress. Low OMS for UG mines is due to constraints in size, human resource, and technology within the UG mines.

Indeed, OC mines have more efficient technology and higher productivity than the UG mines. Thus, the share of production of OC mines is increasing over the years, whereas the share of UG production shows a decreasing trend (Figures 4 and 5).

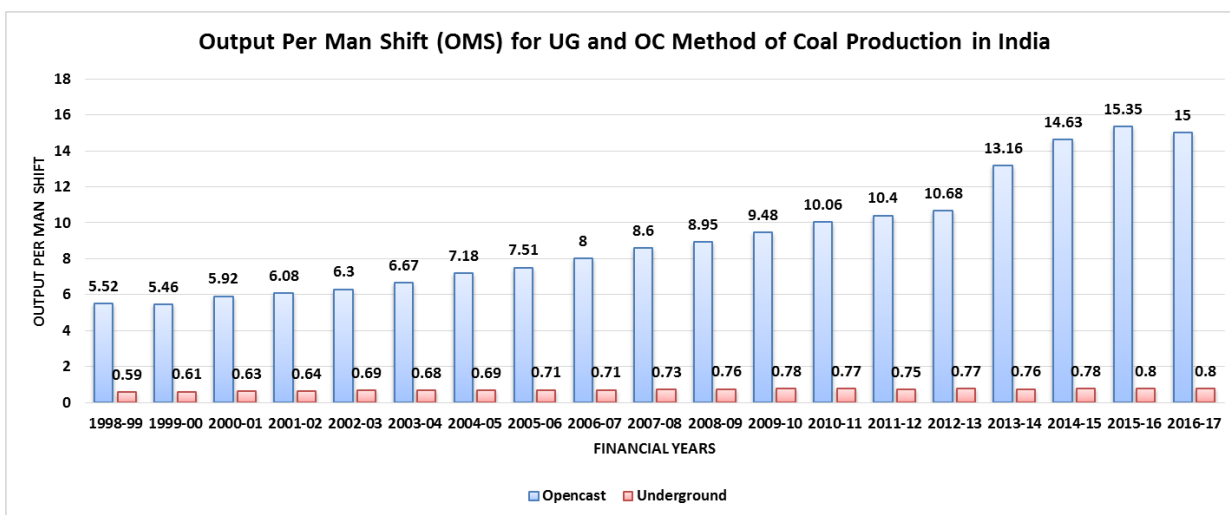


Figure 6: Output Per Man Shift (OMS) of UG and OC mining methods under CIL.

Source: Coal Directory of India (FY1998-99 to 2016-17)

### Advantages of Opencast Method of Coal Mining

**Extraction of coal over a large area:** OC mining method is useful for extraction of shallow coal seams that spread over horizontally and situated over a larger area. Removal of overlying materials exposed the underlying coal seams and helped to extract the underlying coal strata. Therefore, it recovers a more significant amount of coal than UG method.

**Less wastage:** Wastage of coal is less in the OC method as compared to the UG method. In UG mining method, the amount of coal wastage is high during blasting, excavation, extraction, transportation within the mines, whereas, in OC

mines, full exposure of the coal seams and application of modern and sophisticated mining techniques reduces the amount of coal wastage.

**The benefit of using modern and large machinery:** OC mines provides more enormous scope for applying modern, large and efficient machinery, which saves the labour cost and time. Due to the full exposure of coal strata, installation and operating the machinery is natural in OC mines when compared to the UG mines. Equipment used in UG mines are expensive and can be used only for mining, whereas OC mining equipment can also be used for building construction (Yamatomi & Okubo,

2009). With modern equipment productivity and production cost is less in OC mines as compared to UG mines. Blasting, excavation, extraction, and transportation of coal are rather easy in OC mines, as it is operated above ground.

**Less production cost of coal compared to the UG mining:** UG mining method is more expensive than the OC method. Use of large and heavy machinery helps to recover a more considerable amount of coal in OC Mines. As a result, the production cost is much low in the OC method as compared to UG mining.

**Lesser Risk of Accidents:** OC mines have a lesser risk of accidents as compared to the UG mines. OC mining has a less hazardous environment for workers (Zehirov, 2017b).

### **Adverse Environmental Impact of Opencast Coal Mining**

Though the OC method of coal mining is more economical than UG method, OC coal mines have a more significant impact on the environment than UG mines. OC mines are responsible for environmental degradation. OC mines destroyed the land and associated ecosystem, forest, displaced people and affected the environment (Garada, 2015). Destruction of forest and agricultural land, discharge of wastewater are the main adverse impacts of OC mining on the environment. (Chitade & Katyar, 2010). Discharge of wastewater and pollutants changes the habitat pattern and leads to change in the soil, air, and water quality (Baruah et al., 2016).

