ENVIRONMENTAL MANAGEMENT PLAN FOR THE JHARIA COALFIELD - INDIA[1]

by

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Abstract. An Environmental Management Plan (EMP) for the Jharia Coalfield (JCF) was recently completed as part of a World Bank funded project. The JCF, 260 km west of Calcutta, comprises 450 km^2. Bharat Coking Coal Limited (BCCL) operates an area of 258 km^2. Coal mining has been conducted for more than 100 years. There are severe constraints to mining due to geology, coal fires and the large population. BCCL counterpart staff participated actively in all aspects of the work. Air and water are heavily polluted, however, mining operations contribute only to a limited extent to the total pollution. Water contamination is generally due to inadequate sewage treatment and discharge from non-mine facilities such as power plants. The large area disturbed by mining to date will increase, as open pit mining operations are expected to expand significantly. Reclamation to date is generally confined to planting of trees. Areas where cost effective reclamation can be done were identified. Key recommendations include: integrate reclamation activities and mine operations for all future mining; conduct minimal, cost effective, reclamation of areas disturbed to date; continue monitoring programs; investigate feasibility of small reservoirs for water management.

Additional Key Words: reclamation, mining, environment, water quality, coal, India

Introduction

In accordance with the Jharia Mine Fire Control Technical Assistance Project (IDA CREDIT 2450 IN), NorWest Mine Services Ltd. (NorWest) signed a contract In June 1994 with Bharat Coking Coal Limited (BCCL) to prepare an Environmental Management Plan (EMP) for the Jharia Coalfield (NorWest 1997a). The EMP includes major Socio-Economic (i.e. relocation of people) (NorWest 1997b) and Air Quality (NorWest 1997c) components, but these are not discussed as part of this paper.

Background

The Jharia Coalfield (JCF) is located in the south east part of the State of Bihar, approximately 260 km west of Calcutta. The coalfield contains proven coal reserves of approximately one billion tonnes in a crescent-shaped basin of approximately 450 km^2. BCCL operates within an area of approximately 258 km^2. The EMP project area (i.e. the core area, or coalfield, and a 15 km buffer) is between 23° 30' to 24° 00' north latitude and 86° 00' to 86° 45" longitude.

Coal is a primary source of energy in India, providing 60% of the commercial energy. BCCL's current production is approximately 28 million tonnes per year (Coal India Ltd. 1993).

Mining has been conducted in the JCF for more than 100 years (BCCL 1996). Mechanized Open Cast Mining began in 1975. Approximately 60% of BCCL's production is from open cast pits and 40% is from underground mining. The contribution from Open Cast Projects (OCPs) is expected to increase in future years, with a corresponding increase in the disturbed surface area.

The JCF is India's only source of Coking

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Coal, which is a vital component to the steel industry. BCCL currently supplies approximately 40% of the nation's coking coal (NorWest 1997a).

Coal mining is the largest single industry in the immediate area. BCCL employed approximately 144,000 people in 1995-1996. The JCF is a densely populated area with a population of approximately 1.1 million people (Das 1991).

The large population, combined with many mines, pits, quarries, overburden dumps, railways, roads and industrial facilities make the area very congested. The primary environmental impacts include land disturbance, air pollution and water pollution. The contribution to the environmental effects by mining activities requires that corrective action be taken.

Mine Fires

There are approximately 65 (BCCL) coal mine fires in the Jharia Coalfield. The numerous coal seam fires and overburden fires were investigated in an exhaustive study by the fire consultant, GAI/Met-Chem Joint Venture, Pittsburgh/Montreal. The fire consultant determined the extent of the fires and identified and described measures to control or extinguish the fires. The environmental effects of the fires include ground subsidence, loss of productive land and production of gases. The topic of these mine fires is addressed in another paper presented by Michalski (1997) at the 1997 ASSMR Meetings.

Objectives

The key objectives of the Environmental Assessment, Reclamation and Water Management components (NorWest 1997a) of the EMP project are summarized as follows:

- Prepare an EMP for the JCF. This EMP will include reclamation and water management plans;
- Carry out a baseline survey covering the JCF and the area extending 15 km from the boundaries;
- Prepare an environmental assessment of mining activities and the predicted impacts of the proposed fire control technologies;
- Evaluate alternative options for mitigating these impacts;
- Prepare a least cost environmental plan; and
- Train client personnel in the analysis of environmental cells and social issues related to coal mining and the choice of mitigating measures.

Methods

The work, except for some tasks which were contracted to local Indian consultants, was conducted by the Project Team comprised of NorWest personal and BCCL counterparts.

