ADVANCES IN COAL MINING TECHNOLOGY TO MEET REQUIREMENTS OF ENVIRONMENTAL AND SOCIAL NEEDS

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1.0 Introduction

With its contribution of nearly 60% of the total commercial energy consumption in the country coal continues to play a pivotal role in shaping the profile of the national economy of a developing nation like India. A share of such magnitude in the commercial energy spectrum of the country is in conformity with comparatively favourable resource potential of coal vis-à-vis other energy resources like oil and natural gas. To make the coal industry more efficient Government of India has already initiated liberalisation of the coal sector.

While there are a number of daunting issues that need to be addressed as India continues to increase coal production to meet its growing energy needs, perhaps none present as much of a hurdle as the environmental and social challenges, resulting from mining of coal. Sustainable development of the Indian coal sector will require developing the ability to sustain the increased production of coal in the country, and to do so in an environmentally and socially acceptable manner. On one side a gradually increasing industrial growth rate demands quantum increase of coal production and on the other hand stricter environmental impositions like “no-go” areas restrict the growth; the social pressures act as the third dimension to further complicate the problem. It is with this perspective that this paper discusses advanced system approaches like adoption of environmentally sustainable land use zoning in coalfields, use of JFM in mining industry etc to name a few. Constant care for innovative technology development is the key solution towards a meaningful trade off between environmental and social resource generation and production upgradation. A number of recent developments which are / have contributed to sustainable programme in the Indian Coal mining industry have been discussed.

2.0 Gradually increasing coal production – power grade coalfields to drive coal production

The main objective of the Eleventh year Plan of Government of India is to achieve substantial economic headway to arrest widespread poverty and unemployment prevailing in

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the country. Planned growth rate of 8% in the Indian economy corresponds to an estimated growth of 8 – 10% per year of Industrial sector. This growth rate of Industrial sector is possible only when the energy supply scenario in the country is optimistic. Electricity is the preferred form of energy for use by the Indian industry and is a vital requirement for expansion of industrial and agricultural sectors. Nearly two-thirds of the power generated in the country comes from coal-fired power stations and with the steep increase in the international price of oil and natural gas in recent years, the share of coal in electricity generation is likely to go up in the country. Besides cheap and abundant power, a rapidly growing economy would need an expansion of the cement, steel, fertilizer, paper, textiles, and other industries resulting in pushing up the demand for coal in the country. An exercise by Coal India Limited for demand projection of coal for the next 20 years shows that the coal demand would go up from 526 Mtpy in present level to 1267 Mtpy in 2024-25 assuming an annual GDP (gross domestic product) growth rate of 8%, and to 1147 Mtpy if the GDP growth rate is assumed to be 7%. The Ministry of Coal and Mines, Government of India, has envisaged a large-scale expansion of the coal production from the current level of 526 Mtpy to 1061 Mtpy by the year 2024-25.

Coal resources in India are mainly distributed along the river valleys viz. Damodar valley, Sone-Mahanadi valley, Pench-Kanhan valley, Wardha-Godavari valley etc. The bulk of the coal reserves are located in the South-eastern quadrant of the country bounded by 78° East Longitude and 24° North Latitude in West Bengal, Jharkhand, Orissa, Chhatisgarh, southern Uttar Pradesh and eastern Madhya Pradesh. In all, 57 coal basins exist in these areas. Total spread of Gondwana coalfields cover approximately 64,000 sq.km. A total of 194 billion tonnes of coal reserves are estimated of which non-coking coal reserves are as much as 165 billion tonnes (CIL, 1993). 99.5 % of the resources occur in Gondwana formations. Opencast mines are planned normally for deposits within 300 m depth. In all the power grade coalfields substantial reserves are reachable by open cast mining. In fact, in these coalfields coal exploitation is carried out mostly by open cast mining. This trend is to continue in the unforeseeable future.

Resources, infrastructural and geological characteristics of the power grade coalfields present a significant similarity. The coalfields are drained by major rivers which serve as water sources for Thermal power plants and down line coal based industries. Thermal power plants require substantial water quantity. Each of the power grade coalfields have strong communication network through rail and road link which is a prerequisite for industrial development. The power grade coalfields host a number of thermal power plants. The power grade coalfields are in the States of Orissa, Madhya Pradesh, Uttar Pradesh and Jharkhand where climate is tropical to sub tropical. Rainfall is plenty (1200-1600 mm annually) through a distinct south west monsoon ranging predominantly from June to August. Temperature in summer peaks at 48-50°C whereas in winter it drops down to as low as 5°C in some of the coalfields. The power grade coalfields exhibit the following general site related features:

- Valleys amid undulated hilly topography. The plains have elevation range of 250-300 mRL and the hill tops are, in general, at 500-600 mRL.
- Protected and reserve forest cover especially in the hill tops.
- Valleys have substantial agricultural fields because of good drainage at river basin.
- The coalfields have a similar socio-economic profile with predominance of migration economy and agriculture as the second alternative employment.

Lower Barakars are main host formations for power grade coal. The coal seams in all the coalfields are thick, have gentle dips (3° - 8°); seams disturbed by moderate to intense faulting and in all cases the faults are responsible for repetition of coal seams. **Table 1**. lists infrastructural simile of the identified power grade coalfields.

Table 1: Resources and Infrastructures in Power Grade Coalfields

Coalfield	Major river	Major road network	Major Railway branch	Power stations
Talcher	Brahamani	NH-23 and NH-42 and network of State Highways	Cuttack-Talcher branch line	NTPC TPS at Talcher and Kaniha. Captive PPs of NALCO, FCI
Ib valley	Ib	NH-42 and network of State Highways	Howrah-Mumbai main line	NTPC TPS
Korba	Hasdeo	Bilaspur-Kathgora-Ambikapur State Highways	Champa-Korba-Gevra Road branch line	NTPC TPS at Korba, Captive PP of Balco.
Singrauli	Gopad, Rihand, Moran and Dhanser	Network of State Highways	Katni-Chopan Railway line	NTPC TPS at Singrauli, Vindhyachal, TPS at Renusagar, Anpara, Obra
Rajmahal	Ganga	Network of State Highways	Sahebgunj loop line	NTPC super TPS at Farakka, Kahalgaon
North Karanpura, South Karanpura	Damodar	NH-33 and network of State Highways	Central India Chord Line	Patratu TPS

It has been estimated that total coal bearing areas under various coalfields are 22,549 km^2 (Kadekodi, 1989). Major portion of the reserves in Orissa and Madhya Pradesh are still unopened. In India, about 519 coal mines are working at present and the actual area covered by past and present coal mining is 3614 km2.

