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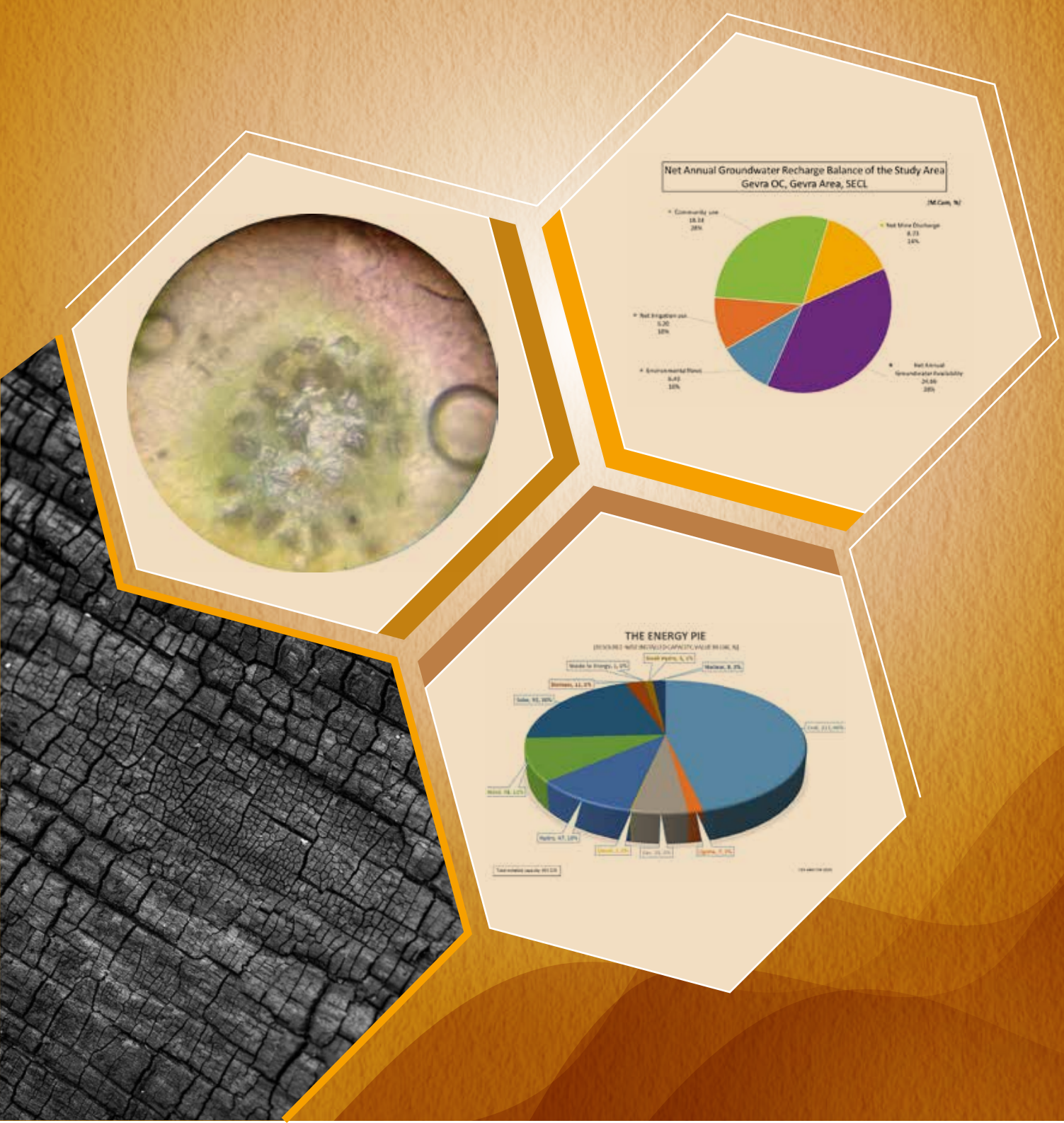

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Contents

खण्ड 45, अंक 4
अक्टूबर–दिसम्बर, 2024

Volume 45, No. 4
October-December, 2024

FAQs ON COAL & SUSTENANCE OF COAL QUALITY

Tadimalla H Mohan Rao[1]

Abstract

Coal, indisputably nature's non-renewable gift to the mankind, has earned a position and place for itself in the world energy scenario that it continues to remain as the inevitable primary source of energy for a few more decades, more particularly so, in the Indian subcontinent (consisting of India, Pakistan, Nepal, Bhutan and Bangladesh). Being mis-propagated as the villain to the survival of humans, it may not be any exaggeration if it is said that coal, in fact, is the major source fuel that presently provides bulk of the energy essential for the very survival of the modern man! As far as the scenario in our country is concerned, domestic coal production has long been the cornerstone of our energy security policy.*

India is the second largest consumer of coal, and coal has hitherto played a crucial role in India's energy sector, accounting for 55% of the country's energy needs and over 75% of its electricity needs. With significant availability of indigenous coal reserves and affordability, coal is likely to continue as the primary source of energy for a considerable period of time to meet the developmental needs of the Nation's rising economy (Source: Niti Aayog's Sept-2021 Report of the Inter-Ministerial Committee on Just Transition from Coal).

Even globally speaking, coal today remains the largest energy source for electricity generation, steelmaking and cement production – maintaining a central role in the world economy. At the same time, coal is the largest source of man-made carbon dioxide (CO_2) emissions, and curbing consumption is essential to meeting international climate targets (Source: IEA's annual coal report: Coal 2023).

* *A subcontinent is an area that stands out distinctively from the rest of the continent, both geographically and culturally.*

[1]*Sr. Manager (QC)/WCL-Rtd*
Author & Corporate Trainer
Consultant-Coal Quality & Allied Matters

Perusal of above observations made by two different authoritative sources in their two separate reports would reveal that we are at a cross roads as to whether to go for the continued use of coal to meet our energy requirements, or to curb using coal in the wake of the warning issued by the global watchdog, that made coal singularly responsible for CO_2 emissions. Needless to say, prudence calls for curbing CO_2 emissions rather than coal use, since the nation cannot afford to move away from use of coal in the near future. Need of the hour, therefore, is the indispensable need of delivering coal in the grades notified and its qualitative use, by which the associated ill affects can be substantially minimized. Effective usage of coal requires a thorough knowledge about its different quality characteristics right from its formation stage, to its classification, gradation, till its end use, and more importantly, even after its end use.

In this regard, it may be apt to quote from the concluding remarks from Chapter C (An Introduction to Coal Quality) of "The National Coal Resource Assessment Review" by Stanley P. Schweinfurth of the U.S. Geological Survey…

Quote :

"Although much is known about coal quality, much also remains to be learned. To this end, research on coal quality is being conducted in both the public and private sectors. Current studies encompass all aspects of the origin, burial history, and composition of coal in order to understand the various factors involved in determining coal quality, such as how and where to find the most appropriate coal for a specific use and how to clean coal to make its use more environmentally and industrially acceptable. In the past, the only consideration given to coal quality was whether coal lumps held together during shipping, burned easily to produce a hot fire, and did not produce too much ash.

Today, however, concerns about human health, the environment, energy demands, and the supply of certain raw materials have broadened our concept of coal quality and have increased our need to know much more about the origins, nature, and effects of coal quality. Fortunately, recent advances in analytical capabilities have made the task of understanding the intricacies of coal quality much easier to achieve. An extensive evaluation of coal quality must be central to coal use. Whatever coal is used for—whether for the direct production of energy, chemicals, synthetic fuels, or the recovery of useful minerals—and whatever problems and solutions accompany that use, depend on the quality of the coal. Thus, additional, sophisticated, multidisciplinary research on coal quality is required for the future.

The results will help make it possible for society to continue to benefit from the good qualities of coal and to make progress in avoiding the undesirable effects of coal use. In the near-term, the most immediate advancements related to coal-quality research appear to be improvements in the efficiency of coal use (including more efficient production of synthetic fuels) and the development of methods to best understand, and thus control, the less desirable components in coal that have the potential to contribute to environmental degradation and adverse health effects."

Unquote:

Stanley P. Schweinfurth's remarks notwithstanding and as very rightly put by him, the ultimate need is to make use of this abundant gift of the nature less harmful to humans and nature, and more useful for general welfare. With this thought ruling high, an attempt has been made to put at one place all content that is related to coal, its formation, and ways and means of sustenance of its quality and other related information in an easy to understand Question-Answer format. The whole content has been crisped into 40 FAQs with relevant answers. It's earnestly believed, the ensuing paper would provide the reader suitable information in this context to the extent necessary. It's hoped, this paper would qualify to be visited for quick reference by all those already from the ranks of the coal industry who are responsible for ensuring delivery of coal in the grades notified. More particularly, the paper would be a ready reference tool for the new joinees of the coal industry, providing everything about the product of their industry in a nutshell, about which they are supposed to have complete awareness...

Q 1 ***What is coal?***

Ans

Coal is a secondary rock, an organic compound formed from plant remains. Coal begins as peat, which forms in mires. A mire is a swampy environment that contains the conditions necessary to allow peat to form and collect into more or less thick beds. Peat is converted to coal through a long and complicated process. A precious non-renewable fossil fuel, coal is the stratified accumulation of carbonaceous matter derived from vegetation, occurring beneath the earth at varying depths, quality of coal becoming higher with increasing depth.

Q 2 ***What are the factors that determine the quality characteristics of coal?***

Ans

The original plant matter, degree of decay, weathering before burial, heat, pressure, degree of alteration after burial, and the degree of presence of the 4 macro constituents of macerals (Vitrain, Clarain, Durain and Fusain) are the factors that determine the quality characteristics of coal. Together all these factors constitute the total internal chemistry of coal formation.

Q 3 ***Why Coal is so complex?***

Ans

Coal is complex because of the wide variety of the complex factors listed above that determine its quality. These factors additionally include (1) the extent of preservation of the plant matter, (2) the geometry and location of the mire, (3) the mineral matter that accumulated with the plant material or that was introduced at some later stage, and (4) the complete process of coalification.

Q 4 ***What coal is composed of?***

Ans

Coal is composed of complex mixtures of organic and inorganic compounds. The organic compounds, inherited from the plants that live and die in the mires, are huge in numbers. These are composed of the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and trace amounts of a variety of other elements. Although only a few elements compose the organic compounds found in coal, these compounds are extremely complex and play a key role in the coalification process.

The more than 100 inorganic compounds in coal were either introduced into the mire from water-borne or wind-borne sediments or were derived from elements in the original vegetation. After plants decompose, the inorganic compounds remain in the resulting peat. Some of those elements combine to form distinct minerals, such as pyrite. Coals may contain as many as 76 of the 90 naturally occurring elements of the

periodic table; however, most of those elements usually are present in only trace amounts (on the order of parts per million). Occasionally, some trace elements may be concentrated in a specific coal bed, which may make that bed a valuable resource for those elements (such as silver, zinc, or germanium). Some elements, however, have the potential to be hazardous (for example, cadmium or selenium), particularly if they are concentrated in more than trace amounts. Although as many as 120 different minerals have been identified in coal, only about 33 of them are commonly found in coal, and, of these, only about eight are abundant enough to be considered major constituents. These are: Quartz, Kaolinite, Illite, Montmorillonite, Chlorite, Pyrite, Calcite, and Siderite.

Q 5 ***How coal acquires mineral matter?***

Ans The living plants in a peat mire absorb mineral matter from (1) the soil they grow in, (2) the water of the mire, and (3) introduced mineral matter, such as water-borne or wind-borne sediments, or volcanic ash.

Q 6 ***What is epigenetic mineralization?***

Ans Introduction of mineral matter into coal seams by low temperature processes after the coal bed was formed is known as epigenetic mineralization. In this process, ions in moving water are introduced into fractures (called 'cleat'), and along bedding planes in the coal bed, and minerals are deposited when the water lost its ability to maintain these mineral-forming ions in solution. This could occur when the ion-bearing water entered a different temperature and (or) chemical environment. Epigenetic minerals commonly include pyrite, calcite, siderite, and kaolinite, and, in rare cases, sphalerite and galena.

Q 7 ***What are Coal balls?***

Ans Coal balls result when mineral matter (such as calcite, pyrite, or siderite) infuses and mineralizes (petrifies) a small volume of peat before it is compressed. Coal balls often contain coalified plant materials that have maintained their original structures because the mineral matter has prevented compression and degradation of the plants. Coal balls, therefore, can be used as an aid in connecting the degraded, compressed plant matter of a coal bed to the original plants.

Q 8 ***What are the Byproducts of coal?***

Ans Coal is a very remarkable and rewarding material. In addition to providing heat to generate electricity (which is currently the primary use of coal), a myriad of other beneficial substances are derived from coal. Perhaps the best known of these substances is coke, which is used in the steel industry to separate iron from its ore. Other byproducts of coal include coal tar, light oil, ammonia, gas, pharmaceuticals, textile dyes, food and wood preservatives, and other simple or highly complex chemicals, which are produced during the production of coke by a process called destructive distillation (a process in which coal is packed in a closed, oxygen-restricted container like retort, or coke oven, and then heated to a high temperature).

Q 9 ***What are Coal Combustion Products (CCPs) and what are their uses?***

Ans

Coal combustion products (CCPs), consisting of fly ash, bottom ash, boiler slag, and flue-gas, also have become important in the economy. As coal burns, it emits sulphur in the form of sulphur oxide. FGD (Flue Gas Desulphurization) is the process by which a chemical, such as limestone ($CaCO_3$), is injected into the flue-gas stream to trap the sulphur by combining with it to produce gypsum ($CaSO_4$). Gypsum is heavy and falls to the bottom of the FGD unit as sludge in a wet process, or as a powder in a dry process. Fly ash is used mainly as an additive in concrete; fly ash may also be used as structural fill or as road-base material and may also be used in waste stabilization and mining applications. Bottom ash is used mainly as road-base and structural-fill material as well as in concrete and as grit for snow and ice control. Of the boiler slag that is used, most is used as blasting grit and roofing granules. FGD gypsum is used mainly in wallboard, with small amounts being used in concrete and agricultural applications.

Q 10 ***What are the theories that suggest the formation of coal? Define them.***

Ans

Two theories suggest formation of coal. These are: a). In-situ theory, and b). Drift theory. In Latin, in-situ means, "in-position."

Under the In-situ theory, coal was formed when gigantic trees and other plant matter buried for a long period of time straight into the earth. As such no pollution occurred by extraneous strata, leading to coal seams having remained relatively thin (about 15 feet of peat makes 1 foot of coal Seam). As such the quality of in-situ coal formations is very high.

Under the Drift theory, coal formation took place when the plant matter drifted away from the original location due to floods and other geological changes. Alternate filling of river basins with earth and plant matter led to formation of several layers and seams are hence quite thick. (Jhingurdah seam of Singrauli with 152 mtrs is reportedly the 2nd thickest seam in the world). As such the quality of drift coal formations is comparatively low.

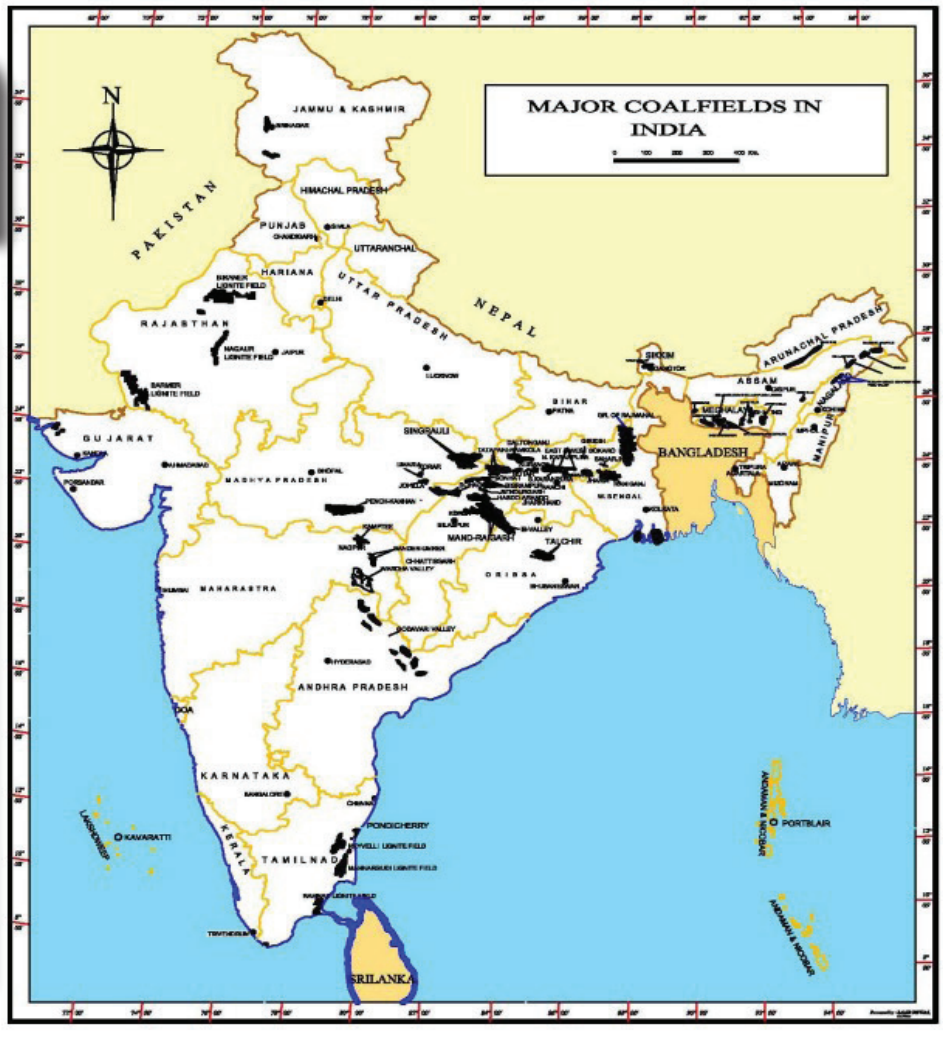
Q 11 ***What was the period of coal formation in India?***

Ans

The first coal-bearing rock units appeared about 225-345 million years ago, at a time known as the Permian and Carboniferous (coal-bearing) ages. Further, there are extensive coal deposits also from the Tertiary, Cretaceous, Eocene and Miocene ages - about 7 to 135 million years ago. Indian coal belongs to two principal geological periods – the Gondwana coal of the Permian age (formed about 270 million years ago) and the Tertiary coal of Eocene to Miocene age (formed about 54 million years ago).