Map Preparation

BCCL acquired a Geographic Information System (GIS) (INTERGRAPH and a dedicated work station, TD3-100-G91 TC) and numerous software modules for information analysis and to prepare the various maps required for the EMP. The base maps, at 1:25,000 scale with 5m contour intervals, were prepared by the National Remote Sensing Agency (NRSA) at Hyderabad.

Soil Inventory

A Soil Survey report was prepared at a scale of 1:50,000 for the project area by the Natural Resources Information Management Services (NRIMS) (NRSA 1995a). Soils were classified according to the United Stated Department of Agriculture (SCS-USDA 1975) Soil Taxonomy System. Approximately 86 pit profiles and 590 shallow pits were dug and described. Soil samples were collected and analyzed for pH, electrical conductivity (EC), organic carbon (OC), percent calcium carbonate ($CaCO_3$), exchangeable bases (calcium, magnesium, sodium and potassium), cation exchange capacity (CEC) and percent sand, silt and clay (McKeague 1978).

NorWest and BCCL personnel inspected soil materials at several of the BCCL plantations and also at selected spoil piles. Soil samples were collected and analyzed for pH, electrical conductivity, phosphorus, potassium and particle size.

Vegetation Inventory

A Vegetation Survey of the project area was conducted by Professor Sri P.K. Mishra (1996) of R.S. More College, Govindpur, Bihar.

NorWest and BCCL personnel investigated the revegetation success of various representative plantation and other reclaimed areas (spoil piles, fire areas) to determine the most appropriate species in terms of growth rates and survival rates. Manuals were prepared for (a) species suitable for reclamation and commercial use, and (b) outlining procedures to establish seedlings in the green house.

Land Use Inventory

A land use study of the project area at a scale of 1:50,000 was prepared by NRIMS (NRSA 1995b). Data bases used for the analysis included the IRS-LISS II data (satellite) and Survey of India topographical maps.

Water Management

NorWest and BCCL personnel conducted field investigations of: each of the jores, and rivers in the coalfield; special problem areas such as the breach area at Gaslitand and fire areas near Katri Nadi and Ekra Jore: several potential locations for future reservoirs; the existing reservoir on Jamuniya River; the area north of the coalfield, noting land use, water wells and drainage patterns; selected coal washeries; and surface and underground mines.

Water Quality

The major emphasis was on the evaluation of the quality of current potable water supplies. Spatial and temporal changes in water quality were examined. Four samplings of all locations were conducted: May and June 1995, September and October 1995, November and December 1995 and February to May 1996. This corresponded to Summer, Monsoon, Winter and Spring seasons.

Sampling. Sampling was conducted at 150 sampling stations consisting of: 5 Coke Plant and Coal Washery effluent ponds; mine dewatering discharges; 5 Filter plants; 17 Ponds; 65 Wells; and 32 River locations.

Analytical Methods. Samples were analyzed for: pH, Specific Conductance, Chlorides, Nitrates, Calcium, Magnesium, Sodium and Potassium.

The capability of the BCCL environmental laboratory was significantly enhanced during the project . Additional equipment was acquired and/or commissioned. The atomic absorption spectrophotometer was commissioned and new equipment installed, such as the reverse osmosis unit (to provide high quality distilled water) and a generator to provide and auxiliary power supply. Most of the samples were analyzed at the BCCL laboratory. Analyses for a few water quality parameters were contracted to the Central Fuel Research Institute (CFRI) at Jamadoba.

Reclamation

The methodology for the reclamation component of the EMP included assessment of reclamation conducted to date and considered future reclamation.

Reclamation to Date. Discussions were held with BCCL headquarters and field officers and staff with current or previous responsibility for reclamation activities. Field investigations were conducted to determine past and current reclamation practices. These included observations and assessment of all significant plantations established by BCCL and, old and recent typical spoil piles, to determine the physical characteristics of these spoil piles and to assess the success of revegetation, be it natural or conducted by BCCL.

Future Reclamation. Recommendations for future reclamation activities are based on: observation of operating open cast mines to determine current materials handling practices; assessment of the types of areas to be reclaimed, including spoils piles, open cast pits, subsided areas, fire affected areas and otherwise disturbed areas; review of existing EMPs for various projects in the Jharia Coalfield; and preparation of economic analysis for various possible reclamation and revegetation alternatives.

Description of Current Conditions

The entire JCF has been disturbed by human activity for a long period, perhaps hundreds of years. The core area has been severely disturbed during the past 100 years or so by underground and surface coal mining and, more recently, by other industrial activity, such as coking plants and refractory plants.