3.0 Importance of environmental protection: restrictions on coal mining

As a fall out of Comprehensive Environmental Pollution Index (CEPI) and ‘no go” area demarcation for environmental protection by Ministry of Environment and Forests (MoEF), Government of India, ambitious coal production planning in the country experienced setback. Coal production, which recorded growth of 7 per cent last fiscal, has dipped to just 2 per cent this year. After a long battle between Ministry of Coal (MOC) and MoEF, MOEF is believed to have cleared recently about 23 projects that were earlier classified as 'no-go' zones recently. Still the fate of 203 coal blocks with a potential output of 660 million tonnes per annum is unclear. As many as 154 projects of Coal India Limited (CIL) are stalled due to delays in environmental and forest clearances at the Centre and state levels. In the absence of permission for coal mining in 203 blocks, about 1,30,000 MW of potential power generation capacity per annum is likely to be stalled.

4.0 Resulting pressure on environment – coal industry to face higher degree of social and environmental challenges

Keeping in pace with rapid growth of power grade coal demand, power grade coalfields are likely to be subjected to a compounded environmental pressure. Power grade coalfields in India are in river valleys that host large tract of forests and agricultural lands amid a majority of tribal population. The pristine environmental quality in typical rural set up are impacted due to large scale open cast mining and also due to coal based industries viz., thermal power plants. McCarthy (2002) observes that in the liberalised era, on one hand, government agencies must help reduce the barriers to private-sector by addressing the uncertainties created by four major issues: legal liability for contamination, uncertain cleanup standards, availability of funding for redevelopment and complicated regulatory requirements; on the other hand, coalfields must be connected to wider community efforts to achieve environmental protection, central city revitalisation and reduced suburban sprawl. Share of surface mining which is more instrumental to land degradation is rising decade after decade. At present, in coal sector the figure is 87%. Land degradation in coal sector, at a very fast rate, compounded with the problem of huge waste generation due to aging (increase in stripping ratio) of the opencast mines have made it abundantly clear that backfilling of the surface mined land has paramount importance in the context. Unfortunately no co-coordinated attempt so far has been made to evolve a strategy for maximization of backfilling in various geomining conditions, in India.

5.0 Technological advancements in mining and environment as solution to the problem

Political and social institutions could exert enormous influence over the mining industry development. Political Institutions including central government, local government and public decision makers are creating international harmonization of environmental standards for better positioning for global competitiveness in mining product. Doing so will improve the corporate image of the mining industries as well as benefit the global consumers. Improvement areas in the coal industry are discussed below:

5.1 Environmentally compatible land use zoning in power grade coalfields

CPCB has initiated macro level environmental zoning for certain districts in the country only for industrial sector. Micro level zoning concept is absent in India till now. Environmentally compatible micro level zoning for a Power grade coalfield in India, developed by one of the authors, may be considered as a significant step towards furthering CPCB's work of implementing environmentally compatible land use zoning. Zoning alternatives include mixed use districts where combination of specified land uses have been suggested. A representative power grade coalfield, adequately exhibiting the conditions and characteristics of power grade coalfields in India, has been adopted as a test case for running demonstration of the development of strategies for environmentally compatible land use zoning. The zoning methodology involves extensive study of a variety of environmental, socio-economic and infrastructural attributes of the site, establishing their relationship with targeted land uses to study land use suitability and working out alternative zoning plans.

The zoning methodology has been developed on the Talcher coalfield or Angul-Talcher area which adequately exhibits the characteristics of power grade coalfields in India. The area has been logically divided into spatial segments or land parcels. Resource and infrastructural attributes, socio-economic attributes and environmental attributes have been identified for the subject land parcels. A framework of using a land use decision matrix, has been developed and applied for each test parcel to understand behaviour of infrastructural, socio economic and environmental attributes. For each land parcel, land use suitability rankings dictated by the testing infrastructural attributes (through the developed framework) were arrived at. Similarly, land use suitability (using the developed framework) from environmental and socio economic angles were separately mapped. Infrastructural and environmental suitability maps were developed at various strategic levels. Infrastructural and environmental suitability maps, at various levels, were logically combined to evolve strategic scenarios. Alternative zoning scenarios with various degrees of environmentally compatible zoning were developed to depict economic and environmental suitability cut offs at varying levels. A higher degree of environmental compatibility with a moderate infrastructural compatibility has been suggested as the preferable option.

Zoning scenario developed through land use suitability framework ensures long term suitability of land uses from economic and social perspectives on sustainable basis. Minimum possible pollution load to human habitats, local or distant is likely because the mechanism restricts land use whenever there are chances of adverse impact or non-compliance of regulatory requirement. Environmental incompatibility cut-off has been suggested to be kept at lower level to ensure minimum possible pollution load. A moderate infrastructural cut-off at a lower environmental incompatibility cut-off ensures adequate infrastructural resource for community at an improved environmental performance. Land use suitability framework has been designed in a way such that protection of the specific natural resources viz., reserve forest areas, protected forest areas, biosphere reserves and areas with unique features of social-cultural, commercial interest are ensured.

Zoning scenarios at 20, 40 and 80 percentile environmental cut off at 20, 40 and 80 percentile infrastructural cut off have been explained in the demonstration project. In fact a few other scenarios can also be developed. The planning team should decide the strategic cut offs depending on current development status and growth possibilities. The best strategy would be to first develop a low level of infrastructural and environmental incompatibility map to isolate the core land use centres. A moderate level of infrastructural incompatibility than can be combined with lower/moderate environmental incompatibility to identify the future growth directions.

Environmental and socio economic attributes and infrastructural attributes have been dealt with side by side. Environmental incompatibility has been depicted with respect to varying levels of infrastructural development. An idea can be made of usability of available infrastructures and resources and requirement of additional infrastructures, from the study. Permissible infrastructural development can be decided based on allowable environmental performance cut off. Resource and infrastructural carrying capacity can be maintained by deciding a strategic infrastructural cut off. Availability of river water, road traffic density, railway goods carrying capacity, soil capability or maximum agricultural yield from agricultural field etc. can be deciding criteria for infrastructural cut off. A safe cushion is required to be planned between availability of resources and supply (or exploitation) of resources. The management of resource exploitation shall be taken care of by safe environmental cut – off.

For coalfields with existing high level of environmental incompatibility environmental attributes related only to the existing development should be considered. For coalfields with existing low level of environmental incompatibility environmental attributes related to the planned proposed developments can also be considered; the zoning exercise shall predict admissibility and type of further development.

While developing methodology for environmentally compatible zoning in our coalfields, Angul-Talcher area (which typically exhibits the characteristics of power grade coalfields in India) was used as study base. Fig. 1 shows Landuse of the area.