Q 12 ***Which coal formation is the chief source of coal in India?***

Ans The Gondwana formation of the Permian age (formed about 270 million years ago), which accounts for 99% of the total coal deposits in the country is the chief source of coal in India, while the Tertiary formation (formed about 54 million years ago) accounts for the balance 1% of coal deposits in the country.



Q 13 ***What are the potentially workable coal seams that occur in India?***

Ans Following table highlights the potentially workable coal seams that occur in India:

Coalfields	Period of formation	Localities in India
Tertiary Coalfields	7 to 65 million years ago	Lignites in Kashmir Valley, Neyveli and Rajasthan, and Makum coalfields of Upper Assam
Upper Gondwana Coalfields	65 to 135 million years ago	Coalfields of Satpura Region
Lower Gondwana Coalfields	225 to 345 million years ago	Coalfields of Raniganj, Jharia, Bokaro, Karanpura, Damodar Valley, Mahanadi Valley, Sone Valley, Pench Valley, Pranhita-Godavari Valley and Wardha Valley

Q 14 ***What are macerals?***

Ans

The particles of organic matter in coal, inherited from the remains of plant parts, are called "macerals." These occur as the individual micro constituents of coal and many different types of macerals can be seen in coal. The identification of the original plants and their parts (such as bark, roots, spores, or seeds) that produced individual coal macerals is helpful in determining coal quality. However, these connections usually are difficult to make because the original plant material has been compressed or altered beyond recognition during coal formation. Macerals are divided into 3 main groups, viz., Vitrinite, Exinite and Inertinite. These 3 main groups are in turn sub-divided into another 3 sub-groups according to detailed character of the mineral, as Vitrite (mainly Vitrinite), Clarite (Vitrinite and Exinite) and Durite (Exinite and Inertinite).

Q 15 ***What are the 4 macro constituents of coal derived from macerals, and how they influence coal quality?***

Ans

Vitrain, Clarain, Durain, and Fusain are the 4 macroscopically distinguishable litho-types (rock-types) derived from macerals. These occur within the coal seams as banded constituents and their presence strongly influences the original (natural) quality of coal. Coal quality keeps on decreasing in the order of presence of the macro constituents from Vitrain to Fusain, with presence of Vitrain contributing to significant increase in coal quality, while presence of Fusain adversely affecting the coal quality.

Coals can range in maceral composition from mostly vitrinite to mostly fusinite, depending on the original plant matter and the degree of preservation. Vitrinite-rich coals are shiny, black, clean, and are subject to conchoidal fracture like glass because of their even texture; they often exhibit iridescence (called "peacock coal") on fresh surfaces. Fusinite-rich coals, in contrast, are, similar to charcoal-dull, black, friable, and dusty.

Q 16 ***What are the stages/processes of formation of coal?***

Ans

Coal formation occurs mainly in two stages; a). Bio-chemical stage or Peat formation stage, called the "Humification Process," and b). Geo-thermal stage or coal formation stage, called the "Coalification Process".

Q 17 ***What is coalification?***

Ans

Coalification is a series of chemical and physical changes, the process that produces coals of increasing rank. Coalification is a continuing process involving increase in both temperature and pressure resulting from burial in the Earth.

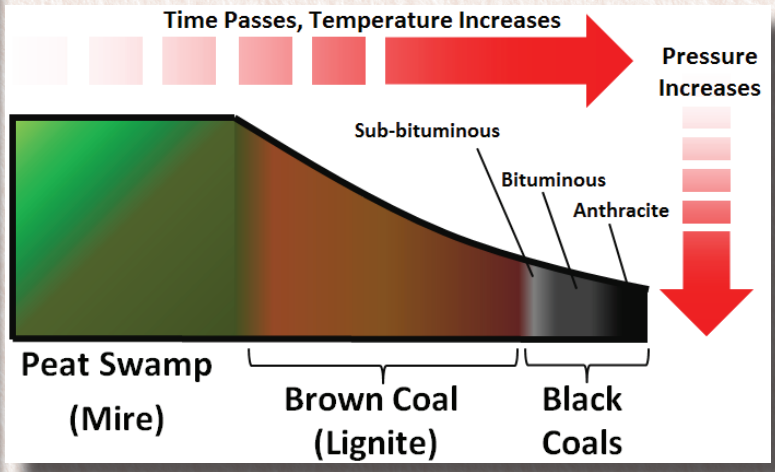
Q 18 ***Which is more important–increasing temperature or increasing pressure–in promoting coalification and why?***

Ans Increasing temperature is considered more important in promoting coalification as higher temperatures eliminate moisture and volatile elements, and therefore, help produce coals of higher rank and higher heat (calorific) value. Higher temperatures are generally associated with deeper burial in the earth, although proximity to an unusual source of heat, such as a volcano, could produce similar effects. Coalification affects both the organic matter and the mineral matter in coal. As coalification proceeds, organic matter, which is relatively rich in water, oxygen, and hydrogen, gradually loses those constituents and becomes relatively enriched in fixed carbon. Some of the hydrogen and carbon are converted to methane gas (CH_4) in the process. When increases in depth of burial and (or) temperature no longer occur, coalification slows and then ceases (unless another source of higher heat affects the coal). Thereafter, the coal will remain at the same rank if it is raised up again (either by tectonic uplift or erosion of overlying sediments, or both) into a region of much lower temperature or pressure. However, once coal is exposed to weathering (oxidation), it is slowly reduced to the equivalent of ash.

Q 19 ***The coalification process is further divided into how many sub stages or series?***

Ans Coalification Process is further divided into 6 series or sub stages, corresponding to the amount of heating that takes place during each sub stage. These sub stages are:

Peat ➠ Lignite (brown coal) ➠ Sub-bituminous ➠ Bituminous ➠ Sub-anthracite ➠ Anthracite, with degree of coalification increasing from Peat to Anthracite. There is progressive increase in maturity/rank and carbon content, and progressive decrease in oxygen, hydrogen, moisture and VM during the above coalification process.



Q 20 ***What is Cleat?***

Ans

During the process of coalification, sets of roughly parallel, closely spaced (from fractions of an inch to several inches) fractures form in the coal. These fractures are called cleat. Cleat tends to form in two sets at right angles to one another; one set, the face cleat, is dominant, while the other set, the butt cleat, may be only poorly developed. Cleat is generally well developed in bituminous coals, whereas lignites and subbituminous coals, both less well coalified, generally exhibit only developing cleat.

Q 21 ***What are 'partings'?***

Ans

Distinct, laterally continuous layers of mineral matter in coal beds are called 'partings.'

Q 22 ***According to the nature of plant material, coals are divided into how many types?***

Ans

2 types; Humic (woody) coals and Sapropelic (non-woody) coals. The coals occurring in the above 6 series/sub stages during the coalification process are collectively known as the Humic coals.

On the other hand, Sapropelic coals are derived from sapropels (loose deposits of sedimentary rock rich in hydrocarbons) and non-woody matter as leaves, spores, cuticles, etc., of plants as well as from organic oozes, algae, fungi, etc., that accumulate at the bottom of lakes or oceans. These coals contain less carbon than normal coals and are typically massive and un-banded and on distillation, yield petroleum. Hence they may be considered as a more or less transitory stage between true coal and petroleum. Rich in liptinites (microscopic organic matter derived from waxy or resinous parts of plants), sapropelic coals have high yields of volatile matter so as to be ignited by a match.

Q 23 ***What values of coal are determined under proximate analysis and why proximate analysis is important?***

Ans

Ash, Moisture, VM (Volatile Matter) and FC (Fixed Carbon). Proximate analysis of coal gives quick and valuable information regarding commercial classification and determination of suitability of coal for a particular industrial use.

Q 24 ***What values of coal are determined under ultimate analysis and why ultimate analysis is important?***

Ans

Carbon, Hydrogen, Oxygen, Nitrogen, and Sulphur. Ultimate analysis of coal is essential for calculating heat balances in any process for which coal is employed as a fuel.

Q 25 ***According to characteristics, Humic coals are divided into how many classes?***

Ans 2 classes; coking coal and non-coking coal.

Q 26 ***What is the essential condition of sampling?***

Ans The whole bulk of coal to be sampled should be exposed, so that all particles are equally accessible to the sampling implement and have the same chance of being included in the sample.

Q 27 ***What is the formula for conversion of Air Dried GCV into Equilibrated GCV?***

Ans Air dried GCV is first determined through the Bomb Calorimeter, and then Equilibrated GCV is derived from the Air Dried GCV with the help of a formula, in which equilibrated moisture and air dried moisture are two separate components. Necessary formula for this purpose is as below:

$$\text{Eq GCV} = \text{Air dried GCV} \times \frac{(100-\text{Eq M})}{(100-\text{Air dried M})}$$

Q 28 ***What are the 'trade names' and 'names as per the standard nomenclature' of unwashed non-coking coal in terms of different sizes?***

Ans Necessary details as specified in "IS: 437 (1979): Size analysis of coal and coke for Marketing (Reaffirmed 2001)"and extracted from the above BIS publication, and as based on the standard nomenclature in vogue are as below:

Trade Name	Name as per Standard Nomenclature	Size Range
ROM (Run of Mine)	Unscreened coal	All sizes (as mined)
Steam Coal	Coal, large	250 mm to 25 mm
Slack Coal	Coal, slack (50)	50 mm to 0 mm
	Coal, slack (25)	25 mm to 0 mm
Dust	Coal, slack (12.5)	12.5 mm to 0 mm

As can be seen from above table, the lower limit of 25 mm in the size range of Steam Coal (Coal, large) is overlapping with the upper limit of 50 mm in the size range of Slack Coal [Coal, slack (50)]. In view of this, for the purpose of grading and consequent marketing, the lower limit of Steam coal (Coal, large) is considered as 50 mm instead of 25 mm, while the last two size fractions, viz., Slack Coal [Coal, slack (25)] and Dust [Coal, slack (12.5)] are ignored.

Thus Steam Coal is the fraction of ROM coal that passes through the screen with 250 mm size apertures, but retains on screen with 50 mm size apertures, while Slack Coal is the fraction of ROM coal that passes through the screen with 50 mm size apertures, whereas ROM Coal is the unscreened coal of all sizes.

Q 29 ***Since when the current GCV system of grading and pricing of non-coking coal in the country has come into force?***

Ans Wef 1st January 2012.

Q 30 ***How the gradation of non-coking and coking coals is determined?***

Ans The gradation of non-coking coal is based on Eq Gross Calorific Value (Eq GCV) also simply called GCV, while the gradation of coking coal is based on ash content, and that of semi/weakly coking coal is based on ash plus moisture content.

Q 31 ***As per the current system of coal gradation, non-coking coals have been divided into how many grades, and what are their corresponding GCV bands?***

Ans

Non-coking coals have been divided into 17 Grades from G1 to G17. Following is the GCV table:

Sl. No.	GCV Band (Kcal/Kg)	Grade
1	>7000	G1
2	6701 to 7000	G2
3	6401 to 6700	G3
4	6101 to 6400	G4
5	5801 to 6100	G5
6	5501 to 5800	G6
7	5201 to 5500	G7
8	4901 to 5200	G8
9	4601 to 4900	G9
10	4301 to 4600	G10
11	4001 to 4300	G11
12	3701 to 4000	G12
13	3401 to 3700	G13
14	3101 to 3400	G14
15	2801 to 3100	G15
16	2501 to 2800	G16
17	2201 to 2500	G17

Q 32 ***As per the current system of coal gradation, coking coals & semi/weakly coking coals have been divided into how many grades, and what are they?***

Ans Coking coals have been divided into 8 grades, and semi/weakly coking coals into 2 grades. Following tables highlight the relevant information:

Coking Coals:

Grade	Ash Content
Steel Gr-I	Upto 15%
Steel Gr-II	>15% and upto 18%
Washery Gr-I	>18% and upto 21%
Washery Gr-II	>21% and upto 24%
Washery Gr-III	>24% and upto 28%
Washery Gr-IV	>28% and upto 35%
Washery Gr-V	>35% and upto 42%
Washery Gr-VI	>42% and upto 49%

Semi Coking Coals:

Grade	Ash + Moisture Content
Semi Coking Gr-I	Upto 19%
Semi Coking Gr-II	>19% and upto 24%

Q 33 ***What are the benefits of high quality (low ash) coal and the hazards of low quality (high ash) coal?***

Ans The huge environmental and economic benefits arising out of the sustenance of the natural quality of coal lead to a win-win situation for both the colliery and the end-user, thereby serving the true interests of the nation. The benefits/hazards of use of high/low quality coal are appended hereunder:

Benefits of using High Quality (Low Ash) Coal	Hazards of using Low Quality (High Ash) Coal
❖ ensures direct contribution to the legitimate profitability of the coal mine	❖ increases transportation costs
❖ meets the stringent environmental requirements	❖ cripples the already overloaded rail network
❖ guarantees the consequent relief from future economic risks	❖ increases the scheduled and unscheduled maintenance hours of the boiler and consequent costs
❖ caters to generation of the same quantum of electricity with much less quantity	❖ decreases capacity factors (reduction in plant availability time for generation of electricity)
❖ leads to conservation of the precious natural resource for use by future generations.	❖ Further downstream, higher ash concentrations (products of incomplete combustion) coat the power station's ductwork, increase corrosion, shorten the plant's expected life, increase the number of solids that have to be collected by emission-control devices leading to higher disposal in landfills.

Q 34 ***How Mire location, climate and Hydrology affect coal quality?***

Ans

The geographic location, climate, and hydrology of the original peat mire also affect coal quality. Peat mires located close to rivers or within river deltas have the possibility of periodic flooding and the introduction of large amounts of mineral matter. Mires along coastlines, while not as easily subjected to river flooding, may be affected by offshore or coastal storms that wash sediment over offshore bars and beaches into the mires located behind them. The added mineral matter may be disseminated in the peat, may occur as layers in the peat, or may cause peat formation to stop.

Climate and hydrology, which to some extent depend on geography, affect the growing season and the amount of rainfall that a mire receives and, therefore, help determine the kind of plants that will grow in the peat mire.

Q 35 ***What are the Controllable and Uncontrollable factors that affect the natural quality of coal?***

Ans

The following factors, most common to all the UG-converted OC Mines & OC Mines, and even a few UG mines, are categorized as uncontrollable and controllable factors. The focus of the mine manager must be on the committed implementation of the controllable factors in order to conserve the natural quality of coal, so that grade slippage can be effectively checked. These factors, in a nutshell, are detailed as under:

Uncontrollable Factors (Geo-mining and natural)	Controllable Factors (which can be & therefore must be enforced)
1. Collapsing of overlying coal seams along-with sandstone and other contaminants into the de-pillared galleries of the UG-converted OC Mines due to blasting	1. Extraction of coal only after exclusion of thick (> ½ Mtr) bands
2. Presence of fire in the galleries	2. Compulsory Stone/Shale segregation from mines' stocks through manual/ mechanical means
3. Blanketing activity resorted to, as a measure to control fire in coal stocks	3. Segregation of the left-over Stones/shale from Sidings' stocks and still carried-over stones/ shale from top of loaded wagons/ trucks
4. Heterogeneity of the quality of coal seams, due to presence of several intermittent thin shale/stone bands of varying thickness within the coal seams	4. Loading of wagons/trucks under strict supervision (Selective Loading)
5. Occurrence of faults and other geological disturbances in the coal seams	5. Enforcement of regular fire-fighting measures at coal stocks with high- pressure water jets
6. Slushy nature of OB, which tends to slip downwards (in the absence of proper OB benches), badly affecting the quality of coal seams	6. Non-mixing of fresh coal with contaminated stock, and separate stacking of fresh coal
	7. Compulsory routing of clean ROM coal through CHPs/FBs
	8. Sweetening of inferior quality coal with superior quality coal so as to ensure the required balance, wherever needed

It may be seen from above that occurrence of the uncontrollable factors is outside the domain of the mine manager (though point no. 3 is somewhat an exception), whereas the controllable factors are the measures that can be well enforced. It's therefore very important that all these measures are regularly enforced with full commitment.