Population Density

The 1991 population of the JCF (i.e. core area) is estimated at 1.1 million. The JCF comprises 450 km^2, therefore, the population density is approximately 2,400 persons per km^2 (NorWest 1997b). To provide a perspective, this contrasts with the 1991 population density of 497 per km^2 for the State of Bihar and 274 per km^2 for India.

Land Use

The north and east part of the Jharia coalfield have been severely disturbed by coal mining. Most of the core and buffer areas have been cleared of forest and the dominant land use is rainfed (dryland) agriculture. Present agricultural practices are not intensive, as paddy agriculture is only found on only 11% of the surveyed area and is restricted to local depressions (NRSA 1996b).

Land Tenure

BCCL has a mix of land, including: land purchased directly from willing private land owners; land acquired under the Bihar State Land Acquisition Act; land from the former mine-owners, vested with BCCL following nationalization; and land leased from the State or Central Government.

The present land tenure situation is a serious disincentive to conduct reclamation because BCCL may not resell the land without the expressed permission of the Central Government. BCCL may reclaim and sell the crops produced (e.g., trees); however, if land cannot be sold, physical land improvements made by BCCL through reclamation do not benefit BCCL.

Soils

The dominant Soil Orders in the core and buffer areas are Alfisols (56%) and Inceptisols (28%). Entisols, Ultisols and Oxisols ocurr to a minor extent (NRSA 1995a). Topsoil (A horizon) ranged between 8 to 23 cm in thickness and generaly has suitable characteristics to warrant separate soil salvage All these soils have suitable topsoil and subsoil for reclamation. Many of the soils have a relatively high percentage of clay (25 to 35%) and are suitable as a mutti cover (soil cover) as a fire control measure. Soil salinity is not a concern in naturally occurring soils.

Approximately 47% of the core and buffer area is designated as "good cultivable land" and approximately 36% of the area is "moderately good" cultivable land (NRSA 1995a). Soils throughout the entire area suffer from accelerated rates of soil erosion due to severe overgrazing.

Vegetation

Vegetation throughout the area has been severely disturbed and the area is overgrazed. Five major vegetation types, or more correctly, land types were identified: forest land, cultivated land, shrub land, barren land and reclaimed land (Mishra 1996).

Forest Land. Significant human encroachment has occurred in areas classified as forest land reserve (i.e. forest, protected forest, and open forest). Illegal cutting of trees and cultivation are common occurrences in the forested land. To some extent, original forest cover has been replaced by the BCCL reforestation program.

Cultivated Land. There is not much variation in seasonal or year round agricultural production. Rice is the only major crop. Oil seeds, maize and vegetables are also cultivated, but to a significantly lesser extent.

Shrub Land. Vegetation consists of a cover of shrubs and herbs with very few or no trees. The area is generally very overgrazed.

Barren Land. A large portion of the core and buffer zone (approximately 25%) was classified as barren land. This land is generally economically unproductive and is considered "degraded land". The area is very overgrazed.

Fauna

Because the vegetation of the JCF is very severely disturbed , the is no wildlife habitat of any significance. Fox, jackal, rodents and snakes are present (BCCL 1988), and there are significant numbers of domesticated animals in the JCF and buffer area. These include buffalo, cattle, sheep, goats, swine and dogs, Although these animals are domesticated, they are not fenced and often have unrestricted access to grazing and settled areas. This results in widespread, serious overgrazing. There is significant bird life in the core area, and particularly the buffer area.

Surface Water

The JCF is drained by a small number of seasonal and intermittent streams (called jores and nallas) which flow essentially from north to south and discharge into the Damodar River. In the north part of the JCF, which has been disturbed by open cast pits, overburden piles and subsidence, significant parts of these disturbed areas do not drain to the Damodar, but water collects in the depressions. Many small ponds (called tanks) have been constructed in lower areas to trap water in the dry season. These can contain a significant amount of water and are vital to the people during the dry season.

Ground Water

Ground water in the JCF has been disturbed by mining for decades. There are numerous reports of wells and pumps "drying up" or being dry for longer periods of time. Lithological and geophysical logs of exploratory boreholes indicate that ground water in the JCF occurs in a multi-aquifer system. However, the yield of even these aquifers is poor in the areas adjoining active mines, where they have been extensively affected by dewatering of mining operations. However, "water logged" abandoned mines and pits are, in general, potential sources of ground water.

Previous studies (BCCL 1988) indicate that during the period January to March (i.e. the dry season) the water table was generally at about 30m below ground level. In some parts of the study area, ground water was at more shallow depths, ranging from approximately 1m to 15m below ground level.