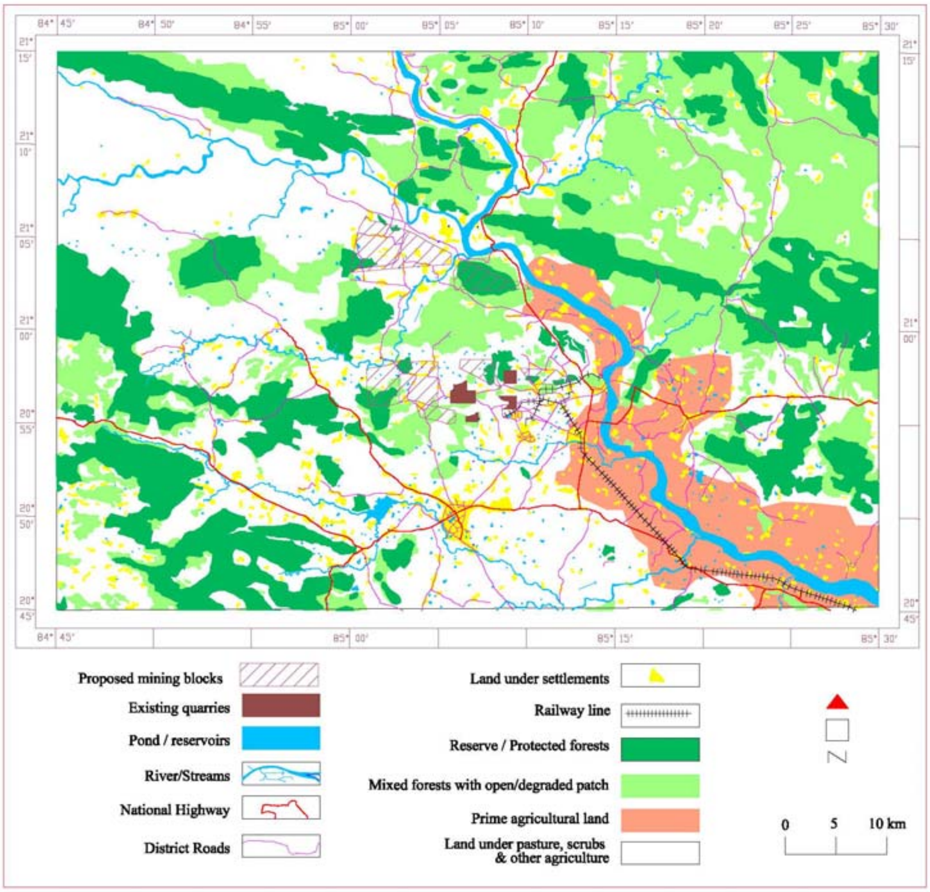
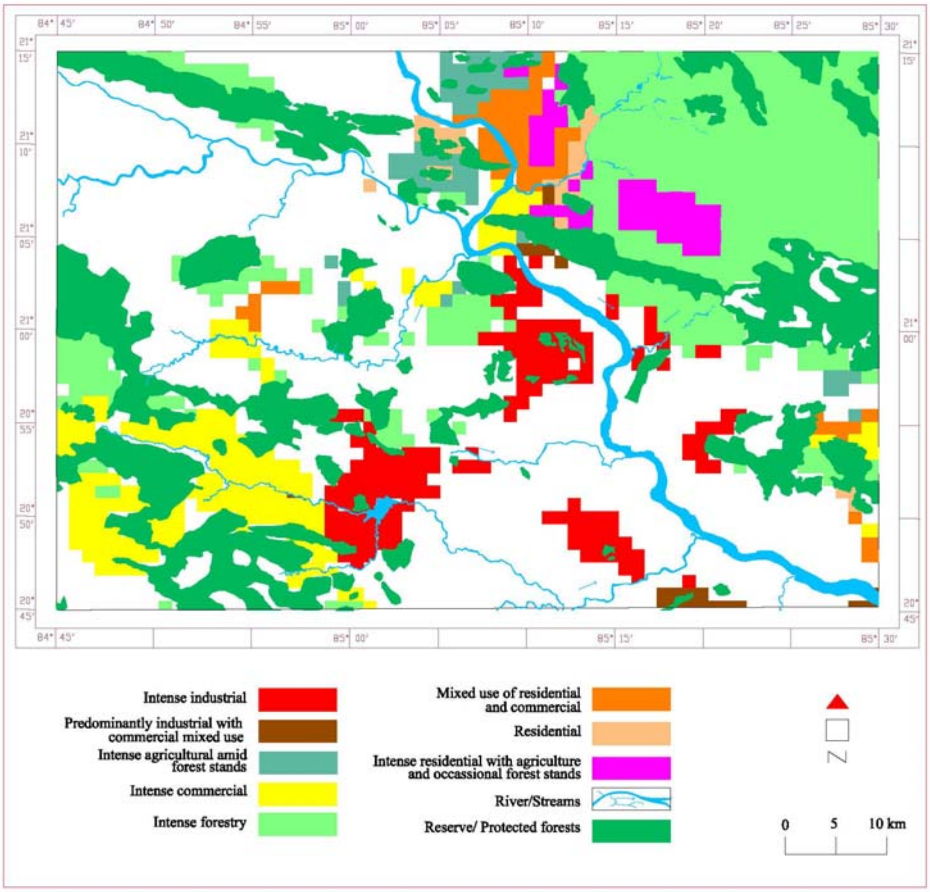


Fig. - 1

For the Talcher coalfield case, the following three strategic zoning scenarios were developed:

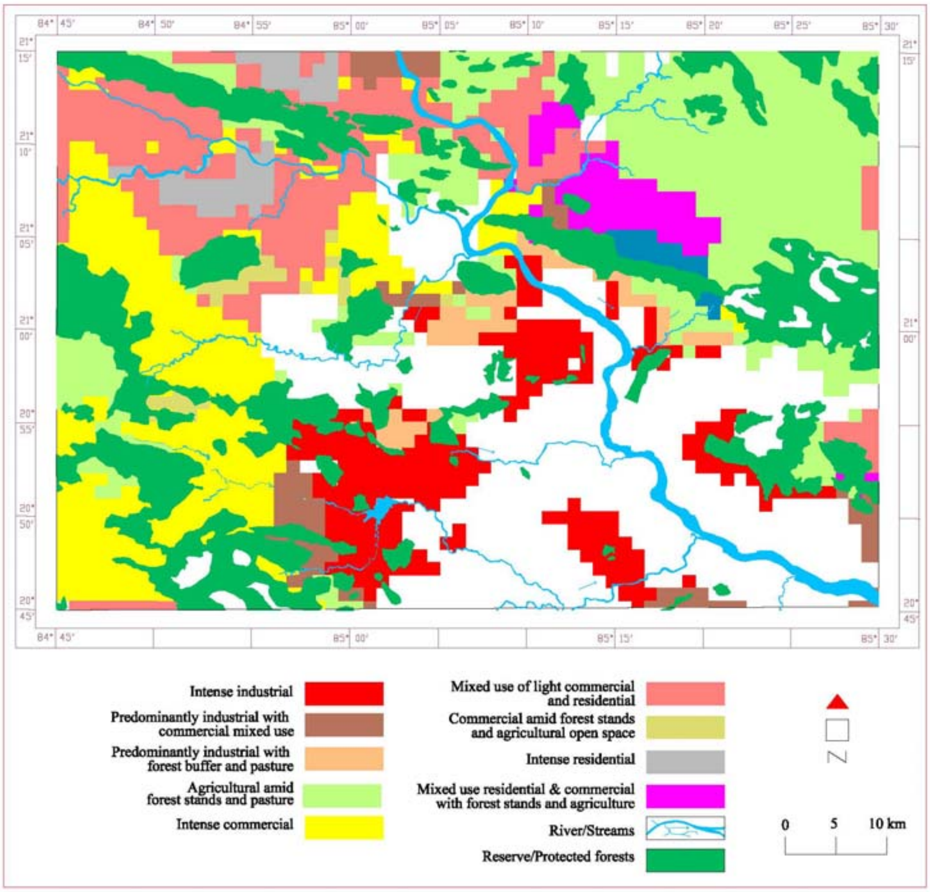
Scenario I: 20 percentile environmental incompatibility at 50 percentile infrastructural incompatibility.
Scenario II: 20 percentile environmental incompatibility at 80 percentile infrastructural incompatibility.
Scenario III: 50 percentile environmental incompatibility at 50 percentile infrastructural incompatibility.