Q 36 ***Is it possible to improve the original quality of coal?***

Ans

Yes, may be technically. The total internal chemistry of coal formation which determines the natural (original) quality of coal, is an uncontrollable factor. It is therefore very important to understand that the original quality of coal, already confirmed during the coal formation stage itself needs to be primarily conserved/sustained, by ensuring scrupulous physical/mechanical segregation of the associated contaminants before commencement of delivery to consumers.

The affinities of trace elements to either the organic compounds or the minerals in coal, affect the quality of the coal. The processes involving crushing, washing, leaching, and use of additives, etc., do contribute in improving the quality of coal to a certain extent. If trace elements present in coal are organically bound, then it is difficult to remove them from the coal by cleaning processes such as crushing and washing, which remove only the mineral matter from coal before it is burned. Organically bound trace elements may be released only by burning, or by deep chemical leaching, which is both very difficult and uneconomical. In contrast, trace elements associated with clays or pyrite may be removed largely from the coal by cleaning processes. However, credibility of this route depends on how meticulously several issues involved in this regard would be taken care of in a sustained way by the operators of the processes in question. Out of these four options, the latter two (leaching and use of additives), more being the methods put to use at the power house-end before combustion of coal, are of less practical concern to the colliery, compared to the former processes, crushing and washing. Suitability of the feed coal forming a decisive role in the coal crushing and washing processes, other major factors include huge operating costs, inconsistent yield rate, inconsistent quality of yield, huge problems encountered in disposal/utilization of the rejects and the consequent very high landed cost.

All these factors are leading to gradual built-up of reluctance at the power producers' end to use washed coal in a big way, despite the fact that several non-coking coal washeries are operating in the private sector.

Q 37 ***What does the term RES mean in the context of power generation, and what different sources of electricity come under RES?***

Ans

RES means Renewable Energy Sources. These include SHP [Small Hydro Power (≤ 25 MW)], BP (Bio Power), U&I (Urban &Industrial Waste Power), Solar Power, and Wind Power. The national data regarding RES is maintained by the MNRE (Ministry of New and Renewable Energy).

Q 38 ***What is the HELE technology?***

Ans HELE technology stands for High Efficiency Low Emission technology. In the Paris Climate Treaty signed in April 2016, while pointing out that the globe is a witness to the damage being caused to the environment world over due to coal mining activities, lot of resentment was expressed against continued use of coal for power generation. From mining to coal cleaning, from transportation to electricity generation and finally to its disposal as end product, the coal mining activity releases numerous toxic pollutants into the environment. As a safeguard to the planet against continued use of coal for thermal generation, the signatories to the treaty including India have assured a gradual switchover to the HELE technologies during coal-based thermal generation so that the emissions can be kept under control. Besides, India has further committed to have about 40% of its total installed generating capacity to be non-fossil fuel based. Thanks to the untiring efforts of the Govt, India has already fulfilled this commitment with the total 'non fossil-fuel' based installed capacity in the country already having clocked at 43.61% as on 30.06.2023 itself!

Q 39 ***What are the reasons for significant increase in coal consumption over the years?***

Ans New capacity addition notwithstanding, deterioration in coal quality in terms of the heating value of coal has enormously contributed for increase in coal consumption, which clearly implies that the lower the quality of coal, the higher will be the quantity of coal required for generation of the same quantum of electricity and vice versa (Source: Siddhartha Bhatt M and Rajkumar N, The Journal of CPRI, Vol. 11, No. 4, December 2015 pp. 773-78).

Q 40 ***What are "greenhouse gases"? Is use of coal the only reason for emission of greenhouse gases?***

Ans Carbon dioxide (CO_2) and nitrogen oxides (NO_x), are known as the "greenhouse gases." These emissions are often attributed to coal use only; however, emission of greenhouse gases also results from the burning of any fossil or biomass fuel, such as wood, natural gas, gasoline, and heating oil. Therefore, the greenhouse gas problem requires a broader solution than just reducing the use of coal. Research currently is being conducted in the United States and several other countries including India into the reduction and disposal of CO_2 from coal combustion.

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Carrying Capacity Assessment in Coal Mine in respect of Air, Water, Noise and Biodiversity

Abhisht Raj[1], Nirbhay Bhatnagar[2]

Abstract

Carrying capacity is regenerative and assimilative capacity of environment of a region to sustain an ecosystem. This paper discusses methodology to assess carrying capacity of air, water, noise and biodiversity and demonstrates the application of methodology on one of Asia's largest Opencast Coal Mine situated in India.

Introduction

Coal Mines are inherently a polluting industry. Primary Environmental Impact from coal mining in India includes Land Degradation, Air Pollution, Water Pollution, Noise Pollution and Ecological & Biological impact on flora and fauna in Core Zone and Buffer Zone. Mining is a temporary activity lasting over a few years but intensity of pollution load is high. Since the environmental impact on area of mining is high but temporary therefore Carrying Capacity assessment of environment becomes essential to ensure sustainability of mining operations.

In the present study, Carrying Capacity of Core Zone and 10 km Buffer Zone has been estimated for one of Asia's largest Opencast Coal Mine vis. Gevra Coal Mine, which has production capacity of 52 million Tonnes Per Year.

Carrying Capacity(CC) of Air, Water, Noise and Biodiversity has been assessed by on-field collection of environmental data and describing environmental status in terms of the data collected and comparing it against the carrying capacity of the Study Area necessary for sustainable coal mining operations. The study indicated the available carrying capacity to cater to future requirement of coal excavation. It could provide a management tool and policy instrument for the sustainable coal mining.

The environmental carrying capacity (ECC) could be understood as "a concept and tool for sustainable development of human settlements; (…) a threshold level of anthropopressure, which the environment is able to balance and withstand without irreversible changes and serious degradation" (Świąder, 2018). One of the most frequently recommended solutions for ECC assessment is the use of environmental indicators as Ecological Footprint and biocapacity (Świąder, 2018).

The ecological footprint (EF) has been assessed impact on air, water, noise and ecology and biodiversity in core zone and buffer zone of

[1]*Manager (Environment), CMPDI, HQ, Ranchi,*
[2]*Functional Area Expert (Ecology & Biodiversity), CMPDI, HQ, Ranchi*

the area. Ecological footprint has been assessed by estimation of Utilization Ratio of Air Quality Parameters, WQI, NDVI, MNDWI, LST maps, Ground Water Exploitation analysis and Carbon emission study in the core zone and buffer zone of Gevra OCP coal mining project.

The biocapacity (BC) measures the nature bioproductivity of a given area, which reflects the biosphere's regenerative capacity (Lin et al., 2016; Özbaş Emine Elmaslar et al., 2019) and provides ecosystem services, i.e., carbon dioxide sequestration (Sylla, 2016). In present study, biocapacity has been assessed by estimation of availability of carbon Sequestration capacity, available Utilization Ratio of Air and Water, Estimation of various bio diversity indices.

The difference between EF and BC could identify the state of the environment. If EF or CF is higher than BC, it represents the state of the environment called an ecological deficit. The state of ecological reserve presents the higher nature bio-productivity of the given area than the demand for resources—BC > EF. A quotient of EF and BC equals one represents the minimum environmental condition—ecological balance (Budihardjo et al., 2013; Galli et al., 2015b). However, the minimum environmental condition (BC ≥ EF) does not guarantee the maintenance and restoration of biodiversity, which is possible if 11–75% of productive ecosystems are preserved for this purpose (Hoekstra, 2007; Moran et al., 2008; Ohl et al., 2008).

Methodology & Results

The estimation of ECC can be done by a categorical selection of processes for ecological resilience and quantification of ecological pressure. The following factors have been included in the scope of study to assess the ecological resilience of the study area:

1. Air environment
2. Water environment
3. Noise environment
4. Ecological & Biodiversity carrying capacity

Air Environment Carrying Capacity

Air is a critical resource for humans, plants, animals, and all other living organisms within a natural habitat. Many air pollutants affect the human and plant health such as PM_{10}, $PM_{2.5}$, SO_2, NO_X, O_3 and NOx, by affecting metabolic function of both humans as well as plants and also interfere with net carbon fixation by the plant canopy. Air pollution can affect wildlife indirectly by changing plant communities. It can harm wildlife in two main ways,

- Affecting the quality of the environment or habitat in which they live.
- Affecting the availability and quality of the food supply.

For assessment of air environment carrying capacity, air quality data has been generated from Eight (08) Air Quality monitoring stations as per National Ambient Air Quality Monitoring Standards, 2009, for the following parameters:

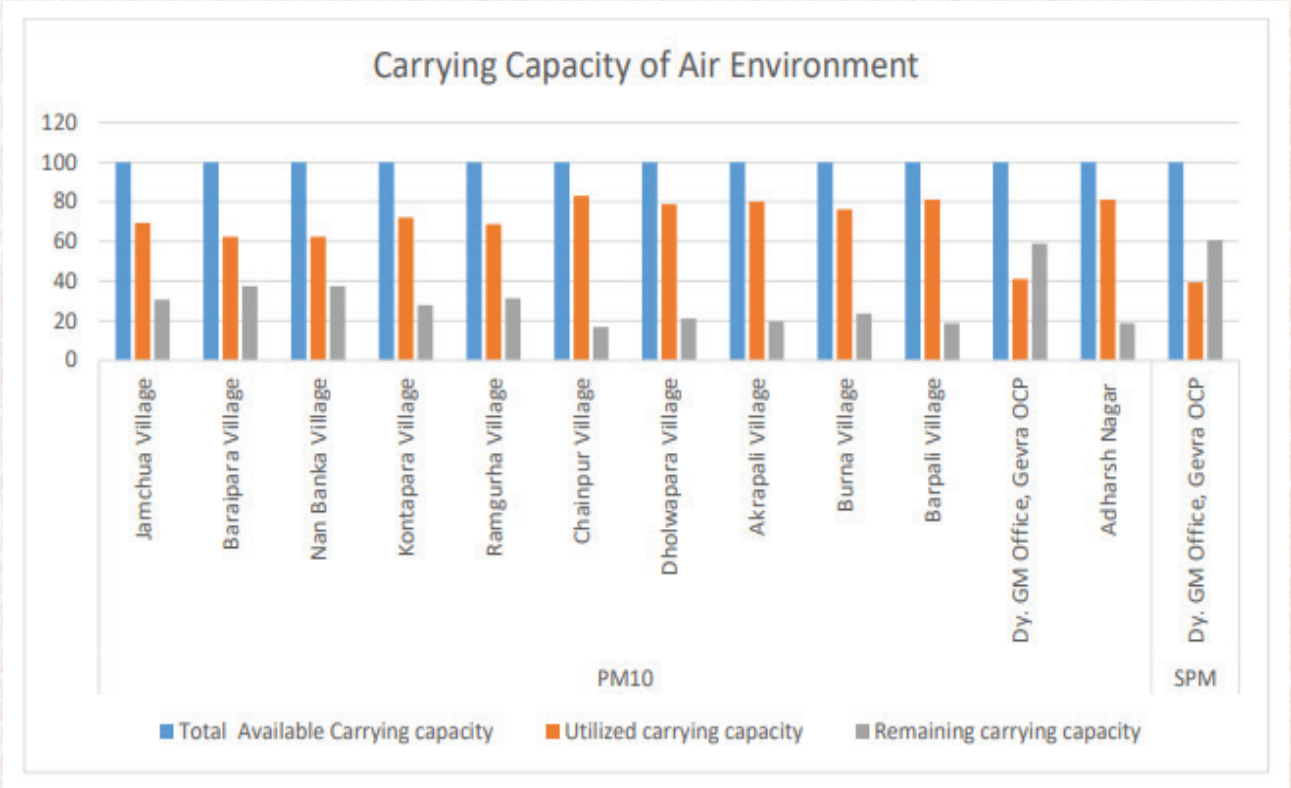
1. PM_{10}
2. $PM_{2.5}$
3. SO_2
4. NOX

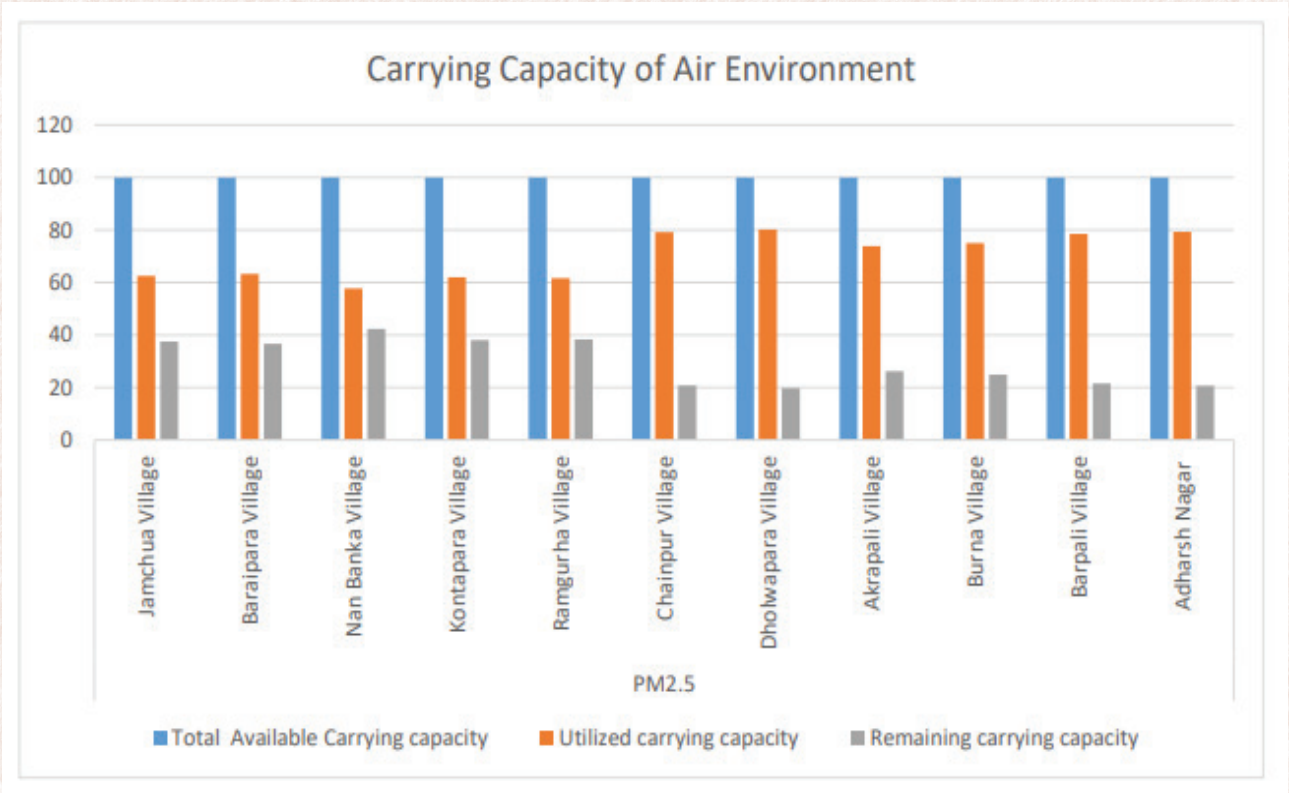
The monitored value has been compared against Coal mine standards for the station in core zone and against NAAQS for stations in buffer zone to determine the Utilization ratio as per the formula given below:

Utilization Ration (UR) = Amount of pollutant load/ECC.

ECC: Coal mine standards for core zone and NAAQS for buffer zone.

If UR > 100%, the resources are overused, or the environment is overloaded.