Infrastructure and Industrial Facilities

Several major railways pass through or very near the JCF. The most important is the Grand Chord Railway between Calcutta and Delhi. This section of double track, located immediately north of the coalfield, carries large numbers of passengers and great volumes of goods.

The most important road is the Grand Trunk Highway, just north of the coalfield, connecting Calcutta and Delhi. There are numerous secondary and tertiary roads throughout the JCF. Most or all of these roads are in a poor state of repair and are generally not maintained.

There are 10 electrical power generating plants near the JCF. The major electrical transmission lines located within the JCF feed power to customers located both within and beyond the JCF. There are 13 operating coal washeries in the JCF and immediately adjacent areas.

There are four by-product Coke Plants (these produce by-products in addition to the coke) operated by BCCL. There are a total of 51 operating Hard Coke Plants units which produce only coke and no commercial by-products.

Within the core and buffer area, there are also miscellaneous industrial facilities including: flour mills, chemical plants, rolling mills, cement plants, rubber processing plants, refractory plants, foundries & engineering and stone crushers (NorWest 1997a).

Mine Operations

BCCL produces high-value coking and non-coking coal from the multiple seams of the Jharia Coalfield. A total of 18 (major) seams are present; the seam dips range from approximately 10° to 65°. The uppermost seam (#18) has been mined out but the remaining seams are currently being mined. The Jharia Coalfield has very difficult mining conditions due to fires, geology (hardness of rock, dip, faulting) and the high population density. BCCL produces coal by both underground and surface operations; the latter generally being referred to as Open Cast Projects (OCP). Each mode of operations uses a variety of methods (NorWest 1997a).

BCCL currently produces at a rate of approximately 28 million tonnes per year (TPY). BCCL's overall yearly production is scheduled to increase by approximately 35% during the period 1996 to 2006.

Mine Planning

BCCL's long-term mine planning (greater than three years) is conducted by the Central Mine Planning and Design Institute Limited (CMPDIL). (e.g. CMPDIL 1989).The planning documents are issued in the form of Project Reports. Environmental aspects are taken into account in the Project Reports. BCCL generally performs all of its short-term (or operational) mine planning.

Underground Mining

Underground production comes from approximately 75 mines ranging in output from less than 50,000 TPY to more than 800,000 TPY. The contribution of underground mining to the total coal production has been gradually declining in recent years as open cast projects (OCPs) have increased output. This change is due to the higher output per manshift from OCPs and it is BCCL's preference to further increase OCP output.

BCCL uses the Bord and Pillar, and Longwall mining methods. To support the overlying strata from subsidence as a result of the Bord and

Pillar mining method, sand stowing is often used. With the longwall method, the coal extraction rate is much greater than for the Bord and Pillar method, and generally approaches an overall figure of 90%. Surface subsidence generally occurs, but it is of consistent depth and evenly spread over a wide area. As a result, it is not as destructive as the irregular subsidence associated with Bord and Pillar mining.

BCCL's total pumping requirements from its underground mines range between 150 to 190 billion litters (40 to 50 billion gallons) per year. This is equivalent to 410 to 520 million liters (110 to 135 million gallons) per day. The pumped water is generally used beneficially for a variety of purposes, including BCCL washeries and supply to adjacent villages (NorWest 1997a).

Surface Mining

Early OCPs, referred to as quarries, were excavated along the coal outcrop areas by manual methods, in the early part of this century. The present physical appearance of these quarries is generally characterized by gradual slopes, substantial regrowth of the vegetation (where permitted by the local people) and the absence of big rocks on the surface which characterize BCCL's more recent mechanized OCPs.

BCCL's current OCP production is from approximately 40 operations with production rates ranging from as low as 20,000 TPY to as high as 1.2 million TPY. Due to the higher productivity of OCPs in comparison to underground mines, in recent years BCCL has made a substantial investment in large OCPs. Nevertheless, the production from OCPs is not expected to dramatically increase beyond the current share estimated to be 60% of the total. In fact, this share may be difficult to maintain due to the necessary land acquisition and resettlement. Norwest conservatively estimates that BCCL requires from 90 ha to 95 ha per year to sustain the OCPs alone. Land for residential (and resettlement) areas, underground mines, stockyards, roads etc. will further increase this amount.

BCCL employs the Shovel/Dumper and Dragline methods to mine coal; sometimes these methods are used in combination, such as in Block II.