The problem of land acquisition is much more prevalent in OC mines. As the OC mines developed over a larger area, therefore it acquires much more land than the UG mines. OC mines required more space than UG mines for the parking of the heavy vehicles, transportation, dumping, storing the coal. Land in OC mines is also used for staff residences, official buildings, workshops and other mundane purposes. Furthermore, a buffer area of empty

spaces should be maintained outside the OC mines in order to prevent the environmental degradations like spreading of dust, reducing the impact of blasting, construction of catchment drains, sediments walls and others. Thus, the problem of land acquisition creates many complexities for the OC mines.

The topography of the mining site is also changed through the process of OC coal mining; as the formation of artificial landforms like mine pits, overburden dump changes the relief, altitude, and slope of the mining site. With these changes in the mining site, natural geomorphic processes also change. Landscape change and formation of anthropogenic landforms is the most devastating impact of OC coal mining. OC mining method not only disrupts the natural topography, but it also alters the natural geomorphic processes of erosion and sedimentation.

The problem of land degradation is another major impact of OC mines. After the extraction is over or in certain situations, if the near surface coal seams are exploited, the OC mines are abandoned. However, in abandoned OC mines, the mining sites are left without backfilling or restoring the topography of the mining site. Thus, the land lost its productivity and leads to land degradation (Table 4).

Currently, OC coal mining is responsible for land degradation due to massive waste generation at a very fast rate, and this indicates that backfilling the OC mines is necessary and very important. However, presently no such steps have been taken for backfilling the OC mines.

Mine water from OC mine generally contains a high level of total suspended solids, total dissolve solids, heavy metals, hardness, Sulphate, oil, grease, Nitrate and pollute the water regime if it is discharged without proper treatment. (Tiwary, 2001b). Wastewater discharged from the OC mines degrade the quality of both surface and sub-surface water.

<b>Table 4: Adverse Environmental Impact of OC Coal Mining.</b>		
<b>Type of Impacts</b>	<b>Activity within OC Mine</b>	<b>Adverse Impacts</b>
Impact on Land	Excavation and dumping.	Alteration of topography
	Closure of OC mine without proper restoration of topography.	Land Degradation and land use, land cover change.
	Excavation and dumping.	Removal of topsoil.
	Spreading of pollutants from mine.	Contamination of soil.
	Excavation and dumping.	Deforestation.
Impact on Water	Excavation and dumping.	Degeneration of rivers and alteration of geomorphic properties of watersheds.
	Discharge of wastewater and runoff from the mine during rainfall.	Acid mine drainage and contamination of surface and sub-surface water.
	Erosion of mine dump.	Sedimentation within the river bed.
	Dewatering within the mine and overexploitation of groundwater.	Lowering the groundwater table.
Impact on Air	Blasting, drilling, excavation, transportation etc.	Generation of dust, reduction of the visibility, particularly in the winter season.
	Blasting, drilling, excavation, and dumping.	Emission of gases and other pollutants in the atmosphere.
Impact on the Ecosystem	Excavation and dumping and related landscape alteration.	Destruction of local ecosystem and habitat of species.
Socio-Economic Impact	Blasting, drilling, excavation, transportation etc.	Noise pollution
	Excavation and dumping.	Destruction of agricultural land.
	Excavation and dumping.	Displacement of people and land loss, damages of infrastructures, social instability, and unrest.
	Dust generation and pollution.	Health issues of local people and mine workers.
	Blasting.	Damages of infrastructures.

**Source: Computed by the Authors**

Blasting, waste removal, extraction, transportation generates a large amount of dust in OC mining areas. Agricultural land, households, institutions, roads, water bodies etc. are surrounded by dust from the OC mines.

Dust particles also reduce visibility and put a negative impact on the surroundings. People living in the OC mining areas are suffering from lungs diseases like tuberculosis (Bhelkar et al., 2015b).

## Conclusion

Mining of coal in India started from the colonial period, and after the independence of India, there is a great reluctance among the government to renovate the coal mining industry. Due to lack of infrastructure and technological constraints, extraction of coal seams with greater depth is not possible always. UG mining is more appropriate techniques for coal seams with greater depth. However, in the present scenario, the UG mining methods constitute only a small portion (6.74% in 2016-17) of overall coal production in India. Mining authorities, whether public or private sector is emphasising on OC mining technique, which is more economical mining method. However, 57% of the CIL extractable coal resource is situated in the forest areas, where regulatory approvals may get more regulated in future and making it challenging to open OC mines in forest areas (Fernandes & Sanzillo, 2013b).