Carrying Capacity of Air Environment
120
100
80
60
40
20
0
Jamchua Village
Baraipara Village
Nan Banka Village
Kontapara Village
Ramgurha Village
Chainpur Village
Dholwapara Village
Akrapali Village
Burna Village
Barpali Village
Dy. GM Office, Gevra OCP
Adharsh Nagar
Dy. GM Office, Gevra OCP
PM10
SPM
Total Available Carrying capacity
Utilized carrying capacity
Remaining carrying capacity


Carrying Capacity of Air Environment
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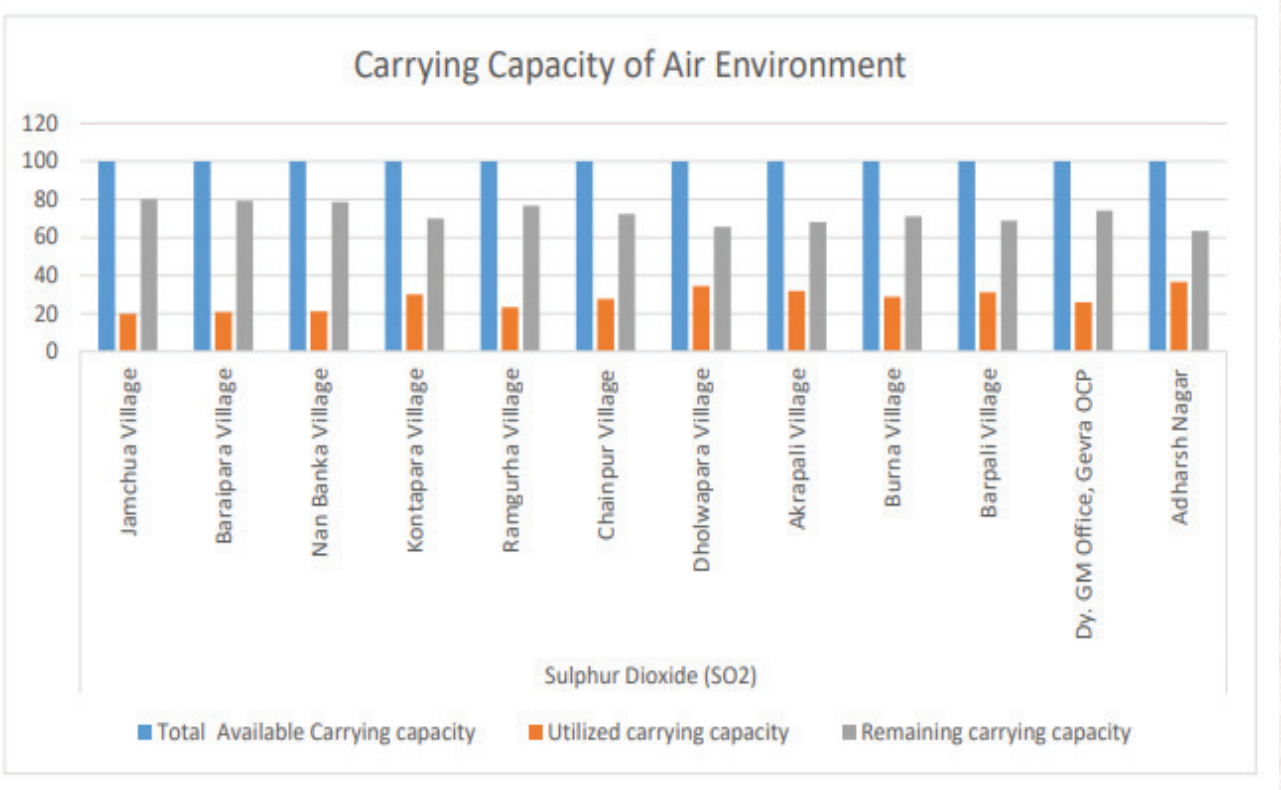
Kontapara Village
Ramgurha Village
Chainpur Village
Dholwapara Village
Akrapali Village
Burna Village
Barpali Village
Adharsh Nagar
PM2.5
Total Available Carrying capacity
Utilized carrying capacity
Remaining carrying capacity



Analysis of result

From the above graphs, it can be inferred that there is sufficient carrying capacity with respect of Air Environment as remaining carrying capacity ranges from 16.9% for PM10 at Chainpur village to 80.12% for Sulphur di Oxide at Jamchua village.

Water Environment Carrying Capacity (WECC)

WECC has been assessed both Qualitatively and Quantitatively.

Qualitative WECC has been assessed by calculation of Overall Water Quality Index (OWQI).

Quantitative WECC has been assessed by calculation of Utilization Ratio (UR) of the mine water and calculation of Modified Normalised Difference Water Index (MNDWI) of water bodies in the Study Area.

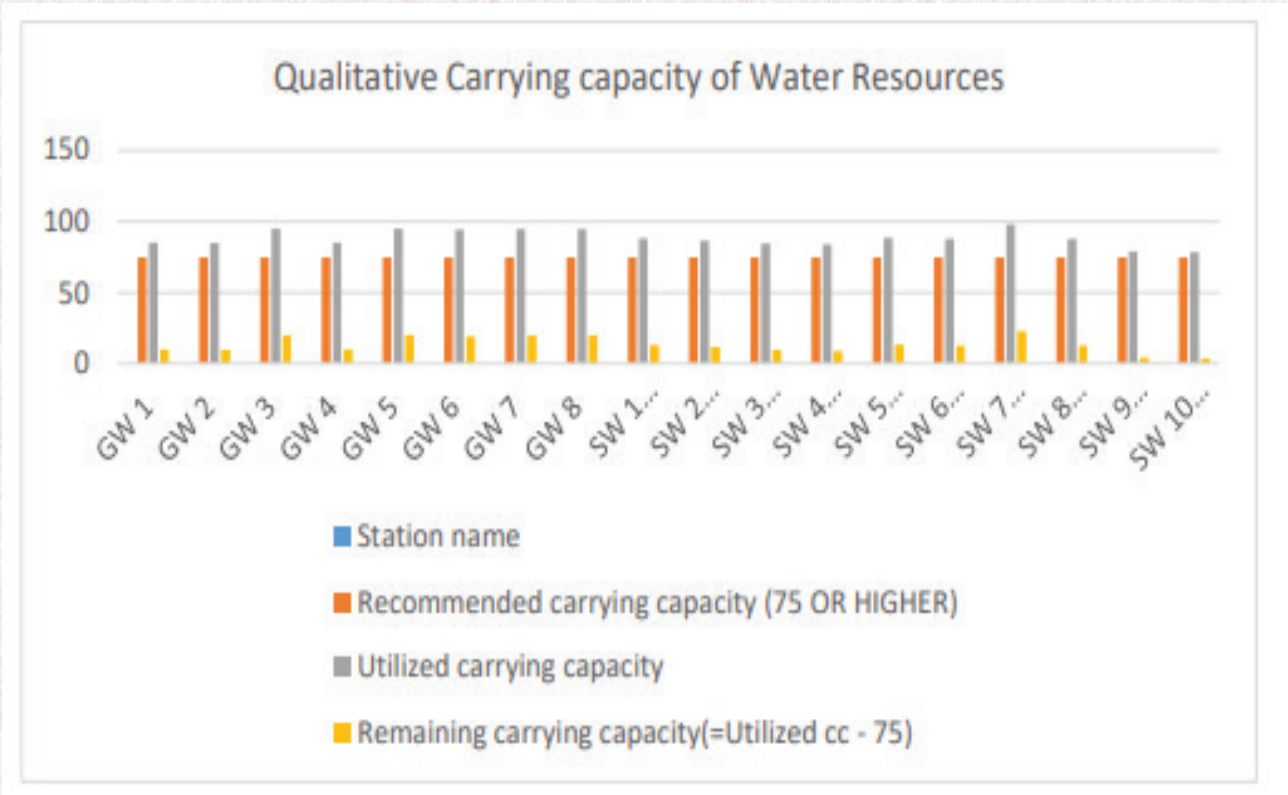
"Overall Water Quality Index (OWQI) is developed by considering sixteen water quality parameters which covers physical, chemical and biological aspects of water. The concentration ranges, for this purpose, have been defined in Indian Standards (IS) and Central Pollution Control Board (CPCB) standards also taking into account International standards of World Health Organization (WHO) and European Commission (EC). This OWQI helps in understanding the quality of water by integrating the complex voluminous data and generates a score to describe the status of water quality"(Development of an Overall Water Quality Index (OWQI) for Surface Water in Indian Context by SURJEET SINGH, N.C. GHOSH, GOPAL KRISHAN, RAVI GALKATE, T. THOMAS and R.K. JAISWAL). The proposed index improves understanding of water quality issues by integrating complex data and generates a score which describes the status of water quality. Based on the status of water quality, the index value range from 0 to 100 and is classified into five categories as given in the following table1:

Table: 1 OWQI value and corresponding class and water quality

Class	OWQI	Status of Water
Heavily polluted	0-24	Heavily polluted
Poor	25-49	Special treatment
Fair	50-74	Needs treatment (Filtration and disinfection)
Good	75-94	Acceptable
Excellent	95-100	Pristine quality

In the present study OWQI has been calculated for Surface Water and Ground Water Monitoring Stations in core zone and buffer zone for the period Mar-May 2022.

Carrying Capacity analysis of Air Quality has generated the following results



Analysis of result

Qualitative Water environment carrying capacity has been assessed by calculation of Overall Water Quality Index (OWQI) at Eight Ground Water stations and Ten Surface Water Stations. OWQI of Groundwater varies between 84.86 and 95.01. Ground water quality has been found to be acceptable at all stations and pristine at two stations. All the parameters have been found to be within permissible limits.

OWQI of Surface water varies between 78.57 and 98.61. Ground water quality has been found to be acceptable at all stations and pristine at two stations. All the parameters have been found to be within permissible limits. The upstream and downstream surface water quality has been found to be of acceptable quality for all the periods and pristine quality for a few periods.

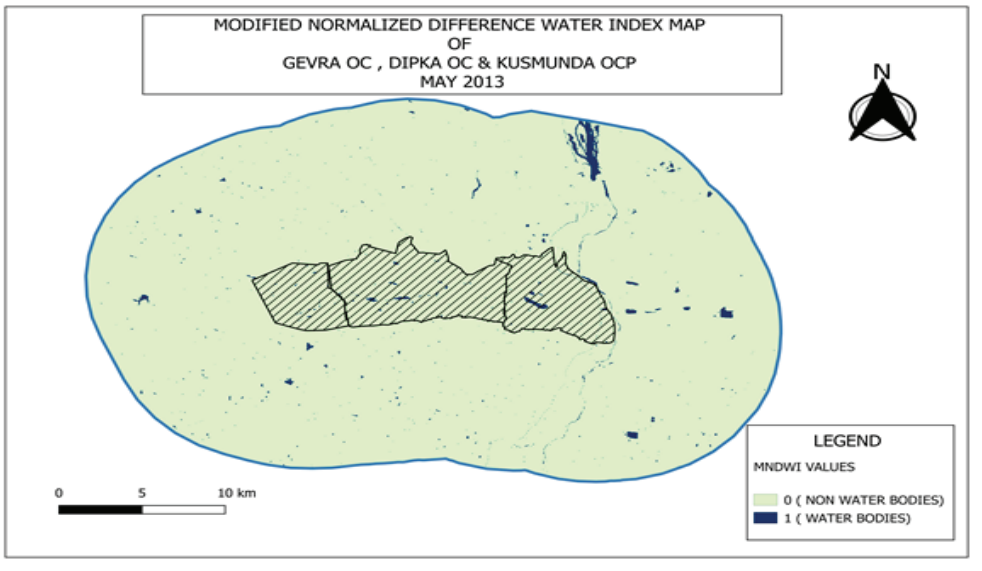
MNDWI

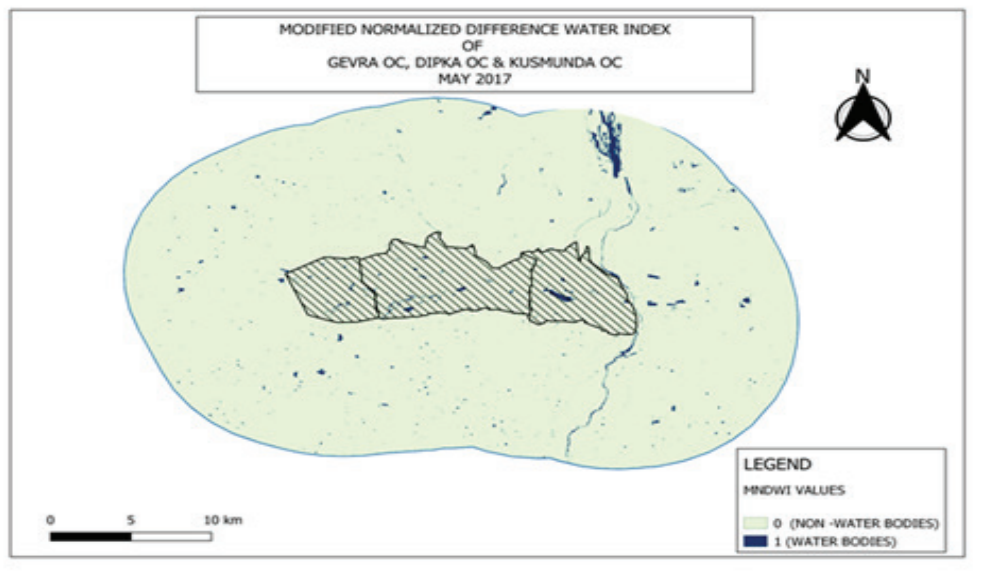
The Modified Normalised Difference Water Index (MNDWI) is used to monitor changes related to water content in water bodies. It is an improvement over Normalised Difference Water Index (NDWI). MNDWI efficiently reduce and even remove built up land noise thus it is more suitable for enhancement of water in built up land areas in the background than the NDWI.1 It is also used to differentiate water from the dry land and is most suitable for water body mapping. It is a remote sensing derived index estimating the leaf water content at the canopy level. During drought events, vegetation canopy can be affected by water stress, which can significantly impact plant development in general and can cause crop failure or lower crop production in agricultural areas.

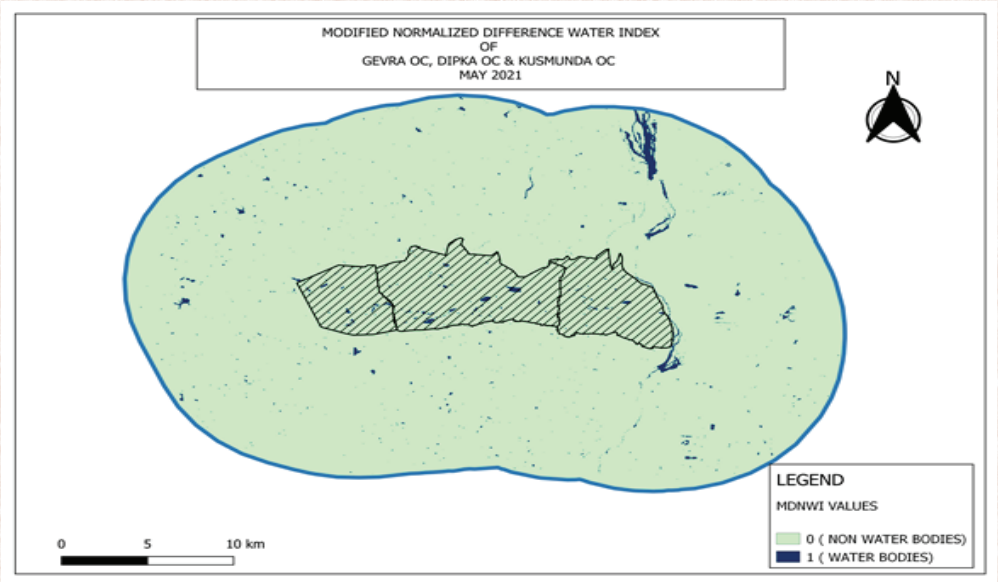
Landsat 8 data is downloaded from USGS Earth Explorer. After downloading satellite image raw data, atmospheric correction and pre-processing is done through QGIS software. The following formula is used in preparation of MNDWI maps:

MNDWI = (Green – MIR) / (Green+MIR)

In the present report, MNDWI maps of three period vis. May 2013, May 2017 and May 2021 has been prepared and compared. The Maps are as follows:







The Modified Normalized Difference Water Index Map of pre monsoon period in the month of May has been compared for three year vis. 2013-14, 2017-18 and 2021-22. These periods correspond to pre EC, pre Expansion and post Expansion period of Gevra OCP. The result has been tabulated as below:

	2013-14	2017-18	2021-22
Area of Water Body (in Ha)	1096.92	1255.41	1249.47

Analysis of result

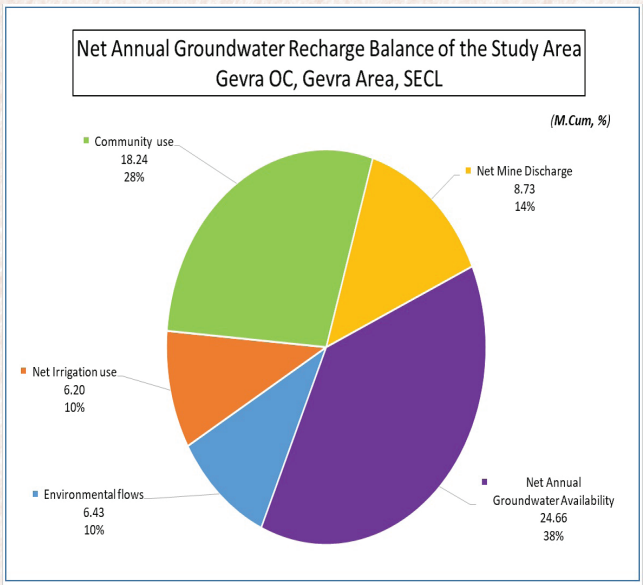
As can be seen from the table, there has been an increase in the Area of Water Body in subsequent periods in the study area, thus there has not been any reduction in water environment carrying capacity despite increase in production.