Scenario I. II and III have been shown in Fig. 2, Fig. 3 and Fig. 4 respectively.



Intense industrial
Predominantly industrial with commercial mixed use
Intense agricultural amid forest stands
Intense commercial
Intense forestry
Mixed use of residential and commercial
Residential
Intense residential with agriculture and occassional forest stands
River/Streams
Reserve/ Protected forests
N
0 5 10 km

Fig. – 2



Intense industrial
Predominantly industrial with commercial mixed use
Predominantly industrial with forest buffer and pasture
Agricultural amid forest stands and pasture
Intense commercial
Mixed use of light commercial and residential
Commercial amid forest stands and agricultural open space
Intense residential
Mixed use residential & commercial with forest stands and agriculture
River/Streams
Reserve/Protected forests
N
0 5 10 km

Fig. – 3

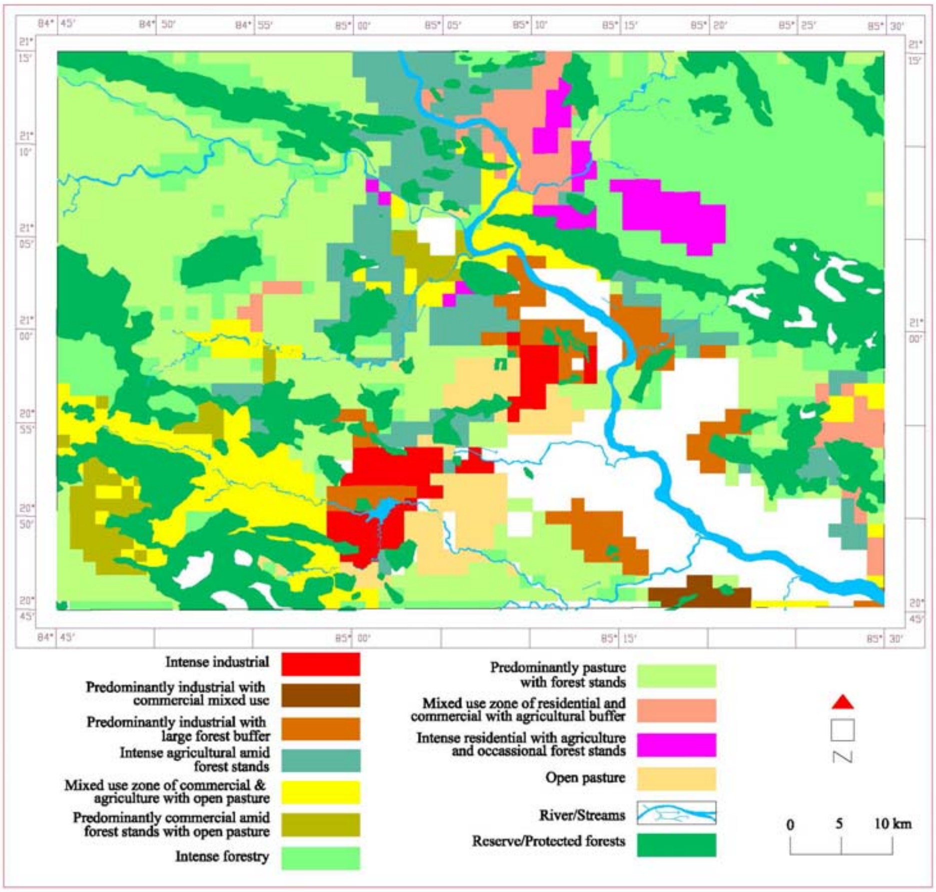


Fig. – 4

5.2 Bigger machines render environmental advantage

Bigger size machines being gradually inducted in higher capacity OCPs are in fact, facilitating environmental advantage because of : (i) Less specific fuel and other resources consumption, (ii) less pollution , dusts etc. dispersion because of bulk handling and (ii) less number of exposed people. In our country largest haulpacks are Komatsu 830E –AC and Caterpillar 793 (both of of 240 t). The biggest machines available internationally are as listed below:

Dumper: Leibherr T 282 B (360 t), Bucyrus MT 6300 AC (363 t), Caterpillar 797 F (363 t). Model BelAZ (420 t) is under development

Hydraulic shovel : Bucyrus RH 400 (9900 t/h, 94 t in single scoop), Liebherr R 9800 (42 m^3 bucket capacity)

Rope shovel : P & H 4100 X PC (59 m^3 bucket capacity)

Dragline : Bucyrus 3270 W (135 m^3 bucket capacity)

Payloader: Le Torneau L 2350 – Generation II (40.52 m^3 bucket capacity)

Dozer : Komatsu 575A – 35D (1150 HP)

For overburden excavation Bucket Wheel Excavators (BWE) are used by Neyveli Lignite Corporation Ltd. While BWEs are environmentally advantageous because they obviate blasting, they can be used only in softer strata.

5.3 Increased backfilling in open cast voids – approaches to achieve AOC

U.S. National Academy of Science Study Committee (NASSC) has given precise definition (Anon, 1974) of Restoration, Reclamation and Rehabilitation. As defined by NASSC, restoration is the replication of the site conditions prior to disturbance; Reclamation renders a site habitable to indigenous premining condition organisms. Rehabilitation defines that disturbed land will be returned to a form and productivity in conformity with a prior land use plan including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values. The amount of maintenance required to achieve rehabilitation is the difference between the post mining goal and the sum of severity of disturbance and the environmental conditions governing the site ecology (Harthill and McKell, 1978).

The overall operational plan consists of two primary components, the mine operational plan and the rehabilitation plan. The operational plan represents the most rigid segment of the concept and may be viewed as the ultimate compromise between mining and rehabilitation proposals. The rehabilitation proposal may consider one or a combination of possible potential post mining land uses such as cropland, pastureland, grazing land, forestry, residential use, industrial/commercial use, recreation (parks or water based), pisciculture, conservation of natural wildlife habitat, developed water resources, landfill sites etc. Among the alternatives, except for the water based choices, all other land uses require backfilling as a prerequisite.