BCCL generally does not backfill the pits. The stated reason for not backfilling is that this backfilling covers up coal which may be needed at a later date. Accordingly, the dumpers create out-of-pit overburden (OB) dumps on adjacent land; preferably on land where subsequent mining will not be conducted. BCCL's success in implementing large scale OCPs is directly dependent on successful land acquisition and Resettlement and Rehabilitation (R&R) of Project Affected People (PAPs). In practice, BCCL has had problems with land acquisition and (R&R). The net result of this is that necessary land for coal mining and OB dumps has not always been acquired and BCCL has been forced to do one or both of the following, both of which impose a heavy cost penalty on BCCL: backfill pits which are scheduled for mining at a later time; and/or create OB dumps over undisturbed land which is scheduled for mining at a later time (NorWest 1997a).

Significant blasting is required for both the overburden and coal in the Jharia Coalfield. Much of the overburden consists of blocky, hard sandstone.

Environmental Impacts

Environmental impacts outlined here are those due to underground mining, surface mining, coal washeries and coke plants.

Underground Mining

The environmental impacts of underground mining are in the following principal areas.

Subsidence. Unless appropriate engineering and operational measures are taken to prevent it, significant subsidence is likely from underground mining operations.

Pumping. Underground mining is generally conducted below the water table resulting in inflows of water which must be pumped out.

Dust emissions. Dust is emitted from several sources, both underground and surface. Underground dust sources are principally at coal transfer points and at the working faces. Surface dust sources include coal transportation, coal crushing and stockpiling and associated transfer points

Sandfilling. A major offsite environmental effect of BCCL's underground mining is on the Damodar River sand used for stowing. Sand removal affects the river ecosystem.

Surface Mining

The environmental impacts from OCPs are much greater than from underground mining and include the following.

Surface disturbance. An estimated area of 90 ha to 95 ha per year is required to support BCCL's ongoing OCP mining activity. All infrastructure, vegetation, drainage control structures (and features) and surficial material over this land will be destroyed if not relocated in advance of the operations.

Dust and sediment. OCPs are generally large, exposed surfaces which may be unstable and are generally devoid of vegetation. The exposed surface may be several hundred hectares and can be a major source of air emissions (dust) and sediment which may end up in jores and water bodies. Dust is also produced by blasting operations, excavation and transportation of coal and overburden, and coal crushing, storage, handling and transportation.

Used Lubricants. Routine equipment maintenance and repair of heavy earthmoving equipment produces quantities of used oil, grease and spent solvents which must be disposed of appropriately.

Pumping. At certain times of the year all water entering the pit will be consumed by the ongoing requirements of the water trucks and no water will be discharged off the mine property. At other times (such as the monsoon) there will be a surplus of water that must be discharged from the mine.

Emissions. Large mine dumpers, if not properly maintained, will emit large amounts of diesel fumes, smoke and particulate matter. Blasting operations will also emit nitrous gases.

Coal Washeries

BCCL currently operates 9 washeries which process 7 million to 8 million TPY of raw coking coal. The coal wash plants primarily use jigs, heavy media vessels and heavy media cyclones to separate coal from waste material.

All washeries draw their water from the Damodar River with the exception of Barora, Mahuda and Lodna which use mine water. Most washeries operate on closed circuits (i.e., recycling the process water) and only require make up water to compensate for water lost during the process. BCCL indicates that approximately 70% of its coal is washed through these closed circuit plants.

BCCL disposes of the rejects (+ 60% ash) by placing it on land adjacent to the washeries; consuming it in Fluidized Bed Combustion plants at the washeries (the first such plant was commissioned at Moonidih in 1994); or sells it to brick plants.

Tailings from the fines circuits are discharged to ponds. The original intent was that the ponds at all washeries would be operated in a cyclic manner by allowing the solids to settle out and recycling the clarified water into the plant. Ponds operated in this manner would have zero discharge from the property. However, this objective of zero discharge has not always been possible due to: insufficient pond capacity; frequent power failures which require that the circuits be emptied before they can be restarted; and occasional flooding during monsoons. The net result is that coal-bearing slurry has been discharged off the property into the drainages and, most frequently, into the Damodar River.

BCCL's washeries are designed to have dust extraction and/or dust suppression systems to reduce dust emissions.

Coke Plants

In ordinary (non by-product) ovens the gases from the volatile matter contained in the coking coal are released into the atmosphere. In by-product type coke plants, the gases are collected and converted into valuable by-products for resale.

BCCL currently operates four coke plants; total coal consumption and coke production is estimated at approximately 250,000 and 180,000 TPY respectively.

The estimated average consumption of water per plant is reported by BCCL to be approximately three million liters (800,000 gallons) per month. Waste products include oil and grease; all products are consumed internally. The plants operate on the basis of closed circuit and there should be no discharge of effluent. Any excess effluent after settling is used for dust suppression.