Utilisation ratio of Available water Resources

Utilization ration (UR) of ground water of Gevra Opencast mine, Dipka Opencast Mine and Kusmunda Opencast mine has been calculated using the following formula.

UR of available water resources = Amount of water consumed/Total available ground water of three mines

If UR is over 100%, water resources are overused.



Analysis of result

The utilisation ratio of available water resources in the study area is 57.36% which is less than the reference value of 100%. While 100% indicates that the carrying capacity has reached, the idea is to never reach 100% and sufficient measures should be applied to keep the utilisation ratio within the range of current assessment i.e. 60-65%. This also calls for regular monitoring of WECC, so that if UR is increasing, corrective measures should be applied to restore the balance.

Noise Environment Carrying Capacity

Sound is an important environmental parameter which affects quality of life of all the living organisms including humans, plants and animals. Activities such as finding desirable habitat and mates, avoiding predators, protecting the young, and establishing territories are all dependent on the acoustical environment.

Sound is what we hear, but noise is the unwanted sound. In general, a growing number of studies indicate that animals, like humans, are stressed by noisy environments. Noise pollution makes it difficult for them to accomplish their activities, which affects their survival. Studies have shown that loud noises cause caterpillars' hearts to beat faster and bluebirds to have fewer chicks. Hence, Noise Carrying capacity has been estimated in the present study to assess the Noise environment of the study area.

Noise Carring capacity has been estimated using the following formula by collecting Noise Level Data at twelve (12) locations in the Study Area and comparing it against the permissible noise levels as per NAAQS 2009.

Name of Noise Monitoring Station with code	Distance	As per Wind Direction	Parameter	Unit	Minimum Value	Maximum Value	Prescribed Standard
N1 Dy. GM Office, Gevra OCP	-	Core Zone	Leq(Day)	dB(A)	68.1	71.5	75
			Leq(Night)	dB(A)	56.6	57.3	70
N 2 Adharsh Nagar	-	Core Zone	Leq(Day)	dB(A)	49.3	53.8	55
			Leq(Night)	dB(A)	36.7	41.3	45
N 3 Jamchua Village	8.49 km	Up Wind	Leq(Day)	dB(A)	48.8	50.1	55
			Leq(Night)	dB(A)	35.1	37.3	45
N 4 Baraipara Village	9.67 km	Up Wind	Leq(Day)	dB(A)	46.5	51.3	55
			Leq(Night)	dB(A)	35	39.5	45
N 5 Nan Banka Village	11.74 km	Up Wind	Leq(Day)	dB(A)	46.7	51.8	55
			Leq(Night)	dB(A)	36.4	39.2	45
N 6 Kontapara Village	9.06 km	Cross Wind	Leq(Day)	dB(A)	46.4	51.3	55

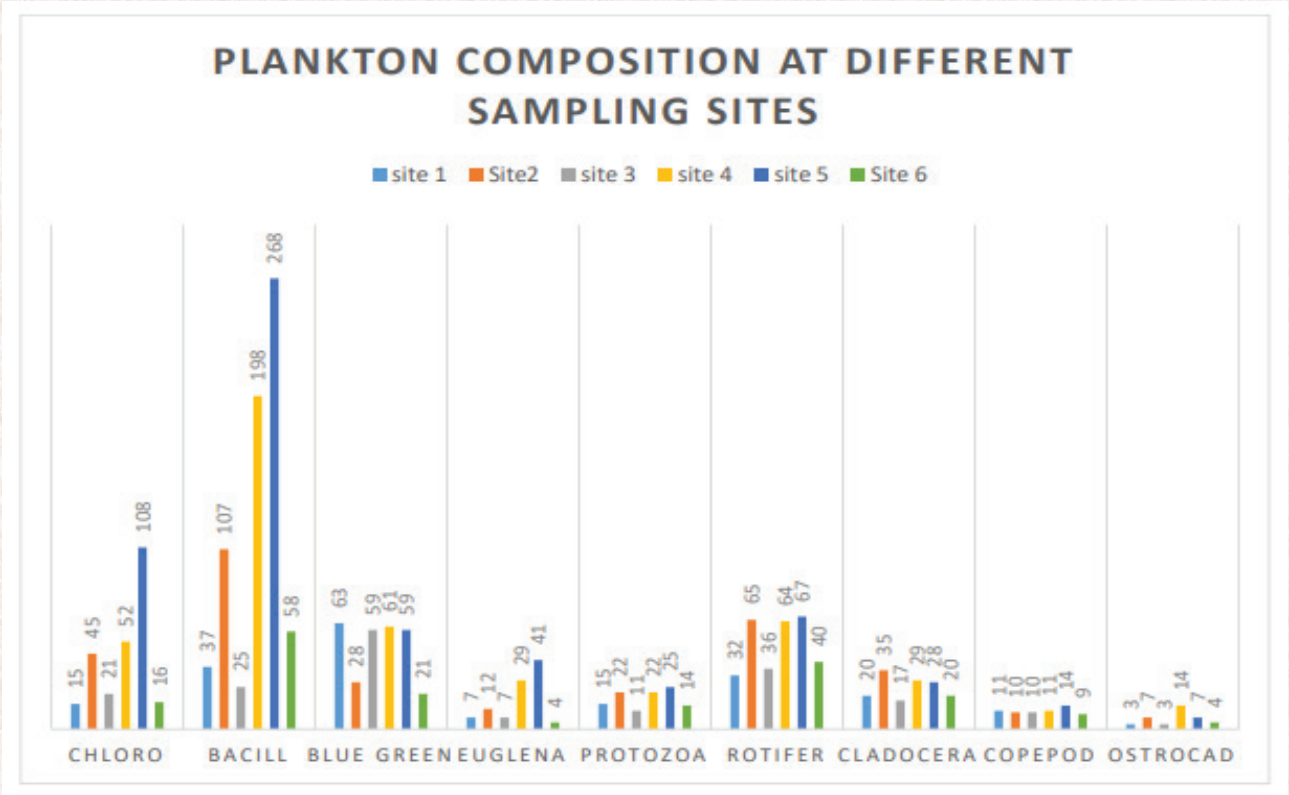
Name of Noise Monitoring Station with code	Distance	As per Wind Direction	Parameter	Unit	Minimum Value	Maximum Value	Prescribed Standard
			Leq(Night)	dB(A)	33.6	38.4	45
N 7 Ramgurha Village	9.09 km	Cross Wind	Leq(Day)	dB(A)	45.5	52.4	55
			Leq(Night)	dB(A)	34.3	37.8	45
N 8 Chainpur Village	4.77 km	Down Wind	Leq(Day)	dB(A)	48.5	52.5	55
			Leq(Night)	dB(A)	32.7	37	45
N 9 Dholwapara Village	5.04 km	Down Wind	Leq(Day)	dB(A)	47	51.6	55
			Leq(Night)	dB(A)	35	38.8	45
N 10 Akrapali Village	8.01 km	Down Wind	Leq(Day)	dB(A)	46.5	52.6	55
			Leq(Night)	dB(A)	35.2	38.8	45
N 11 Burna Village	8.93 km	Down Wind	Leq(Day)	dB(A)	47	50.9	55
			Leq(Night)	dB(A)	35.6	39	45
N 12 Barpali Village	12.79 km	Down Wind	Leq(Day)	dB(A)	48.1	50.2	55
			Leq(Night)	dB(A)	34.6	36.3	45

There is sufficient carrying capacity with respect of Noise Environment as Sound Level has been found to be within the permissible standards at all the Noise Monitoring Stations.

Biodiversity Carrying Capacity analysis

The cumulative assessment study is carried out in the Gevra area of SECL, where more than 50 million ton of coal is extracted annually. The study is undertaken in order to estimate impact of mining and other related activities in this area on the water bodies and forest, in the broad sense flora and fauna. Related to this study water samples are collected 6 different areas (Hasdeo River, reservoir, the water canal of the area and a natural stream). The phytoplankton and zooplanktons were quantified and identified in the laboratory. The aquatic macro-organism are also surveyed and identified. The core and buffer zone area surrounding mine area is visited, flora and fauna details are recorded as per standard Protocol. Four species Ostracoda, Twelve species of Copepods, Eighteen species of Cladocera, Thirty One species of rotifers, Twelve species of Protozoa (Zooplankton); Nine species of Euglenophyceae, Twenty Four species of Cyanophyceae (Blue green algae= cyanobacteria), Twenty Eight species of Bacillariophyceae (Diatoms), Twenty Nine species of Chlorophyceae (Green algae) – Phytoplankton are observed from the six study areas. Reservoir built across the Hasdeo River has more number of planktons. Hasdeo river water near Korba town is contaminated more in the summer months due to dumping of wastes, using water for bath, washing cloth and automobiles, grazing animals etc. More algal bloom formation is observed there.

The canal coming from thermal power station is also having more blue green algae, the temperature of water is also higher ie more than 45^{o} C and emits characteristic odour. The water gets cooled when 3-4 kilometers downstream. The river water 3-4 km downstream to Korba town is relatively clean. Still dumpings of plastics and old cloth in the river is observed. The stream water is also relatively clean. Forty Six species of macro invertebrates, Forty species of aquatic herbs/grasses and Sixty species of fishes observed in the water bodies.

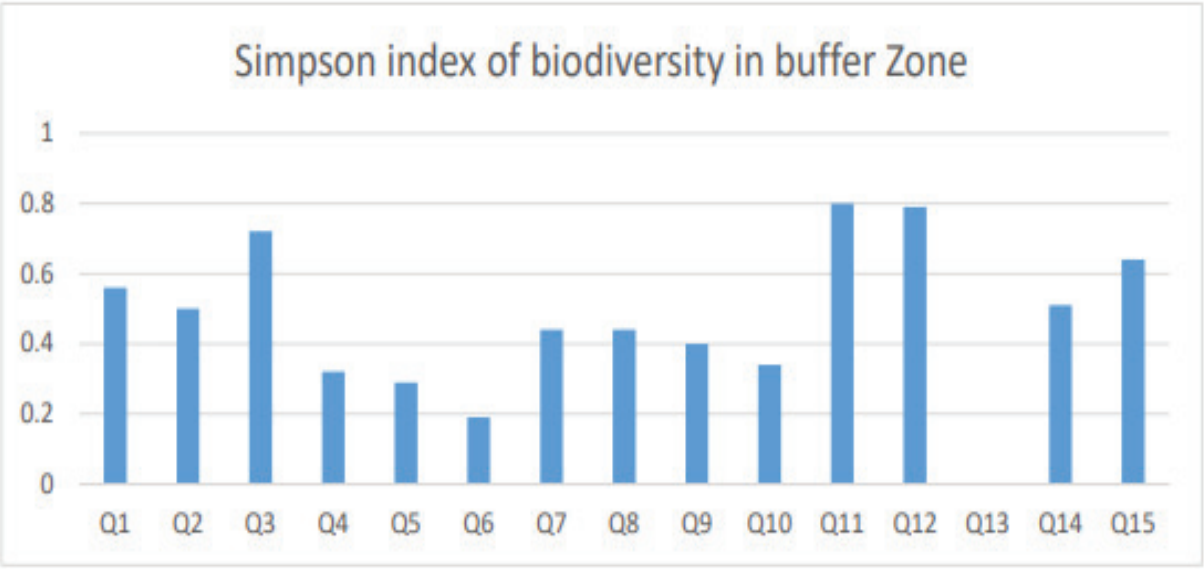


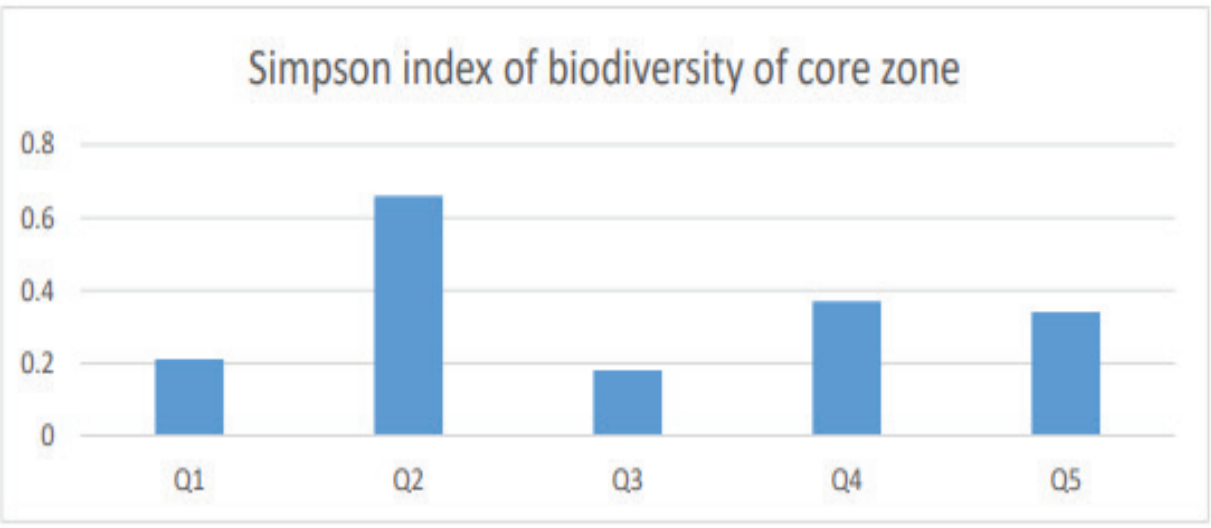
Fifteen nos. of 10 x10m quadrat study, general survey made in the buffer zone to collect details about herbs, shrubs, climbers, trees, birds, mammals, rodents, insects etc. Five nos. of 10 x10 m quadrat survey is carried out in the core zone area. Thirteen nos. of tree species were observed in the core zone quadrat. Twenty Six nos. of tree species were observed from the buffer zone quadrat. The forest type is Peninsular sal forest and mixed dry deciduous forest. In the core zone old green belt plantations of Eucalyptus, Senna siamea, Pithecellobium, Pongamia is observed.

Five species of mammals, Ten species of birds, Four species of reptiles have been observed in the core zone. Ten species of mammals, Nineteen species of birds, Seven species of reptiles, Four species of amphibians were observed in the buffer zone. No schedule I species were reported from the study area. No rare endangered, endemic, threatened flora, fauna is observed from this area.

6 locations were studied for phytoplankton and zooplankton study during the months of May and June 2022. The canal water is very hot in May, the temperature is around 45 degree near the thermal power station during May month. When it moves away the temperature comes down gradually. The water is rich in blue green algae. It also has unique odour due to its biological composition. The river water away from the town is clear and with conventional hydrophyte, plankton macro vertebrate composition. Near the town the Hasdeo river water movement is less, there the level of dust dumping, contamination is more. The blue green algae, zoo plankton composition is high. At some places the algal bloom formation is observed, which an indication of polluted water. In June, after the

start of monsoon rain, the water level increased. Planktons in the unit area comparative to May month became less. The water in the reservoir is stagnant, the biological composition is relatively balanced. Diatoms, other algae, different type of zoo planktons, hydrophytes, macro invertebrate population water insects are high, molluscs are also observed in the study area. The Nalla is relatively small and water flow is observed. It is having its normal biological composition. 31 tree species are observed in the quadrat studies of core zone and buffer zone. 10 mammals, 19 birds, 7 reptiles species observed. No rare threatened species of Flora and Fauna is observed. Usually in the wild conditions more than 600 species of trees, shrubs, climbers, herbs, grasses, epiphytes and parasite species present. As far as fauna is concerned (Mammals, birds, reptiles, amphibians, fishes, insects, worms and butter flies), it will be double the number of species of flora.





The biodiversity index is normal 0.86 to -0.99; as the physical condition of different water body varies. The water quality of the out let of the thermal power plant canal may improve further when it is stored in a reservoir and cooled through sprinkler overnight and then released. The carrying capacity river decreases in summer due to less water flow and less water level, which is

natural phenomenon. In the monsoon season it increases as the water level and flow increases in the river. Ambient temperature is more suitable for aquatic organisms. In all other aspects the carrying capacity of the water bodies is normal.

Way forward

Air, Water, Noise and Biodiversity carrying capacity has been assessed by on field analysis of pre-defined parameters and it has been observed that the study area has available carrying capacity as per the pre-defined parameters. Further, it is proposed to assess the carrying capacity of the study area by using remote sensing derived environmental indices and also to assess the Carbon Sequestration Capacity of the area and compare vis a vis the carbon footprint of the area.