Backfilling facilitates the following:

- Backfilling supports revenue earning post mining land use, thus, attaches/restores some economic value to the land that is otherwise considered lost.
- Backfilling helps maintain the aesthetic beauty by repairing ugly scars on earth's crust in the form of mined out voids and overburden dumps.
- In most cases backfilling generates the "non substitutable" land resource in two ways. First, the filled void and secondly, the saving in overburden disposal land.
- Reclamation engineers in advanced countries consider that it is not always a necessity that the pre-mining landuse needs to be restored. A better need based land use can be planned.
- Surface air and water contamination as a result of air borne and water borne particulate erosion from overburden materials stacked in dumps, are reduced considerably when the materials are buried by backfilling.
- Backfilling in most cases, partially or completely precludes the formation of overburden dumps. Thus safety problems due to slope failure of dumps etc, are avoided.
- Huge quantity of water accumulated in surface mine void acts as a potential threat to a nearby mine. This danger is avoided when the void is filled.
- Backfilling also caters to the social needs of ethnic people. Regeneration of forests offers them livelihood. Resettlement of the mining project affected people (PAP) also can be arranged in prepared site (backfilling) of a different nearby mine.

When the coal seam dips at an high angle (>30° with horizontal) backfilling is believed to be difficult or only partially possible (IBM, 1995) in the Indian Coal mining industry. Following reasons are cited.

- Overburden roll down and can jeopardize safety of man and machinery in work zone. In some cases a safe distance is maintained and also a barrier (boulder in mud) is erected but if dip is very high retention of overburden materials in position becomes difficult.
- In case of coal seams, when dip is high, less effective space is available for accommodating overburden. In case of high dip excavation, as the excavation advances, the ratio of vertical dimension to horizontal dimension increases; consequently effective space decreases as compared to a flat or near flat deposit excavation of similar quantity. As such, with high dip excavation, effective space for overburden accommodation is less.

Approaches for restoration of mined out area

Backfilling methodology depends mainly on deposit mineralisation, operational method, sequence of mining, available machinery, topography and also availability of overburden materials and soil. The planning engineer should also consider geologic, ground water and surface water conditions while developing the methodology. Backfilling methodology for each mine is unique and typical which makes any attempt to evolve a generalised methodology, if not futile, but definitely over averaged. In the following paragraphs conditional diversities for backfilling in coal sector have been discussed.

In general, where backfilling seems feasible the ideal approach is to first prepare the land profile sections at close intervals for the existing / proposed voids, internal and external overburden dumps, etc. These profiles should then be compared with the pre-mining profiles with a view to bring back the original contour (approximate original contour) of the land to assess the requirement of overburden and soil and to study the feasibility of restoring original contours. In the rest of this section, various approaches the reclamation engineer should follow to attain possible Approximate Original Contour (AOC) has been discussed (Almes, 1979). Besides geo-mining feasibility, economics is an important factor (Macpherson, 1987) which guides the decision of backfilling. An alternative to permanent external dumping may be rehandling of OB after mining ceases. But this is not followed anywhere in India because of very high unproductive cost involved.

In terrain with relatively flat slopes i.e. less than 15°, the requirement to achieve AOC should not have a major impact on cost or operational procedures, provided there is sufficient overburden material to fill the pit and cover the highwall. In steep slope terrain, particularly for slopes steeper than 24 to 27° this requirement can be very costly and sometimes impossible to implement. While IBM and other Government stipulations are not very specific about AOC the US regulation is specific about AOC, including eliminating highwalls and any piles or depressions which do not fit into final contour. However there is some flexibility if sufficient overburden material is not available. US regulation insists meeting three conditions (i) satisfying (AOC) (ii) covering the highwall and (iii) providing a stable slope. Meeting all the three conditions specially in steep slope mining, under Indian conditions, can be economically prohibitive.

5.4 In pit crushing in large open cast coal projects

Besides obviating economic disadvantage of conveying the waste OB, in-pit crushing is environmentally beneficial due to less truck transportation requirement and confining concentration of work area within pit geometry. The flow of material utilizing an in-pit movable crusher and conveyor system starts with the trucked material being dumped into the feeder pocket. The material is crushed and fed onto horizontal transfer belts in the pit or directly onto a major upslope belt taking the material out of the pit. There may be more than one of either belt type with transfers at each belt junction depending on the pit geometry and depth. Once the material exits the pit, it must be conveyed to the plant facilities or dumps. Conveyor and crusher installations should be designed in advance and planned for in the same manner as mine haul roads. As a general rule, it is wise to plan on establishing conveyor beltways and crusher installations as part of the normal course of mining instead of requiring custom excavation or placement of material to establish conveyor routes and crusher stations. This is dictated by simple economics that a specific earth moving construction project is a costly capital item and an additional expense outside of mining. A few points should be emphasized when setting out to evaluate in-pit crushing and conveying with movable or even stationary equipment:

- Understanding the working geometry of the equipment to be utilized or evaluated.
- Establishing the operating schedule and the surge capacity of the materials handling system.
- Incorporating the crush-convey equipment into the mine geometries with minimal custom earthwork.
- Using time sequenced mine plans in sufficient detail to quantify material movement and materials handling equipment moves.
- Proper interaction of all mining and materials handling equipment over the mine life.
- Additional stripping requirements to establish the system and consider all alternatives to maintain consistent material flow.

5.5 Improved coal transportation system

Within the mine lease, use of covered conveyor is the default practice these days. Use of Long Distance Belt Conveyor (LDBC) for transportation of coal to CHP and Washery has been chosen as a preferred option not only for economic gain but also to credit environmental advantages of obviating road runs. Use of pipe conveyors has not been tried in our coal industry as yet. The pipe conveyors offer a modern environmental friendly option to the bulk material transport problem. “Pipe conveyor” is used where spillage of materials, environmental issues and limitations in routing prevents the use of unconventional conveying systems. At the loading point, the pipe conveyor is open in a conventional trough form, after which it is formed into a pipe shape for the transport length. This completely encloses the material within the pipe. At the end of the transport run and just before the discharge pulley the belt again opens thus allowing materials to be discharged in a conventional manner.

Regarding coal evacuation rapid improvements are expected when dedicated Railway Freight Corridors becomes operational. The dedicated Railway Freight corridors under construction especially the one in eastern sector (Ludhiana to Dankuni) which passes through or near to the major coal bearing regions of the country will greatly improve coal transportation economics and also associated environmental gains. Economic gains would be possible due to increase in parcel sizes and speed of transportation and consequent reduction in transit losses. Only goods trains will ply on these corridors and because the block stations will be 50 km apart in contrast to approx. 5 km on existing lines, transportation will be faster. Wagons of higher capacity (125 t) shall be deployed in place of 55 t and 70 t wagons deployed now. Rake sizes will be enhanced to 100 instead of 58 wagons deployed now. Train speeds will also be increased.

Prior to envisaging the Dedicated Freight Corridors, slurry transportation of coal to transport coal from the eastern region Coalfields to the Western region Power plants were thought of. The project, however, did not materialize.

5.6 Use of geo-textiles in coal projects for environmental protection

Use of geo-textiles and hydro-seeding for greening large rocky dump slopes are common in coal industry today. Geo-textiles made of jute and coir are used for anchoring and support of the plantation base.