Over-extraction of surface coal seams by OC method of mining will exhaust the near surface coal seams in future. Moreover, to reduce the production cost, environmental aspects and sustainable measures were neglected in the arena of OC mining. Thus, OC mining is degrading the environment in various part of the country. Due to the unprofitable condition and lack of modern technology, environmental impacts by OC mines in India is much higher when compared to the other countries. Allowing the private sector in the OC mining sector is making the situation more complicated. Private OC mines are more concerned with profit rather than taking environmental measures. OC mines in India should be more concerned with environmental impacts. Therefore, provision of sediment wall, catchment drains to entrap sediments, afforestation programme, backfilling of mines, processing of wastewater, dust suppression from wastewater and minimising the impacts on land, water and ecosystem are much required in OC mines of India. OC mining authorities in India should promote sustainable mining measures.

Extraction of deeper coal seams with OC mining method may not be feasible due to the higher

Stripping Ratio. Thus, in order to maintain the current rate of production, and to meet the demand for coal in the future, more emphasis should be given on UG mining. Introduction of modern technology and efficient equipment is much needed in UG mining. Therefore, application of Longwall mining can help to increase the production from UG mines, and it will also help to reduce the production cost. Longwall mining technique has an advantage over the traditional Board and Pillar's method because it has facilities for more recovery of coal in the strata and helps to increase productivity.

Half of the total production of Coal India Limited (CIL) is from 15 mines which are OC mines and other 452 mines constitute 50 % of the total production (Coal Vision, 2030d). Thus small scale mining operation does not become feasible for modernisation. In respect of UG mines, 87 % among them are either semi-mechanised or operated in a old-fashioned (manual) way (Coal Vision, 2030e).

In the FY 2010-11, the Geological Survey of India (GSI) has explored a total of 115 seams, among which 79 seams lie below the depth of 150 metres, and 43 seams are below 300 metres depth. Therefore, UG mining is more efficient to extract these seams. However, UG mining have higher production cost and lower productivity as it extracts only 40-70% of the coal deposit. Thus, extraction of deeper coal seams can increase the production cost and market price of coal. The price of electricity can also increase with that. Thus, current coal price in India does not permit for UG mining (Fernandes & Sanzillo, 2013c). Thus, small and unprofitable mines should merge to make bigger and profit gaining mines. Investment is much required in UG mines to promote modern technology and increase production. Ignoring the UG mining sector may affect the future coal production in India, as in future when near-surface coal resource is depleted or extraction is carried through OC method will be unprofitable due to higher stripping ratio, adopting UG mining will be the solution. However, in the present scenario, most of the UG mines are closing every year and the UG production shows a declining trend. Thus,

investment and the opening of new UG mines are much needed, keeping in view the future coal demand. Allowing private sectors in the UG mining sector may be a right solution, as the private sector will provide investment and technology for the UG mines and UG mines will help to sustain the future coal production of India.

Increasing the import of coal from the other countries is not a solution to meet the rising coal demand of India. If coal import increases, the domestic coal sector may face intense competition in future. Increasing the import will also affect the Gross Domestic Product (GDP) and the economy of India.

In India, selling of raw coal is done by either through E-auction or through Long-term Fuel Supply agreement (FSA). Price of Raw coal which sold under FSAs by CIL is not always reflecting the market price of the coal in the international market, while the coal sold under E-Auction reflect the market price. Therefore, the price of coal sold under FSAs is much lower than the coal sold under E-auction (Mishra & Suhag, 2017). Price of coal should be determined to keep in view the international price of coal. Giving subsidies in coal price only cannot save this sector.

Generation of electricity consumes nearly 75% of domestic coal production (Chikkatur, 2008b). Energy demand will increase in the future due to population growth, industrial expansion, and infrastructural development. Exploration effort by CIL is inadequate keeping in view the future coal demand (Fernandes & Sanzillo, 2013d). Demand for electricity and coal is so high in the country that the coal mines are violating environmental regulation and norms. Therefore, the main challenge before the government is to enforce and tighten the existing regulations. (Chikkatur, 2008c).

Coal conservation and finding alternatives to coal in the energy sector is much required. Dependence on coal not only degraded the environment, but it also affects the economy as the coal import of India is rising over the years. Thus, more emphasis should be given to non-conventional energy sources like solar energy,

wind energy, and atomic power etc. Instead of heavy dependence on coal government should take the initiative to popularise the non-conventional and eco-friendly sources of energy. Conservation measures of coal should also be taken keeping in view the future coal demand of India. Saving electricity and energy, increasing the use of nonconventional sources of energy is required in this regard. Also, lower grade coal should be mixed with superior quality coal for use in industries. Furthermore, coal wastage should be reduced during transportation. Coal is a resource of our country, and we have to realise rather than understand the value of coal keeping in view the future coal demand of India and by this way conservation of this precious resource is possible.

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