Soft coke, a major fuel for the population of JCF, is also produced locally. It is manufactured by burning coal in open stacks resulting in the emission of smoke. The smoke produced in the process of manufacture of soft coke and hard coke contains both gaseous and particulate matter. The gaseous component consists of CO, SO_2, NOx and unburnt hydrocarbons. Any water discharged by the coking process is likely to be contaminated (NorWest 1997a).

Reclamation to Date

Approximately 6,400 hectares have been disturbed in the north and east parts of the Jharia coalfield due to mining and associated activities. Other mining-related disturbances in the coalfield are coal preparation plants (i.e., coal washeries) and their associated settling ponds and reject piles. Although these areas have some environmental concerns, they comprise a small percentage of the total disturbed area.

Erosion and sedimentation from disturbed areas is low. The mines do not have collection ditches or sedimentation ponds to trap sediment, however, many pits and subsidence areas serve the same purpose and perform well as unintentional sediment traps. The mines are probably not adversely affecting the sediment levels in the drainages by a significant amount.

Reclamation to date has focused on the planting of blocks of trees, usually a combination of one to four species of trees. Tree planting has generally been on subsided land and, to a lesser extent, along roadways. BCCL indicate that to date 3600 ha have been planted to trees (saplings) (BCCL 1996). Revegetation success has been mixed due to lack of maintenance, overgrazing and removal of trees by the local population. Reclamation to agricultural crops has not occurred to date. Quarries (i.e., manually excavated pits) and associated OB dumps from the earliest development period in the coalfield have revegetated naturally to various degrees with species that are valuable for erosion protection and low quality forage.

Significant reclamation and fire control work was conducted at some areas such as Jogta. However, this is not typical and underground mine fire areas were generally fought by trenching, water blankets, digging up of the fire area and placement of mutti[3] followed by compaction. Some of these reclaimed areas were restored to plantations.

[3] Mutti is a general term for surface or subsurface soil material which is usually stone free, has a significant amount of clay and silt, and can be compacted. Clay plus silt content is generally greater than 50%.

We are not aware that any topsoil has been salvaged, stock piled and respread on reclaimed land. A possible exception to this are some of the fire areas where mutti has been placed as a soil seal (NorWest 1997a).

Current Reclamation Standards

There are several Acts which pertain to coal mine reclamation, including: the Water Prevention and Pollution Control Act; the Air Prevention and Pollution Control Act; and the Environment Protection Act (Sarkar and Sarkar 1996; Maudgal 1990). The legislation gives authority to Central (national) and State Pollution Control Boards to set standards and control emissions. There are specific standards for air and water quality. However, coal mine reclamation requirements are less explicit Environmental Management Plans (EMPs) are required for new mines and major expansion of existing mines. These plans must be approved by the Central Ministry of Environment and Forests. The EMPs may require practices such as soil salvage and replacement.

Future Reclamation

Generally, the overburden spoil material is nontoxic and does not contain acid-forming materials. The two biggest obstacles to reclamation and good vegetative productivity are the presence of large durable sandstone boulders; and the lack of organic material and nitrogen in the OB.

The piles naturally go through a cycle of growth of aggressive plants and it does not appear that any chemical constituent in the material would prevent successful reclamation. Some of the hand-dug, old spoil piles have revegetated naturally with no assistance. Through the use of specially designed equipment, such as a Caterpillar D-10 dozer fitted with a special blade (similar to a "brush-rake used for land clearing) with strong, large tines, to remove large rocks, the piles could be flattened and the large boulders removed from the surface material at the same time. This will allow the finer-grained material to remain, thus providing a better growth medium. The piles do not have to be completely flattened; the height and slopes would only have to be reduced to the level that would allow successful revegetation. In many cases, adjacent pits could be partially filled by the earthwork operation, thus adding more area for final land use.

The goal of the entire process is to develop a method of reclamation of some of the piles, pits and subsidence areas that will be economically viable on their own, where the future revenues from planting trees or harvesting crops will pay for the actual restoration work. If this can be done, a strong argument for doing the work can be made.

Potential Post-Mine Land Uses

The potential post-reclamation land uses include: tree plantation; combination tree plantation with forage production (agro-forestry) (Tejwani 1994); non-irrigated forage land; and basic revegetation for erosion protection. Reclamation to rice paddy, cereal production, vegetable production and resettlement areas may be practical to a limited extent, particularly in areas to be mined in future.

Key Reclamation Considerations

Important considerations for reclamation and post-mining land uses include the following.

Soil Compaction. The surface material should not be left compacted prior to sapling planting. Numerous studies and widespread experience in many parts of North America have shown that subsoil compaction is one of the most serious problems in reclaimed areas.