Geo-textiles serve multiple functions. The function is to arrest downward and outward movement of soil owing to lateral support and anchorage. Geo-textiles are various combinations of geocomposites, geogrids, geonets, geomembrane and/or other materials. The geocomposites or jute/ coir mats are able to provide higher performance that can often be obtained by combining the attributes of two or more materials. The basic functions that are performed by such combinations are separation, reinforcement, filtration and drainage. In case of erosion resistance the geocomposites or jute/ coir mats are used for separating the ground surface from the prevailing atmospheric conditions i.e rainfall of high intensity in this case. The general goal of such system is to protect the accumulated soil from gully or sheet erosion either indefinitely or until vegetation can establish itself.

The geomatting is a flexible, three dimensional matting produced from nylon filaments welded together where they cross to form open structure matting, having 95% free space. The polymer type is polymide 6 having density of 1140 kg/m^3 and mat density 25 kg/cm. The longitudinal tensile strength of such material should not be less than 1.5 kN/m. It should be resistant to all chemicals in those concentrations, which are normally contained in the earth and surface water. It should be light and easily installable and should have low inflammability and low smoked formation. It should not have toxicity and should not have any nutritive value and should be unpleasant for burrowing animals and rodents.

The slope surface is first prepared which is provided with minimum 75 mm grass seed bed using agricultural soil, manure, mulched in coir/hay/straw, etc. on 3 dimensional geosynthetic erosion control mat or followed by jute geotextile net. The matting holds the mulch or sod in place reducing the incidence of erosion. The tensile strength of the netting act like horizontal reinforcement and multiples the roof litters zone strength of the grass system by a considerable magnitude. The matting structure reinforces grass stems, litters zone and soil throughout maturity of the turf i.e. through pre-emergence, establishment and maturity. Whereas the upper grass zone reduces the velocity at the soil surface by interfering with flow, the soil protection, particularly when the sward is laid down by the drag force of high velocity flows provides green cover. The middle zone (litter layer) provides soil protection. The lower zone (roof structure) provide reinforcement and mechanical stabilisation of soil particles close to soil surface by anchorage of soil / root composite into underlying sub soil. The matting is held in position providing wooden pegs and security pin as prescribed by manufacturers.

The slope length shall have drainage cum anchor ditches in which the protective matting is properly secured by filling stone and sand well compacted. Free end of the slope is followed by two layers of gabions of geogrid nets. The soil at the back of the gabions are properly compacted.

For spreading seeds on the prepared coir bedded slopes, hydroseeding technique is generally followed. Hydroseeding is application of seed, fertilizer and / or lime, fiber mulch and water mixture to soil by means of a hydraulic applicator.

Regarding use of polymer based geosynthetics, critics say that considerable amount of non biodegradable materials (polymers) are introduced into environment through this technique. However, researches are being carried out to reduce the extent of polymers and at the same time maintaining the strength properties of the material.

5.7 Utilization of Coal mine discharge water

With increased rate of extraction at deeper level large quantities of water accumulates in mine sump which is pumped out from the quarry. Extraction of aquifer is of course marked as environmentally disadvantageous but systematic use of the water for other uses are believed to be compensating the ill effects to some extent. The possible meaningful uses of the waste water obviate drawing water from nearby river or other surface or ground water sources. Some of the uses are listed below. The mine discharged water can be used (i) in Coal handling Plant and Coal Washing plant, (ii) for dust suppression on haul roads (ii) plantation areas

5.8 Reforestation of mine areas: improved techniques

Two emerging points have been discussed here: (i) the use of Joint Forest Management (JFM) while carrying out afforestation in coal mine areas and (ii) planning biodiversity in a dedicated nursery in a cluster of OCPs. While the later concept is being practiced partly in some projects the JFM idea is new to coal industry.

The Forest Department is implementing major afforestation schemes in various states through the Joint Forest Management (JFM) programmes. The concept of JFM was evolved to put an end to the constant conflict between villagers and forest department officials. Under this concept, plantations are created and maintained by the Forest Department with active participation of local villagers’ co-operatives [called Forest Protection Committees (FPC) or Van Suraksha Samities (VSS) or Village Forest Committees (VFC)]. Although schemes vary from state to state and are known by different names in different Indian languages, usually the FPC /VFC and the forest department enter into a JFM agreement. Villagers agree to assist in safeguarding forest (natural or created) resources through protection from fire, grazing, and illegal harvesting in exchange for which they receive Non Timber Forest Produce (NTFP) and a share of the revenue from the sale of timber products. Labourers required for various plantation works are drawn from amongst the co-operative members (approximately 70 man-days are required for preparatory work, creation and maintenance of each ha of plantation). The JFM schemes have been very successful in many areas in the country and now the concept is being used in other countries also.

JFM when applied in coalfields will render a rapid forest growth as well as develop a social relationship with the tribal neighbours. The scheme offers the following advantages:

- Appropriate choice of species in consultation with local villagers.
- Provide an alternate source of income by generating employment and other resources to villagers displaced by the project.
- Avoiding conflict with local villagers to ensure success of the plantations.
- Usually coal mines occur in clusters and land degradation in these areas is extensive. Consequently the requirement for ecological restoration is huge. Because of the large areas involved, the schemes are likely to be economically viable.

The following points are important for an improved plantation planning with JFM that cares of biodiversity also.

- The plant species present in the area and their proportion before mining commenced should be listed from past records available with the Forest Department.
- Villagers' co-operatives should be formed to undertake ecological restoration works. The mine operators and the co-operatives should enter into an agreement in line with JFM agreements between FPCs and Forest Departments. All plantation and associated works should be carried out through these co-operatives.
- First a large central nursery should be set up to provide plants for biological reclamation / ecological restoration of degraded lands. Initially pioneering species of grasses and herbs will be cultivated in these nurseries for providing seeds for initial reclamation / stabilization of the degraded lands. The seeds collected from these plants should be planted in the field by hydro-seeding.
- Meanwhile saplings of locally growing tree species should be developed in the nurseries from seeds collected from mother trees or purchased from the Forest Department or by nurturing seedlings collected from the field (especially for species such as Banyan, Peepal and Figs etc.). The mix of saplings species should be based on species composition of the original vegetation and the relative survival rates of individual species' saplings.
- Once the saplings are transferred to the field, their protection should be made the responsibility of the local villagers' co-operatives.
- It has been observed that the JFM schemes' success have been ensured by providing funds to local villagers on a pro-rata basis for implementing village development works of their own choice. Similarly the mine operator should implement development works of the villagers' choice in the respective villages. A scheme of rewards based on survival rates should also be put in place to offer incentives to the village co-operatives managing the plantations. These measures will raise the survival rate of saplings by inviting better protection and management.