बायोरिमेडिएशनः खुली खदान क्षेत्रों में प्रदूषकों की समाप्ति के लिए एक प्रभावी विधि, झारखंड पर ध्यान केंद्रित करते हुए

*Dolly Krishnan[1]***,*
Medha Kumari[1],
Twinkle Kumari Krishnan[1],
Mohit Verma[1],
Vipul Suman[2],
Rajiva Kumar Singh[3]

सारांश

खुली खदान (Open Cast Mining) झारखण्ड में कई मूल्यवान खनिजों के साथ कोयला खनन के लिए सबसे पसंदीदा विधि है। हम सभी इस बात से भली भाँति परिचित है कि खुली खदान बहुमूल्य खनिजों के दोहन की इस विधि की विभिन्न प्रक्रियाओं के दौरान पर्यावरण को क्षति भी पहुँचती है, जिसका पर्यावरण पर नकारात्मक प्रभाव पड़ता है। केन्द्रित प्रदूषण बोर्ड (CPCB) द्वारा पर्यावरण और वन मंत्रालय, भारत सरकार के परामर्श से किये गये अध्ययन के अनुसार, रामगढ़ में खुली खदान के विभिन्न गतिविधियों के कारण प्रदूषण का स्तर गंभीर हो रहा है। जिसके परिणाम स्वरूप विभिन्न स्वास्थ्य और आर्थिक समस्याएँ उत्पन्न हो चुकी है। मानव जनित स्त्रोतों से उत्पन्न अपशिष्ट पदार्थ, जैविक प्रदूषक, जहरीली गैसें और भारी धातु पारिस्थितिकी तंत्र के लिए हानिकारक है और इसके इर्द-गिर्द में रहने वाले मनुष्यों और वन्य जीवों के लिए भी हानिकारक है क्योंकि ये प्रदूषक मिट्टी में मिल सकते हैं और खाद्य श्रृंखला में भी प्रवेश कर सकते हैं।

बायोरिमेडिएशन एक जैविक प्रक्रिया है, जिसमें जीवित जीवों का उपयोग पर्यावरणीय प्रदूषकों को कम विषैले (हानिकारक) रूपों में बदलने के लिए किया जाता हैं। जो मिट्टी और हवा से प्रदूषकों के उन्मूलन के लिए एक प्रभावी और आर्थिक रूप से व्यवहार्य विधि सिद्ध हो सकती हैं।

स्टोमेटल आवृत्ति का अवलोकन करके हम उन पौधों का रैंकिंग करते हैं जो पर्यावरण से अशुद्धि को समाप्त करने में अधिक लाभकारी होते हैं। इस अध्ययन में स्थानीय जैसे- Plumeria rubra, Artocarpus neterophyllus और Azadirachta indica और कुछ सूक्ष्मजीवों पर ध्यान केन्द्रित भविष्य की दृष्टि को ध्यान में रखते हुए खुली खदान क्षेत्रों के आस-पास प्रदूषकों के उन्मूलन के लिए किया गया किया।

कुंजी: नकारात्मक प्रभाव, जहरीली गैसें, बायोरिमेडिएशन, समाप्ति, उन्मूलन

[1]Researchers, Brainology scientific Academy of Jharkhand (BSAJ) , Ranchi , Jharkhand-834002
[2]State consultant, Water Quality ,PMU, Drinking water and sanitation dept, Govt of Jharkhand
[3]General Manager (Exploration), CMPDI, Ranchi, Jharkhand
First Author - Medha Kumari , BSAJ- medhabsaj@gmail.com
****Corresponding Author- Dolly Krishnan, BSAJ,*

परिचय

झारखण्ड, जो भारत के पूर्वी भाग में स्थित है, अपने समृद्ध खनिज संसाधनों के लिए प्रसिद्ध है, जिससे यह भारत और वैश्विक स्तर पर खनिजों का महत्वपूर्ण निर्यातक बन गया है। इस राज्य के खनिज संसाधनों में कोयला, लौह अयस्क, ताँबा अयस्क, मीका, बॉक्साइट, चूना पत्थर और यूरेनियम शामिल हैं (Kumari and Hansdah (2023))। इन संसाधनों के कारण ओपन कास्ट माइनिंग झारखण्ड में खनिज प्राप्ति का एक प्रचलित विधि है। विशेषकर रामगढ़, धनबाद, और बोकारो जिलों में, जहाँ बड़े पैमाने पर खनन गतिविधियाँ हुई हैं। (Kumar and Saikia (2020))। ओपन कास्ट माइनिंग झारखण्ड में उपलब्ध महत्वपूर्ण खनिजों एवं कोयला के दोहन के खनन उद्योग को गति देने के साथ अर्थव्यवस्था के विकास में योगदान दी है उसके साथ इस विधि के विभिन्न प्रक्रियाओं से विभिन्न पर्यावरणीय एवं स्वस्थ समस्याएँ भी उत्पन्न हुई है।

झारखण्ड 24 जिलों में विभाजित है और छोटा नागपुर पठार में स्थित है, जिसकी अक्षांशीय विस्तार लगभग 22°00' से 24° 37'N और देशांतर विस्तार 83°15'E से 87°01'E तक है। झारखण्ड की भौगोलिक स्थिति विविध भूभागों के बीच है, जिसमें मुख्यत: उष्णकटिबंधीय नम पर्णपाती और उष्णकटिबंधीय शुष्क पर्णपाती वन, पहाड़ और उपजाऊ भूमि शामिल है। राज्य की रणनीतिक स्थिति और खनिजों की प्रचुरता ने इसे खनन गतिविधियों का केंद्र बना दिया है, जो आर्थिक विकास के साथ पर्यावरणीय संरक्षण को संतुलित करने की आवश्यकता को रेखांकित करता है।

ओपन कास्ट माइनिंग से गहन पर्यावरणीय क्षति होती है। खनिजों को निकालने के लिए शीर्ष मिट्टी और चट्टानों की परत को हटाने की प्रक्रिया स्थानीय पारिस्थितिक तंत्र और परिदृश्य को नष्ट कर देती है। (Prathap, A., et.al., 2016). खनन संचालन के लिए वनस्पति को साफ कर दिया जाता है, जिससे कई प्रजातियों के आवास की हानि भी होती है और उस क्षेत्र में कार्बन डाइऑक्साइड अवशोषित प्राकृतिक क्षमता में कमी आती है। (Saini, 2018)। वनों की कटाई, मिट्टी के कटाव को बढ़ाता है, जो मिट्टी की उर्वरता को काम करती है और जो स्थानीय कृषि को भी प्रभावित करती है(Saini, 2018)। इसके अतिरिक्त, मिट्टी की संरचना का विघटन और भूस्खलन और बाढ़ का खतरा बढ़ जाता है, जो पर्यावरण और मानव बसावट के लिए और भी खतरा उत्पन्न करता है (Pacetti et al., 2020)।

ओपन कास्ट माइनिंग द्वारा उत्पन्न प्रदूषण केवल भूमि के क्षरण तक ही सीमित नहीं है। खनन गतिविधियों के दौरान निकलने वाली धूल-कण हवा को भी प्रदूषित करती है, जिससे आसपास के निवासियों को श्वसन समस्याएँ और अन्य स्वास्थ्य सम्बन्धी समस्याएँ होती है। (Pacetti et al., 2020)। खनन मशीनरी और प्रक्रियाओं से उत्सर्जित जहरीली गैसे, जैसे सल्फर डाइऑक्साइड और नाइट्रोजन हाइऑक्साइड वायु को प्रदूषित करते है, जो अम्लीय वर्षा का कारण बनती है, जो मिट्टी और वनस्पति को नुकसान पहुँचाता है। (Pacetti et al., 2020)। जल प्रदूषण भी एक महत्वपूर्ण चिंतनीय बिंदु है। खनन स्थलों से बहने वाला जल, जो प्राय: भारी धातुओं और विषाक्त पदार्थों से भरा होता है, स्थानीय जल स्त्रोतों को प्रदूषित करता है, जो मानव और जलीय जीवन दोनों के लिए गंभीर बीमारी का जोखिम उत्पन्न करता है। (Zhang et al., 2018)। जल प्रदूषण से पेयजल की गुणवत्ता प्रभावित होती है और नदियों और धाराओं के प्राकृतिक पारिस्थितिक तंत्र का विघटन होता है।

खनन क्षेत्रों के आसपास में खनन का स्थानीय समुदायों पर सामाजिक और आर्थिक प्रभाव भी महत्वपूर्ण हैं। झारखंड में कई समुदाय अपनी आजीविका के लिए कृषि और प्राकृतिक संसाधनों पर निर्भर करते है (Sakhre, S.et al., 2020)। खनन गतिविधियों के कारण भूमि और जल संसाधनों का क्षय, कृषि उत्पादकता में कमी के परिणाम स्वरूप किसानों की आय का नुकसान का कारण बनता है। इसके अतिरिक्त, खनन संचालन अक्सर स्थानीय निवासियों के विस्थापन का कारण भी बनता है, जिससे स्थानीय निवासियों को नए स्थान में स्थाननांतरित होकर उस नए स्थान के वातावरण के अनुरूप, ढलने के लिए मजबूर होना पड़ता है। इसके परिणामस्वरूप इन समुदायों की सामाजिक संरचना बाधित होती है, जो दीर्घकालिक सामाजिक और आर्थिक चुनौतियाँ उत्पन्न करती है।

ओपन कास्ट माइनिंग के प्रतिकूल प्रभावों को कम करने के लिए, स्थायी खनन प्रथाओं और उन्नत एवं आधुनिक प्रौद्योगिकीयों को अपनाना महत्वपूर्ण है। बायोरिमेडिएशन एक जैव-प्रौद्योगिकी-आधारित प्रक्रिया है, जिसमें पर्यावरण

में प्रदूषकों का हटाने या बेअसर करने के लिए जीवित जीवों (बैक्टीरिया, कवक, पौधे) या उनके एंजाइमों का उपयोग किया जाता है, एक आशाजनक समाधान प्रदान करती है। स्थानीय वनस्पतियों और सूक्ष्मजीवों का उपयोग करके, प्रदूषकों को कम विषैले रूपों में परिवर्तित किया जा सकता है, जो मिट्टी की बहाली और हवा की गुणवत्ता में सुधार करने में मदद करता है। इसके अतिरिक्त, कठोर पर्यावरणीय नियमों को लागू करना और खनन गतिविधियों की निगरानी कर पर्यावरणीय प्रभाव को कम करने में मदद कर सकता है। वनरोपण और पुनर्वनीकरण परियोजनाओं को बढ़ावा देना भी पारिस्थितिक संतुलन को बहाल करने और स्थानीय पारिस्थितिक तंत्र की सहनशीलता को सुधारने में सहायक हो सकता है।

ये प्रदूषक मिट्टी और पौधों में जमा हो सकते हैं, जो अंततः खाद्य श्रृंखला में प्रवेश करते हैं, जिससे मानव और जानवरों के लिए स्वास्थ्य समस्याएँ उत्पन्न होती हैं। बायोरेमेडिएशन इस समस्या का आशाजनक समाधान प्रदान करती है, जिससे हानिकारक प्रदूषकों को कम विषैले रूपों में परिवर्तित किया जा सकता है। यह विधि दोनों लागत-कुशल और पर्यावरणीय दृष्टि से अनुकूल है। इस शोध में, हम स्थानीय पौधों की प्रजातियों और सूक्ष्मजीवों का उपयोग करके ओपन कास्ट माइनिंग क्षेत्रों में प्रदूषण को कम करने पर ध्यान केंद्रित किया है।

बायोरेमेडिएशन में आपस में जुड़े हुए कई प्रक्रिया शामिल होती हैं। उदाहरण के लिए, फाइटोरीमेडिएशन, पौधों का उपयोग करके प्रदूषक को मिट्टी और जल से अवशोषित, संचय और विषमुक्त करने की प्रक्रिया है। कुछ पौधों की प्रजातियाँ भारी धातुओं और अन्य प्रदूषकों को अपनी जड़ों के माध्यम से अवशोषित करने और अपनी ऊतकों में संग्रहित करने की क्षमता रखती हैं, जिससे मिट्टी को साफ किया जा सकता है। एक अन्य महत्वपूर्ण प्रक्रिया सूक्ष्मजीवों का विघटन है, जिसमें विशिष्ट सूक्ष्म जीवों जैविक प्रदूषकों को हानि रहित पदार्थों में तोड़ते हैं। ये सूक्ष्मजीवों प्रदूषकों का मेटाबोलिज्म कर सकते हैं, प्रभावी ढंग से उनकी सांद्रता और विषाक्तता को कम कर सकते हैं। इसके अतिरिक्त, पौधों की अधिक स्ओमेटल फ्रीक्वेंसी अधिक प्रदूषकों को अवशोषित करने में मदद करती है, जो प्रभावी/ बायोरेमेडिएशन में सहायता करती है। इन जैविक प्रक्रियाओं को मिलाकर, बायोरेमेडिएशन प्रदूषण स्तर को काफी हद तक कम कर सकती है, जो ओपन कास्ट माइनिंग द्वारा प्रभावित पारिस्थितिकी तंत्र की सेहत को बहाल कर सकती है।

बायोरेमेडिएशन

तंत्रः

बैक्टीरिया जैसे सूक्ष्मजीव, प्रदूषकों को भोजन स्रोत और ऊर्जा स्रोत के रूप में उपयोग करके उन्हें कम हानिकारक पदार्थों या हानि रहित उत्पादों में परिवर्तित करके उन्हें विघटित कर सकते हैं।

इन-सीटू और एक्स-सीटू

बायोरेमेडिएशन या तो इन-सीटू (संदूषण के स्थान पर) या एक्स-सीटू (प्रदूषित सामग्री को उपचार के लिए किसी अन्य स्थान पर हटाकर) किया जा सकता है।

प्रकारः

बायोरेमेडिएशन के निम्नलिखित प्रकार हैं -

बायोस्टिम्यूलेशनः पोषक तत्वों को जोड़कर या पर्यावरणीय परिस्थितियों को संशोधित करके प्राकृतिक रूप से पाए जाने वाल सूक्ष्म जीवों के विकास को प्रोत्साहित करना।

बायो ऑग्मेंटेशनः विशेष प्रदूषकों के क्षरण को बढ़ाने के लिए विशिष्ट सूक्ष्मजीवों का उपयोग।

फाइटो रेमेडिएशनः मिट्टी से प्रदूषकों को अवशोषित करने और उन्हें डिटॉक्सीपाई करने के लिए पौधों का उपयोग करना।

लाभः

बायोरेमेडिएशन कई लाभ प्रदान करता है, जो निम्नलिखित हैं:

लागत-प्रभावीः यह पारंपरिक रासायनिक या भौतिक तरीकों की तुलना में उपचार का अधिक किफायती तरीका हो सकता है।

पर्यावरण के अनुकूलः यह प्राकृतिक प्रक्रियाओं का उपयोग करता है, जिससे हानिकारक रसायनों का उपयोग कम होता है।

प्राकृतिक: यह पर्यावरण में मौजूद प्राकृतिक माइक्रोबियल गतिविधि का लाभ उठाता है।

सीमाएँ:

बायोरेमेडिएशन सभी प्रदूषकों के लिए उपयुक्त नहीं है, और कुछ वातावरणों में इसकी सीमाएँ हो सकती हैं।

विधि

अध्ययन क्षेत्र चयन

झारखंड, भारत के दो अलग-अलग क्षेत्रों रामगढ़ और राँची में किया गया। रामगढ़ जिला, जो अपनी व्यापक खनन गतिविधियों के लिए जाना जाता है, और राँची जिला, का अध्ययन, एक गैर-खनन नियंत्रण क्षेत्र के रूप में किया गया। रामगढ़ की खनन-संबंधित पर्यावरणीय दबावों के संपर्क के कारण, यह सील पौधों की शारीरिक स्थितियों पर संभावित प्रभावों का आकलन करने के लिए उपयुक्त था और इसके विपरीत, राँची, जो खनन के प्रभाव से न्यूनतम प्रभावित है, तुलनात्मक आधार प्रदान किया।

पौधों की प्रजातियों का चयन

रामगढ़ और राँची जिलों में सामान्य रूप से पाये जाने वाले प्रमुख पौधों की प्रजातियाँ चयनित की गयी और उन प्रजातियों को प्राथमिकता दी गयी जो पर्यावरणीय तनाव कारकों के प्रति संवेदनशील होती हैं, क्योंकि ये खनन-संबंधित स्थितियों पर अधिक स्पष्ट प्रतिक्रियाएँ दिखाती है।

नमूनाकरण डिजाइन

दोनों जिलों में अध्ययन सीालों का चयन करने के लिए यादृच्छिक नमूनाकरण दृष्टिकोण अपनाया गया। प्रत्येक जिले में विभिन्न पारिस्थितिक परिस्थितियों का प्रतिनिधित्व करने के लिए कई नमूनाकरण स्थान स्थापित किए गये। प्रत्येक स्थान पर चयनित पौधों की कई व्यक्तिगत शाखाएँ संकलित की गयी ताकि विश्लेषण के लिए पर्याप्त संख्या में पत्तियाँ प्राप्त की जा सके।

पत्तियों का संग्रह और तैयारी

स्वस्थ और पूरी तरह से फैली हुई पत्तियाँ चयनित पौधों के ऊपरी भाग से एकत्र की गयी और संदूषण को न्यूनतम करने के लिए निष्फलित बल्प्राणों का उपयोग किया गया। एकत्र की गई पत्तियों का लेबल किए गए प्लास्टिक बैग में रखा गया और आगे की प्रक्रिया के लिए प्रयोगशाला में भेजा गया।