Soil Amendments. Based on site specific OB sampling, proper soil amendment additions such as mulching and/or fertilizer can be specially planned for each particular site. Nitrogen addition is essential. Legumes in the overall forage seed mix will also help increase the nitrogen levels. The possibility of adding sewage material, if it becomes available, to the OB prior to planting should also be investigated.

Site Management. Once the site is planted, it is crucial that grazing be prevented in the first few years when the young trees are vulnerable. During the first three years or so tree saplings will need to be watered during the dry season.

Community Involvement. If the local community is not involved in the reclamation process and does not support it, excessive grazing and total and/or partial removal of trees will take place, resulting in great loss.

Proposed Reclamation Projects

Reclamation of the entire JCF at this stage is not realistic, due to the prohibitive cost and the fact that areas mined in the past will often be disturbed again in the future by mining activity. The Expert Committee on Restoration of Abandoned Coal Mines (1989) estimated that the total cost to reclaim the Jharia Coalfield is in the order of Rs. 400 crores ($114 million US). A major reason for not implementing this report was the great cost.

It is recommended that BCCL undertake small scale physical reclamation projects covering land that will not be disturbed in the future, to supplement its existing program of biological reclamation (tree planting over subsidence areas). These small scale reclamation projects should include planting of fast growing tree species on the reclaimed land in order to defray the costs of reclamation.

More than 20 sites that have reclamation potential were identified. Of these, five areas were identified to serve as examples and provide practical insight as to how reclamation could best be carried out.

The economic assessment of one of these sites (Jamunia) is typical of what could be expected from a well-designed program of physical reclamation. The results, shown in Table 1, indicate that reclamation of these selected sites is almost a break-even situation in the 15 to 20 year timeframe and will result in the least-cost physical reclamation scenario for BCCL.

Water Management

Water for domestic use, for the approximately three million people who live in the coalfield area (core and buffer), comes from three sources: Topchanchi Reservoir, Damodar River and shallow wells and water pipelines. It is well known that shortages are already being experienced during the dry season. Potable water is one of the, if not the most, important concerns in relocating people from the mine operation areas. Regarding uses other than potable water, many small tanks and minor dams have been constructed in or near the drainages throughout the coalfield. During the dry months the minor drainages cease to flow, shortages become serious, both for urban and rural populations. The water problems in JCF are severe and should be addressed.

Construction of Small Reservoirs. It would be possible to alleviate many of the water problems through the use of strategically placed, small reservoirs located upstream of the Coalfield in the

Table 1 - Economic Assessment of a Typical Reclamation Project (Jamunia)

Scenario	Crop and Annual Growth Rate	Economic Rate of Return				
		10 yrs	15 yrs	20 yrs	25 yrs	30 yrs
1	Forage - 4 tons/ha forage Luecana - 5 tons/ha fodder Luecana - 2 tons/ha fuelwood	-27%	-16%	-11%	-8%	-6%
2	Forage - 4 tons/ha forage Luecana - 5 tons/ha fodder Luecana - 6 tons/ha fuelwood	-42%	-6%	-2%	0%	1%
3	Forage - 4 tons/ha forage Eucalyptus - 6 cu. m/yr mine timber	-25%	-8%	-3%	0%	1%
4	Forage - 2 tons/ha forage Eucalyptus - 15 cu. m/yr mine timber	-7%	3%	6%	8%	8%

Metamorphic zone. The reservoirs would vary in size from 200,000 to more than 2,000,000 cubic meters. Some might be able to use existing railway embankments as a starting point for the reservoir.

The benefits of the storage reservoirs are numerous and include: reduction of peak flows downstream by 30% to more than 80% resulting in reduction of damage and loss of life downstream from large flood events; the reservoirs can supply potable water to existing towns as well as areas selected by BCCL for resettlement of people; and, considerable water quantities could become available to fight mine fires. A problem associated with the reservoir plan is the complicated land ownership and the fact that persons displaced by the reservoir must be resettled and rehabilitated.

Water Quality

Water contamination is due in large part to the fact that existing sewage treatment facilities are inadequate to cope with the large JCF population and the many septic tanks. Vehicle (truck) washing in ponds is also a concern. Analyses of water samples from above and below the major facilities and coal mines suggest that contamination resulting from all BCCL activities within the JCF is estimated about 10 to 15% of the total contamination. The remainder is attributable to other sources, such as electric power plants, coal washeries, and household wastes. The contamination from all these sources must be reduced.