5.9 High efficiency dust suppression system

The addition of wetting agents and polymer binders to the water used for haul road dust suppression can decrease both the application frequency and the amount of water required. The wetting agents improve the performance of the water in wetting the surface material thoroughly. The polymer binders cause the surface particles to hold together reducing their likelihood of becoming airborne (dust). It also makes the haul roads more compacted with less loose surface material. Dust suppression chemicals can be used with both water carts and sprinkler based solutions. Liquid Polymer Surfactants offers the benefits like : (i) reduces water usage by over 50% (ii) dramatically reduces dust levels (iii) reduces grading frequencies by a minimum of 50% (iv) increases road compaction by over 50% (v) improves site safety (vi) very cost effective due to reduced tanker trip & grader requirements. Extensive researchers have been carried out in Central Institute of Mining and Fuel Research, Dhanbad, regarding usability of haul road wetting agents. Sporadic trials have also been made but this improved technique has not been practiced successfully by Indian Coal Industry as yet.

Other improved dust suppression arrangements like, atomised spraying in trunk haul road, use of dry fog system at material transfer points in CHP etc. are common in large coal projects.

5.10 Environmental friendly underground support system

Studies carried out under S & T programme have resulted in saving scarce timber by the introduction steel supports which have longer life than timber and amenable for repeated use. Support types are : screw pipes, triangular chocks, tubular and rectangular chocks and pit props. The supports developed under various projects were subjected large scale testing both in laboratory and under different mining conditions. To overcome shortcomings of steel props another S & T project was carried out at RDCIS (SAIL) Ranchi in collaboration with CMPDIL. Under the project light weight rigid steel props of round and octagonal tubular cross sections of 2.8 m length with load bearing capacity of 3 t have been developed with reduction of weight of upto 20% when compared with conventional steel props. High strength (minimum specified yield strength: 350 MPa) weather resistant steel has been used for fabrication of these props.

In India, more than 100 million t of fly ash is produced annually whose disposal poses serious threat to the environment. Hardly 15% of this finds some use. For gainful utilization of this waste material, a research project was undertaken by CIMFR to develop fly ash based supports suitable for underground coal mines. Fly ash, polymers and fibres were used for manufacturing the product. Load bearing capacity of fly ash props with 60% fly ash, 35% resin and 5 % fibre of 3m length and 100mm dia. Was found to be around 10 t which compares well with timber props. Costs of fly ash made props are slightly higher than timber props but in the long run the former proves to be economical because of longer life.

In our coal industry use of the improved variety of steel props have minimised use of timber. Fly ash made props, however, is yet to find recognition.

Another improvement point is silviculture of Australian acacia (*Acacia auriculiformis)* on derelict mined land, not only for biological reclamation of the land but also for providing as support timber. Australian acacia is suitable for the purpose because (i) the species is fast growing (the trees can be harvested after 7 years), (ii) the species is hardy and can be grown easily on derelict mined land and, (ii) gives better log material because of no branching. Environmental advantages are (i) preservation of native species (ii) gainful economic use of derelict mined land (iii) financial and social benefits for local villagers who are engaged for plantations.

5.11 Underground Mine subsidence modeling

Underground mine fire in coal blocks in BCCL compounded by land subsidence is at present the largest environmental threat faced by Coal India Ltd. Thousands of people are suffering due to loss of fertility of land, land degradation and air pollution. Managing the problem were so difficult because the old underground mines were in fact, interconnected due to (i) subsidence induced cracks, and (ii) illegally advanced work zone which are not shown in survey maps. Due to this interconnection oxygen flow from surface and working underground mine continued in abandoned mines maintaining the fire.

Advanced coal mine planning taking the land subsidence points into consideration will prevent repetition of the already done mistakes. Indigenously developed Subsidence prediction tools are available in MECON Ltd. and Central Mining and Fuel Research Institute (CMFRI).

5.12 GIS based human tracking system for underground Mining

Tracking of workmen, machines and others in underground is one of the issues which needs attention with regard to safety in an underground coal mines. With the advances in communication and computers it is possible today to keep a track on the location of workmen and machines. For this reason an efficient, simple, cheap and feasible system is required so that it could be accepted in all mines. One of the solutions to this is using Radio Frequency Identification and Detection (RFID) technology, which is very cheap and efficient, integrated with and Geographical Information System (GIS) and visual basic.

This technology enables tracking of people and objects, supporting the conception of pervasive networks if identities are linked in real-time to their locations. This is a type of automatic identification systems that use radio waves to transmit and uniquely identify objects (Finkenzeller, 2002; Heijden, 2006). The purpose of an RFID system is to enable data to be transmitted by a portable device, called a tag, which is read by a RFID reader and processed according to the needs of a particular application. An RFID reader is a device that can read data from and write data to compatible RFID tags. Communication between tag and reader enables the location information of an item to be recorded and transferred to a server through a computer network, thus allowing the movement of the item to be tracked and traced (Javier and García, 2007). An RFID tag consists of an integrated circuit with memory, which is essentially a microprocessor chip. The tag has an unique identity (ID) that can be broadcasted to a reader that is operating on the same frequency and under the same tag protocol. (Javier and García, 2007). The ID of the object is a serial number that is transmitted wirelessly to a reader. Three types of tags are possible namely Active tags, Passive tags and Semi Active tags depending upon the power source used by the tags. The communication infrastructure is a collection of wired and wireless network communications that carries out a series of information transfer and deliver the data that are stored in a tag to the reader (Javier and García, 2007).

5.13 Methane removal from underground mine and utilization

Use of certain types of bacteria collectively known as Methanotrophs are capable of utilizing methane as their sole source of cellular carbon and energy (Whittenbury, 1970). Methanotrophs were tried in Indian coal mines for possible reduction of methane composition in air to reduce risk of methane explosion. Since the share of underground mining is dwindling day by day (only about 17% at present) so is the extent of researches for underground work zone. However, for safe and environmental friendly working in gassy mines use of Methanotrophs are a viable option.

The methanotrophs are nonpathogenic and taxonomically are assigned to several different genera. These bacteria are designated as type I or type II depending on the intracytoplasmic membrane arrangement displayed when grown on methane (Davies, 1970). Methanotrophic bacteria aerobically oxidize methane via a sequential pathway with biomass, carbon dioxide and water being the primary end products of the process (Haber, 1983). Some isolates under certain conditions also have the capability to grow on alternate carbon and energy sources such as alcohols, propane, short chained organic acids, hexadecane, etc. (Reed, 1978).

Attempts for Extraction of Coal Bed Methane (CBM) from virgin coal blocks are going on in full swing in the country. However, attempts for extraction of CBM from gassy coal mines have not been tried seriously in our country. In 1980s the pilot project in

Ramjibanpur colliery did not yield encouraging results. Concerted effort with the latest technology available today can prove successful use of methane from gassy coal mine.

5.14 Improved Mine designing system

With development of computation and software industry mine designing has improved appreciably. Developing alternative scenarios or simulating a hypothetical condition was not thought of earlier. With improved computation it has become possible to integrate the environmental stand points into mine planning; numerical modeling of underground stress scenario, prediction of land subsidence and resulting slope and strain, environmentally compatible land use zoning etc are a few examples.