पत्तियों को स्ओमेटल विश्लेषण के लिए तैयार करने के लिए, नाखून पेंट के इम्प्रिंट्स पत्तियों की निचली एपिडर्मिस पर बनाए गए। सूखने के बाद, इम्प्रिंट्स को सावधानीपूर्वक छीलकर माइक्रोस्कोप स्लाइड्स पर एक उपयुक्त माउंटिंग माध्यम का उपयोग करके चढ़ाया गया।

स्टोमेटल विश्लेषण

स्ओमेटल घनत्व, आकार और वितरण को तैयार किए गए पत्तियों के इम्प्रिंट्स के सूक्ष्मदर्शी परीक्षण के माध्यम से निर्धारित किया गया। माप के लिए एक यौगिक सूक्ष्मदर्शी जिसमें माइक्रोमीटर आयपिस होता है, का उपयोग किया गया। इम्प्रिंट्स की डिजिटल छवियाँ भी कैप्चर की गई और छवि विश्लेषण सॉफ्टवेयर जैसे Image का उपयोग करके विश्लेषण किया गया।

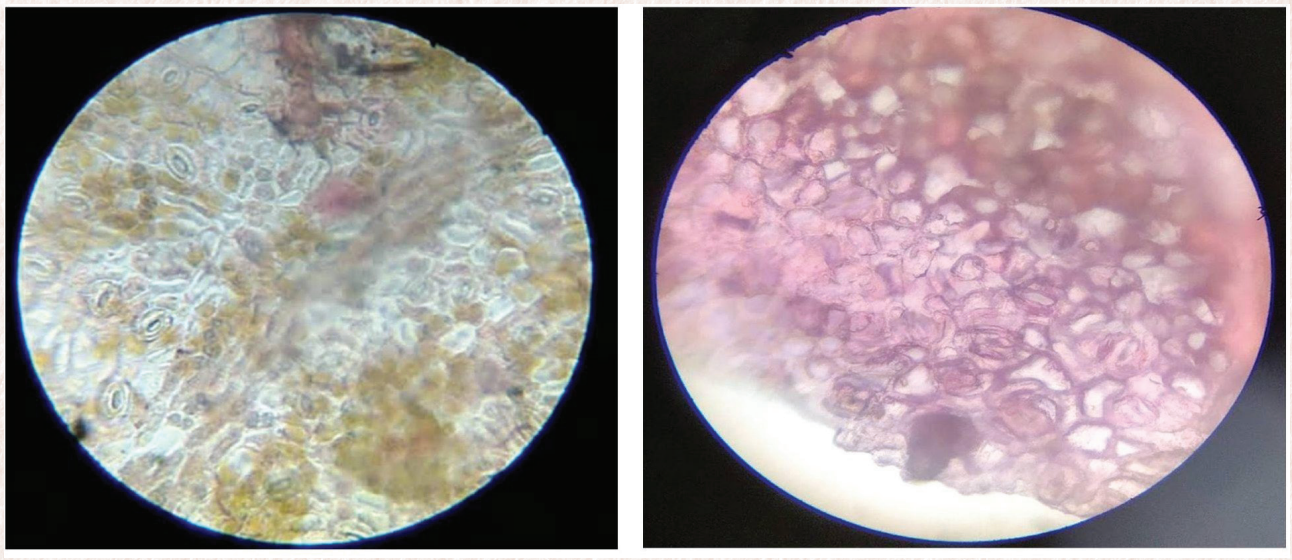
डाटा विश्लेषण

पत्तियों से स्टोमेटल विशेषताओं की तुलना के लिए सांख्यिकीय विश्लेषण किया गया। स्टोमेटल घनत्व, आकार और वितरण में अंतर को उपयुक्त सांख्यिकीय परीक्षणों का उपयोग करके मूल्यांकन किया गया। परिणामों की व्याख्या खनन गतिविधियों के पौधों की शारीरिक स्थितियों पर संभावित प्रभावों के संदर्भ में की गयी। इन विपरीत वातावरणों से पौधों की स्टोमेटल विशेषताओं की तुलना करके, यह अध्ययन खनन-संबंधित परिवर्तन के प्रति वनस्पति की शारीरिक प्रतिक्रिया की अंतर्दृष्टि प्रदान करने का प्रयास है।

अवलोकन

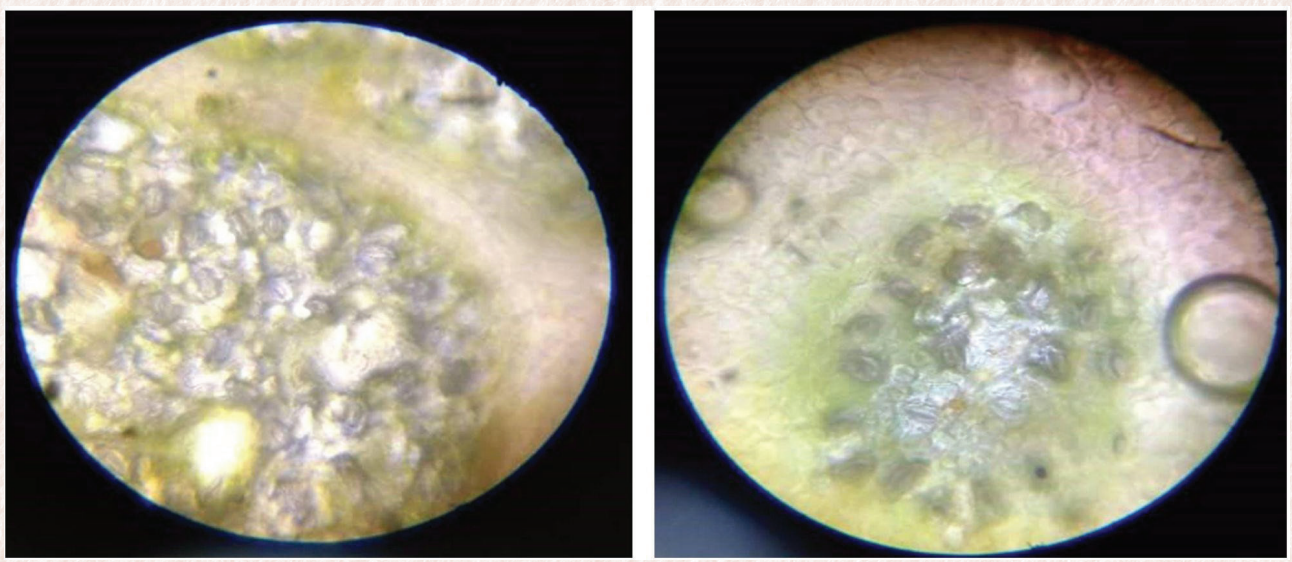
Plumeria rubra, Artocarpus heterophyllus, और Azadirachta indica की पत्तियों के स्टोमेटल विशेषताओं का तुलनात्मक विश्लेषण खनन और गैर-खनन क्षेत्रों से किया गया। विशेष रूप से, अधिकांश पौधों की प्रजातियों ने खनन क्षेत्र में अधिक स्टोमेटल गिनती प्रदर्शित की, जबकि गैर-खनन क्षेत्र की पत्तियों में यह संख्या कम थी। हालांकि, खनन क्षेत्र में स्टोमेटा प्राय: बंद और धूल कणों द्वारा ढके हुए पाए गए, जो प्रदूषित वातावरण के प्रति संभावित तनाव प्रतिक्रिया को दर्शाता है। इसके विपरीत,

Azadirachta indica (नीम) ने अच्छी तरह से विकसित स्टोमेटा प्रदर्शित किया, जो उसकी सहनशीलता और खनन से उत्पन्न कठिन परिस्थितियों के साथ अनुकूलन की क्षमता को दर्शाता है। ये निष्कर्ष सुझाव देते हैं कि खनन गतिविधियाँ पौधों में शारीरिक परिवर्तनों को प्रेरित करती हैं, जिनमें स्टोमेटल व्यवहार में बदलाव शामिल हैं, जो पौधों की वृद्धि, प्रकाश संश्लेषण और समग्र पारिस्थितिक तंत्र की सेहत को प्रभावित कर सकते हैं।



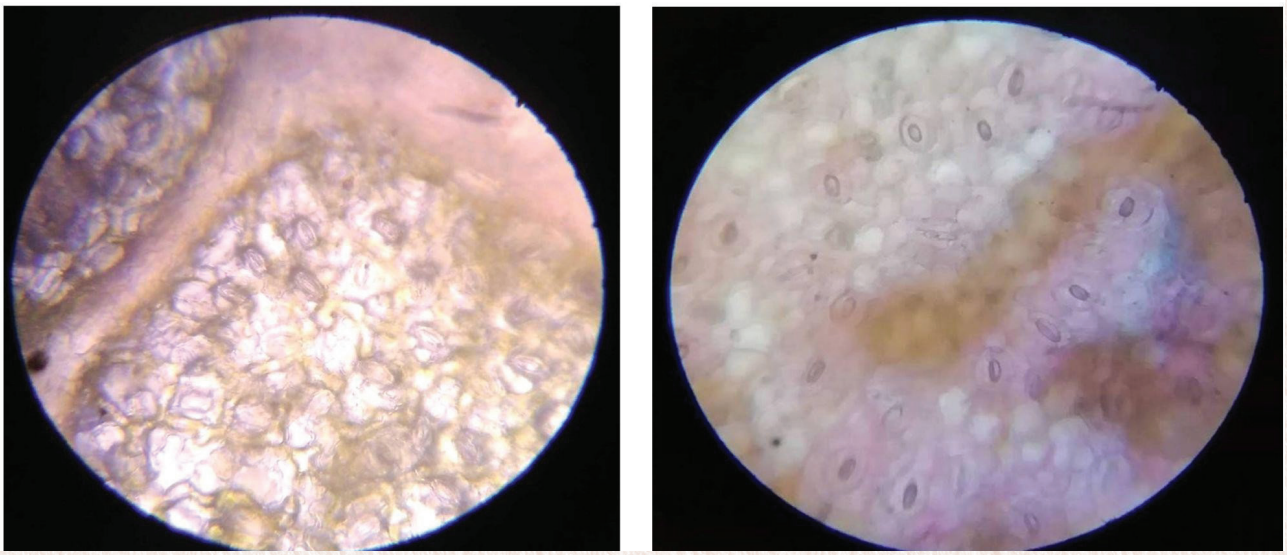
A B

Figure 1- Stomatal imprints of Plumeria rubra leaves. (A) Leaf from a mining area, showing less number of stomata (B) Leaf from a non-mining area.



A B

Figure 2.-Stomatal imprints of Artocarpus heterophyllus leaves. (A) Leaf from a mining area, (B) Leaf from a non-mining area.



A B

Figure 3. Stomatal imprints of Azadirachta indica leaves. (A) Leaf from a mining area exhibiting a higher density of well-developed stomata compared to (B) leaf from a non-mining area.

परिणाम

Plumeria rubra, Artocarpus heterophyllus, और Azadirachta indica की पत्तियों के स्टोमेटल विशेषताओं का खनन और गैर-खनन क्षेत्रों से तुलनात्मक विश्लेषण किया गया। अध्ययन से पता चला कि सभी तीन पौधों की प्रजातियों के लिए खनन क्षेत्र से प्राप्त पत्तियों में स्टोमेटल घनत्व में लगातार वृद्धि का रूझान था, जबकि गैर-खनन क्षेत्र की पत्तियों में यह कम था। हालांकि, स्टोमेटल व्यवहार में महत्वपूर्ण अंतर देखा गया। जबकि गैर-खनन क्षेत्र के पौधे सामान्य स्टोमेटल कार्यप्रणाली प्रदर्शित किया, खनन क्षेत्र के पौधों में बंद स्टोमेटा की अधिक मात्रा देखी गई, जो अक्सर धूल कणों से अवरूद्ध होते हैं।

Plumeria rubra और Artocarpus heterophyllus ने खनन वातावरण के प्रति महत्वपूर्ण स्टोमेटल परिवर्तन को दर्शाया, जो तनाव को संकेत करता है। इसके विपरीत, Azadirachta indica (नीम) के अपेक्षाकृत अच्छे स्टोमेटा प्रदर्शित किया, जो उसके खनन-संबंधित तनावों के प्रति अधिक सहनशीलता को इंगित करता हैं।

निष्कर्ष

वर्त्तमान अध्ययन का उद्देश्य Plumeria rubra, Artocarpus heterophyllus, और Azadirachta indica जैसे चयनित पौधों की स्टोमेटल विशेषताओं पर खनन गतिविधियों के प्रभाव की जाँच करना था। इस अध्ययन के परिणाम स्पष्ट रूप से प्रदर्शित करते हैं कि इन पौधों की स्टोमेटल संरचना पर पर्यावरणीय परिस्थितियों, विशेष कर खनन क्षेत्रों में, महत्वपूर्ण प्रभाव डालती हैं। अध्ययन में देखे गए सभी प्रजातियों में एक सामान्य अवलोकन यह था कि खनन क्षेत्र में पौधों में स्टोमेटल घनत्व बढ़ा हुआ था, जबकि गैर-खनन क्षेत्र के पौधों में यह कम था। यह सुझाव देता है कि पौधे बढ़े हुए वायुमंडलीय कार्बन डाइऑक्साइड स्तर के प्रति अनुकूलन प्रक्रिया दिखाते हैं जो अक्सर खनन संचालन से संबंधित होते हैं। हालांकि, इन स्ओमेटा की कार्यक्षमता प्रभावित हुई है, जैसा कि उनके प्रमुख रूप से बंद स्थिति और धूल कणों द्वारा अवरूद्ध होने से स्पष्ट है। ऐसा स्टोमेटल व्यवहार संभवत: पानी की हानि और प्रदूषकों के अवशोषण को न्यूनतम करने के लिए एक रक्षात्मक तंत्र के रूप में कार्य करता है। अध्ययन ने Azadirachta indica (नीम) की असाधारण सहनशीलता को भी उजागर किया। प्रतिकूल परिस्थितियों के बावजूद, इस प्रजाति ने अच्छी तरह से विकसित स्टोमेटा प्रदर्शित किए, जो इसे खनन क्षेत्रों में फाइटोरीमेडिएशन या वनरोपण के लिए उपयुक्त उम्मीद्वार के रूप में इंगित करता है। इस अध्ययन के निष्कर्ष पौधों की शारीरिक स्थितियों पर खनन के

प्रतिकूल प्रभावों को उजागर करते हैं। स्टोमेटल विशेषताओं में देखे गए परिवर्तन पौधों की वृद्धि, प्रकाश संश्लेषण और समग्र पारिस्थितिक तंत्र की सेहत पर प्रभाव डालते हैं। खनन के प्रतिकूल प्रभावों को कम करने के लिए, ठोस पर्यावरणीय प्रबंधन रणनीतियों को लागू करना अनिवार्य है, जिसमें वनस्पति बहाली और नीम जैसी सहनशील पौधों की प्रजातियों का उपयोग शामिल है। इन स्टोमेटल परिवर्तन के पौधों की उत्पादकता और पारिस्थितिकी तंत्र की कार्यप्रणाली पर दीर्घकालिक प्रभावों की जाँच के लिए आगे के शोध की आवश्यकता है।

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50th Year of Coal India: Prospects of Coal in India

Nitish Kumar[1]

Introduction

November 1st, 2024 marked a landmark event in India's energy story. Coal India Limited (CIL), India's own coal behemoth, entered the 50th year of its foundation. Starting from a modest 79 million Tonnes (MT) of coal production in its year of inception, over the years its production has risen to around 10 times that value! The production stood at 773 MT in FY 2023-241. This is a feat in itself as CIL accounts for around 80% of India's domestic coal production and contributes to 40% of India's primary commercial power generation. Along with this, it is one of the largest employers in India with over 2.2 lakh plus full-time employees. However, amidst all its contributions, CIL finds itself standing at the crossroads of an international and domestic energy transition to non-fossil fuel based 'green energy' resources.

So, what does the future hold for coal in India and Coal India? This study analyses the critical position that Indian coal sector and CIL is at and where they may be headed, all the while being the backbone of India's energy security.

Coal- A Strategic Resource

The installed capacity of power generation in India can broadly be broken down into two categories: power from fossil fuel-based and power from non-fossil fuel-based resources. The fossil fuel resources include: Coal, Lignite, Gas and Diesel; while the non-fossil fuel-based resources include Hydro Power, Wind Power, Solar Power, Biomass, Waste to Energy, Small-Hydro Power, and Nuclear Power.

Based on the recent data for October 2024[2], the contribution of each resource (absolute value and %) among the total generation capacity of 455 Giga Watts (GW) in the overall Energy-Pie for India has been furnished in Figure 1.