Reclamation Costs and Effectiveness

NorWest's experience in western North American indicates that the cost of fully integrated reclamation (regrading, topsoil salvage/replacement, and revegetation) ranges from Rs. 260,000 to Rs. 875,000 per ha ($3,000 to $10,000 per acre). However, it should not be expected that reclamation will always yield positive economics. In fact, in most cases it costs more to reclaim the land than the land is worth on the open market. At best, reclamation will increase the value of the land, but generally not enough to pay for its reclamation. For example. in the American state of North Dakota, land in the coal field generally sells for less than $400/acre yet the reclamation cost of such land ranges from $3,000 to $10,000 per acre. However, there are certain special cases where reclamation is cost effective. For example, where reclaimed land can be used for housing development.

The Expert Committee on Restoration of Abandoned Coal Mines (1989) estimated reclamation costs for various Indian Coalfields. These costs varied greatly for different coal fields; for example, Raniganj Coalfield reclamation cost was estimated at Rs. 290,000 per ha (US$3,300 per acre), whereas the Jharia Coalfield reclamation was estimated at an average of Rs. 2,074,000 per ha (US$23,000 per acre).

It was recommended that BCCL undertake small scale physical reclamation projects covering land that will not be disturbed in the future. This physical reclamation will supplement BCCL's existing program of biological reclamation (tree planting, generally over subsidence areas). BCCL indicate that it is expected 1,500 ha of tree saplings will be planted over the next five years on subsidence areas, fire areas, OB dumps, quarries and roadsides (BCCL 1996). Accordingly, Norwest identified five physical reclamation projects and prepared detailed designs and cost estimates for each. In addition, Norwest prepared detailed economic analyses of planting fast growing tree species on the reclaimed land in order to defray the costs. Clearly, reclamation of the entire JCF as a single project is unrealistic and cannot be implemented. On the other hand, the reclamation projects developed by Norwest can be implemented.

The estimated reclamation costs of the five selected sites ranged from Rs. 189,000 to Rs. 326,000 per hectare with an average cost of Rs. 240,000 per hectare (US$2,740 per acre) (NorWest 1997a).

Recommendations

Numerous recommendations were made. Only a few examples of the general recommendations are given here.

Reclamation Concepts

Integrate Planning. Integration of mine planning and reclamation planning is essential to achieve integration of mining and reclamation practices.

Integrate Operations. Mine operation and reclamation practices must be integrated to allow progressive reclamation as mining progresses. If this is not done, effective reclamation (i.e. creating a land surface after mining similar to pre-mining) will not be achieved, due to technical problems of backfilling old pits and prohibitive costs.

Minimum Reclamation. Previously disturbed areas will generally be reclaimed to a minimum standard only. Reclamation will generally be limited to some surface stone removal and planting of trees or forage. Costs to reclaim derelict sites to a high capability land use are generally prohibitive.

Establish Standards. Areas mined currently or in future will be reclaimed to realistic, specified standards to achieve designated post mine land uses.

Salvage Unconsolidated Material. All unconsolidated overburden material above bed-rock soil should be salvaged. The surficial materials (unconsolidated) in the Jharia Coalfield are generally very thin (a few meters or less), except in the east part of the JCF. Large quantities of unconsolidated material are required for reclamation and soil cover for fire control

Evaluate Reclamation Efforts. Performance evaluations for mine managers and area managers must include achievement of reclamation targets. Performance evaluation for all mine managers and/or area managers must give the same importance to achievements of specific reclamation targets, as specified in EMP's or legislation, as the importance given to achievement of coal production targets.

Reclamation Objectives

BCCL must have clearly stated reclamation objectives. The reclamation objectives must be clearly stated and communicated to mine operations personnel. The major objective should be to establish the post mining landscape to some level of economic value. Other objectives should include the following:

- To stabilize the soil, minimize soil erosion and degradation and begin the process of rehabilitating or rebuilding soil fertility, structure and tilth.
- To return the land to a self supporting plant community or to sustainable agricultural production.
- To utilize excess labor to the fullest extent possible in reclamation work.

Reclamation Targets

In North America land reclamation seeks to return the land to pre-mining land use and biological/agricultural capability. This usually involves carrying out a detailed premine survey of land use, soils, vegetation communities (terrestrial and aquatic) plus a detailed list of special features (i.e. endangered species, historical or culturally significant sites). This level of rigor may not be appropriate to the Indian context. Nonetheless reclamation targets must be clearly established.

Future Reclamation

Recommendations were made for areas of existing disturbance and areas of future disturbance.

Existing Disturbed Areas. These include: overburden dumps with or without recontouring; pits and quarries; subsidence land; fire control cover; and areas for resettlement.

Areas Disturbed by Mining in Future. Reclamation and mine operations must be integrated and reclamation conducted to India regulatory standards, BCCL and Coal India policy and lender policy

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