A few examples of blending environmental standpoints into mine planning (with or without computer aided) are given below:

- Proper sequencing of the coal blocks such that it not only helps is achieving the consistent desired quality but also requires less inter block transportation thereby reducing fuel and pollution
- Selection drills keeping in mind that it should have an in-built water injection system/ dust extraction system. A small quantity of detergent if added with water reduces the water consumption by reducing the surface tension of water.
- Permanent ramps to be made much within the minimum statutory requirements so as to facilitate the one – way traffic. Arrangements of atomised spraying installed at road dividers. Road gradient has a bearing with fuel consumption of transport vehicles
- The box cut to be laid along the boundary of the non-mineralized and mineralized area so that concurrent reclamation of the slopes and the berms can be carried out
- The lower benches of the mine can be water logged and it could be split into two parts one for recharging the ground water table while the other for pisciculture.
- Practising concurrent backfilling to the maximum extent possible. One of the authors has developed a mathematical model (and a software) along with ISM Dhanbad, which facilities designing maximum backfill in coal mine. External dumping to be done in lifts with overall slope angle not exceeding 28 deg. Factor of safety for dumps should not be less than 1.3.
- The sump capacity in the working pit should be adequate enough to keep the bench floor dry but at the same time dewatering should not be done to an extent that the draw down curve of the aquifers moves deeper further.
- Deep hole drilling and blasting should be invariably done with the use of in-hole and surface delay by means of NONEL system. This not only helps in controlling the noise & blast induced ground vibration but at the same time helps in maintaining a uniform floor condition & of course good fragmentation
- The fragmentation of blasts plays another important load in controlling the dust while loading. Optimizing the blast design parameters viz. burden, spacing & hole diameter can do this.

6.0 Gradually improving social acceptability of coal mining

Coal Mining industry has played a key role in development of remote regions of the country. With population growth, decrease in per capita land availability and many restrictions on land use, the industry is facing increasing land acquisition problems. Coal industry has suffered in the past from the bad reputation that it lacks concern for the socially disadvantaged people who are displaced or live in the nearby villages. The commendable community development work being done by coal companies, the progressive R&R policy adopted by Coal India Ltd and the transfer of lessons learnt from the World Bank's Coal Sector Environmental and Social Mitigation Project would hopefully bring in a major change to the social dimensions of the coal mining sector in the country.

Coal India Ltd hardly faced any problem in acquiring land in the 1970s and early 1980s as it followed the practice of offering jobs to at least one member of each displaced family from whom land of a minimum size [generally taken as two acres (or 0.8 ha) of irrigated land and three acres (or 1.2 ha) of unirrigated land] was acquired. A total of 33,470 land losers were employed by the subsidiaries of CIL during the period 1973 - 1993. There were no corporate guidelines from CIL in those days on the subject detailing the rehabilitation package to be offered to the land oustees. Meanwhile, the wages in the coal sector grew rapidly with the implementation of the periodical National Coal Wage Agreements, the number of land oustees increased dramatically with growth of population and fragmentation of the land holdings. Coal Indi Ltd, already suffering from a load of surplus labour, could not offer so many jobs to the land oustees as demanded, a large number of dissatisfied land oustees were formed and many CIL projects started facing land acquisition problems. In many mines the problem arose due to the CIL practice of legally acquiring all the land required for the whole life of a new mine before start of the mining operations after paying the legal compensation but not evicting the people until such time as the mine has advanced to the location and the land is physically needed. It was also realized by CIL in this period that not all people who live in communities occupying or using land required by the mine are land owners and they may include tenant farmers, squatters, unemployed youth, small traders and agricultural labourers. The LA Act or the CBA Act does not provide any assistance for them and they often provided the leadership to those opposed to the land acquisition programme

CIL Board adopted an R&R Policy in 1994 to overcome the emerging problem of land acquisition and to provide a uniform guideline to its subsidiaries. In tune with the international thinking of the time on the subject of involuntary displacement (World Bank OD 4.30 of 1990 on involuntary resettlement), the Policy stated one of its objectives as to ensure that the Project Affected Persons improve or at least regain their former standard of living or earning capacity after a reasonable period of transition. The Policy clearly stated that employment can be given only if feasible and following the policy of each subsidiary company regarding the minimum size of land acquired. This Policy had two important departures from the previous practice in the field of R&R in the mining industry. It recognized every adult member of the land owners family as the unit of entitlement (earlier it was families) and also recognized that landless people, squatters and tribals residing in the village being acquired are also eligible for R&R assistance. The Policy requires the coal subsidiaries to provide community facilities of school, road with street light, public drain, pond, dug well and/or tube well for drinking water supply, community centre place of worship, dispensary, grazing land for cattle and playground at the resettlement site.

The Policy was revised in 2000. The offer of employment against land has been made more difficult in the revised Policy by making it subject to approval by the Board of Directors of the concerned subsidiary company. The Policy now includes an alternative provision for payment of one time cash grant (Rs one lakh for the first acre and Rs 75,000 each for subsequent acre of land) in lieu of employment. It recommends the issue of photo identity cards to each entitled project affected person eligible for economic rehabilitation benefits, based on a socio-economic survey of the affected area The main thrust of income restoration for PAPs in this policy continues to be jobs with contractors and assistance regarding non-land-based self employment.

In 1996, CIL went for a large-scale financial support from the World Bank called Coal Sector Rehabilitation Project for 25 of its opencast mines. The World Bank funded a separate Coal Sector Environmental and Social Mitigation Project (1996 - 2002) to mitigate the environmental and social impacts deriving from the investment component of the CSRP. According to CGM (World Bank Division) of CIL, 10 of these 25 mines had land acquisition components involving resettlement of 2129 families within the ESMP period (originally estimated as 2656 families) and all these families have been resettled. A novel feature of the ESMP was the utilization of NGOs by CIL for carrying out base line studies and as facilitator in the planning and implementation of the Resettlement Action Plans. Experience shows that of all these tasks included in the ESMP, income restoration of the PAPs was the most difficult. However, the experience of implementing the ESMP tasks through democratic participation of the stakeholders has been valuable.

7.0 Conclusions

Power grade Coalfields in India are subjected to environmental pressure due to rapid growth of power grade coal demand. Under business-as-usual scenario environmental sustainability of the coal bearing regions, which are already in a degraded state, are anticipated to be further degraded. The situation is further aggravated due to recent “no-go” area demarcation by Ministry of Environment and Forests, Govt. of India. Adoption of advanced techniques for environmental management is the only solution to this problem. Most of the improvement points require a holistic approach to cover the regional extent - measures like environmentally compatible land use zoning is most important among them. System approaches like application of JFM for afforestation in mine areas, revised R & R policy etc shall bring quantum improvement. Technology development for environmental sustainability comes from advanced measures like utilisation of mine waste water, use of high efficiency dust suppression system, eco-friendly support system, use of geotextiles for greening rocky dumps etc. which have already yielded significant results. Integrating environmental standpoints into mine planning like maximising backfilling, lesser extent of road transport length etc are important.

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