[1]*Deputy Manager (Geology), CMPDI, Regional Institute-V, Bilaspur*

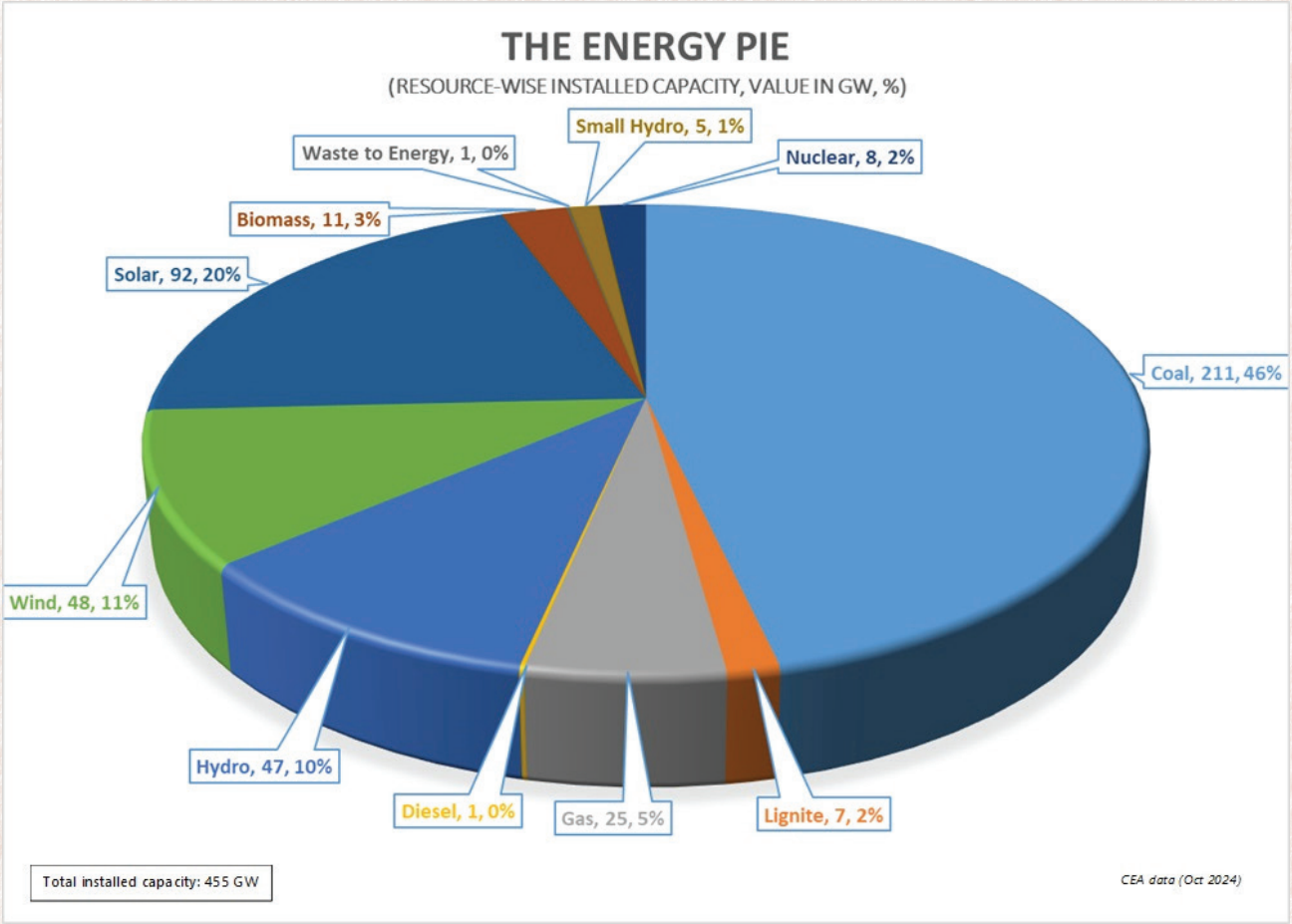

Figure 1: Proportion of various resources in overall installed capacity of 455 GW (Oct, 2024)

Significantly, coal and lignite-based power contributes around half (48%) of the total installed capacity, followed by Solar (20%), Wind (11%), Hydro (10%), Gas (5%), Biomass (3%), Nuclear power (2%). In the current scheme of things, Coal is one of the most abundant, dependable, and affordable fuels. These qualities, coupled with the heavy reliance on coal in the overall energy mix make it a highly strategic resource for India's energy security and a prime moving force for the nation's sustained economic growth.

The Crossroad for Coal?

However, with a growing global focus on Climate Change, adoption of mechanisms like Paris Agreement (2015) by the Conference of Parties to the *United Nations Framework Convention on Climate Change (UNFCCC)*, and building-up of efforts towards "Net Zero" processes, the energy scenario is set to undergo a paradigm shift from the *status quo* in power generation. Coal finds itself right in the middle of the transition. Calls for "phasing-out," "phasing-down" coal-based power has been making rounds in the Energy Policy circles. But to what effect?

In this study, India's power generation capacity data sets spanning 15 years have been collated and analysed, with more recent data being given more weightage. The absolute values of Resource-wise Installed Capacity have been charted out in Figure 2. The plot shows the contribution of various sectors in the total installed capacity, across data sets from four years: 2010-11[3], 2020, 2023 and 2024[2].

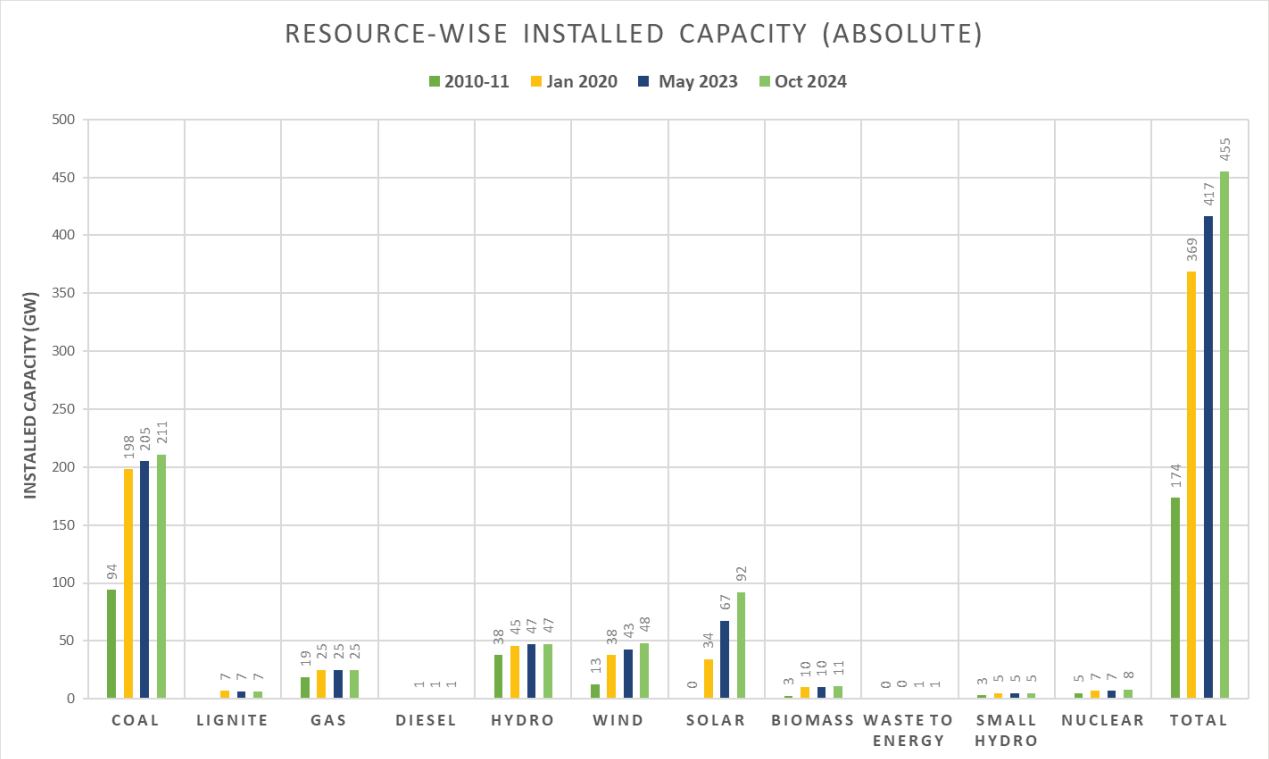

Figure 2: Resource-wise installed power generation capacity (absolute values in GW)

Evidently, the total installed capacity has more than doubled from 174 GW in 2010-11 to 455 GW in 2024. While coal was driving this growth in the 2010-decade, the 2020 decade has witnessed a significant rise in solar power capacity driving the overall installed capacity. Also, the annual growth in solar-based power has been much higher (170% since 2020) than the growth in coal-based power (6.5% since 2020). However, coal-based power generation capacity is still showing a consistent growth, albeit statistically lower.

This trend may have to do with many reasons. While the solar power sector in India is relatively new and hence seeing larger growth, the coal-based power is a matured sector with growth having been stabilized over decades. The international and domestic shift in energy policies towards more adoption of non-fossil fuel-based renewable resources may be another major factor. The capacities of other sectors like lignite-based, gas-based, hydro power, wind power, small hydro, and nuclear power have been quantitatively more-or-less constant.

For a clearer picture though, the percentage of proportions of respective resources to the total annual installed capacity has been plotted for the same years in Figure 3. The trends of various resources give a clear account of where the Indian energy sector is headed.

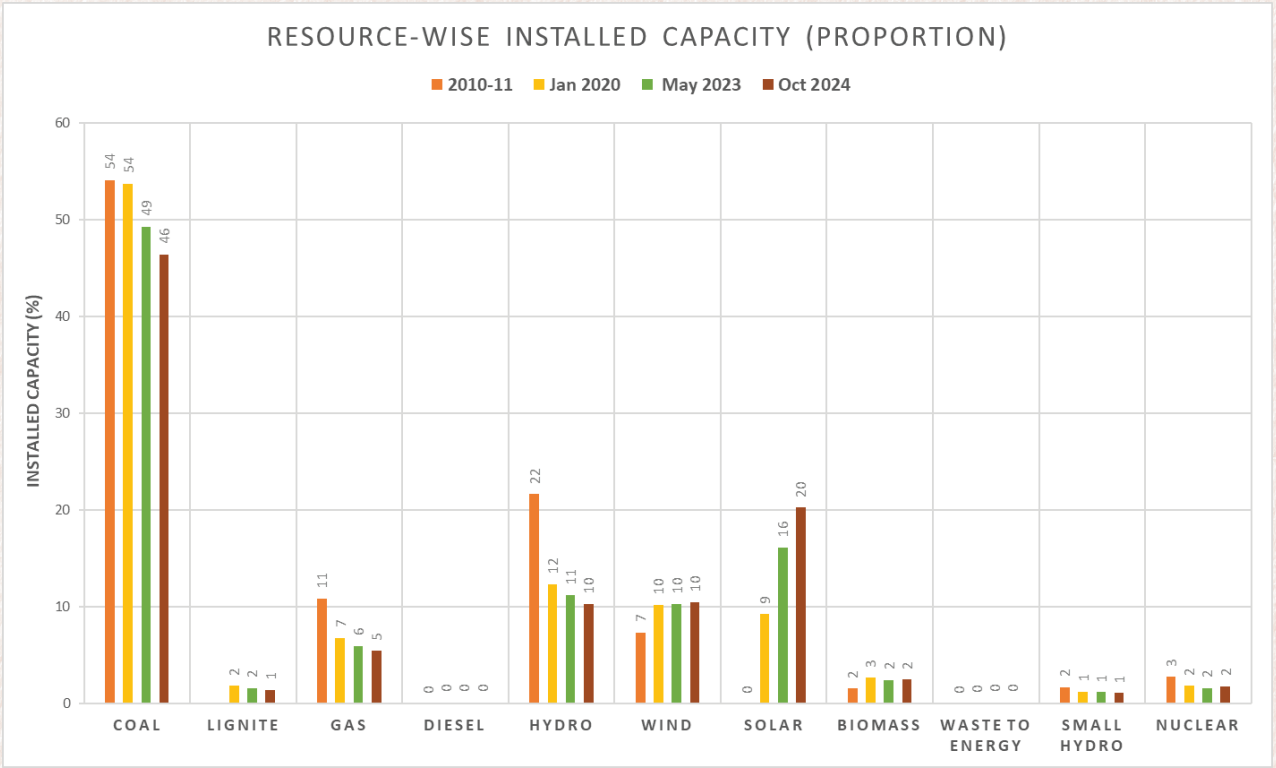

Figure 3: Resource-wise installed power generation capacity (% of total)

The coal-based power generation proportion has been steadily declining (from 54% to 46%) in the overall capacity. Renewable sources of energy have grown, majorly due to growth in contribution by solar power (from 9% to 20%) in the overall capacity. This is in line with the global and domestic shift to greener energy resources.

The Role for CIL

However, analysing Figure 2 and Figure 3 together reveals that **though the proportion of coal-based power is falling, its absolute value is steadily rising**. This is in sync with meeting the rising energy demands of the nation.

The Integrated Energy Policy (2006) report4 for India had projected a peak installed capacity requirement of 778 GW- 960 GW by 2031-32. The report suggests that for the peak scenario, coal will have to be the most important energy source accounting for not less than 41% of the energy mix under any scenario and potentially being even more. Even at base-case scenario of 41%, India would need 1.6 billion tonnes of coal (about 60% more than the current All India Coal production of 997.25 MT.) Thus, in an estimated doubling up of the existing capacity, Coal will have to keep playing the role of the affordable and dependable resource.

It is in this context that CIL, world's and India's largest coal producer will continue to play a crucial role in meeting India's growing energy demand. CIL is a Maharatna company under the Ministry of Coal, Govt. of India, and is headquartered at Kolkata. As a holding company, it operates more than 300 coal mines through 7 major production subsidiaries- Bharat Coking Coal Limited (BCCL), Central Coalfields Limited (CCL), Eastern Coalfields Limted (ECL), Mahanadi Coalfields Limited (MCL), Northern Coalfields Limited (NCL), South Eastern Coalfields Limited (SECL), Western Coalfields Limited (WCL) and a

Mine Planning & Design company – Central Mine Planning and Design Institute Limited (CMPDIL) offering consultancy services to respective production subsidiaries.

With the domestic coal supply requirement projected to reach 1511 MT in 2029-30, CIL is expected to produce around 75% of it (1130 MT), while SCCL (Singareni Collieries Company Limited) and captive and other mines together are expected to produce the rest5. Numbers tell the tale of CIL's importance in India's coal sector.

As the Union Minister of Coal & Mines, Shri. G Kishan Reddy said in his Congratulatory Address on CIL's 50th Foundation Day, "Coal is yet to peak to its full potential. Coal India has to ramp up production to higher levels in future with equal importance to people-oriented social responsibility, welfare and safety."

Thus, in line with its Vision of being committed to provide energy security to the country by attaining environmentally & socially sustainable growth through best practices from mine to market, apart from continuously striving to increase the coal production and off take, CIL is now diversifying into solar power, pithead power stations, coal gasification and critical minerals.

Accordingly, CIL has to continue to remain a central component of India's energy landscape and increasingly manage a tightrope-walk of increasing coal production on the one hand, and managing and mitigating the social and environmental impacts on the other. Its motto of pursuing "Mining with a human face" needs to be continually enhanced in letter and spirit through efficient mechanisms like: A well-structured implementation plan of its Rehabilitation and Resettlement Policy for Project Affected People; Growing CSR activities to cover more sectors like education, healthcare, women empowerment, skill development, sports; Stepping up the greening efforts in mining areas through plantation activities, creation of Eco-Parks etc.

Concluding Comments

As the world grapples with the dual imperatives of decarbonisation and climate resilience, "phasing out" and "phasing down" of coal is going to become a reality with upscaling of alternative sources of energy. Nevertheless, while this may be 'climate justice' for the developed countries who have already had their share of coal exploitation in the past, for developing countries the scenario has to be different. As India has already highlighted at international fora like the UNFCCC, Common but Differentiated Responsibilities and Respective Capabilities (CBDR–RC) has to be the principle driving the energy story.

In the current scheme of things, though the share of coal in India may continue to fall in the overall energy mix, the absolute coal production will have to constantly keep growing. Just that the concerns surrounding coal, especially environmental, need to be dealt with more proficiently, leveraging the latest and upcoming technological advancements throughout the whole supply chain of coal- from exploration to mining operations to transport to thermal power generation. This shall be accompanied with strategic upscaling of allied techniques like Surface and Underground Coal Gasification, Coal Bed Methane etc.

For India, the crossroad at which the coal sector is standing is, in fact, more a one-way street which needs to be treaded only more responsibly now. While coal is set to remain the major contributor in the primary energy generation in India, it is Coal India that would keep driving the majority of growth in India's domestic coal production.

"Perhaps time's definition of coal is the diamond."
Khalil Gibran

On the same thought, perhaps for the time it remains indispensable, we need to make the best use of coal and treat it no less than diamond. It is no coincidence after all that CIL's logo is centered around the iconic "black diamond", fittingly representing the importance of both coal and Coal India to India.

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