PROBLEMS OF RECLAIMING AREAS AFFECTED BY MINE FIRES - A CASE STUDY[1]

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Abstract.--Fires in underground coal seams in the Jharia Coalfield of India often break through to the surface, causing severe problems of subsidence, air pollution, and destruction of surface vegetation. The Indian Government has begun a program to extinguish these fires and reclaim the damaged areas. One of these efforts, the Jogta fire project, is described in this paper. The reclamation effort at Jogta consisted of: (1) excavating the subsidence cracks and filling them with impermeable material; (2) leveling, compacting, and sealing the entire surface to prepare it for the use of heavy, rubber-tired equipment; (3) hauling in quarry refuse to establish a subsoil base with a slope of 5 to 10 pct to minimize erosion by rainfall; (4) hauling in topsoil to further seal the surface and provide a medium for plant growth; (5) irrigating the area and planting with over 30 hardy species of vegetation; and (6) creating ponds to take advantage of the surface profile resulting from backfilling operations. These efforts have resulted in the reestablishment of pre-mining ecological conditions. The procedures, problems, and results of various aspects of the reclamation effort are described.

INTRODUCTION

The coal industry of India is about 200 years old; the major coalfields, shown in figure 1, occur in sedimentary formations in the eastern half of the country. Most of the coal is bituminous, with some lignite, and is classified as coking or non-coking for reserve estimation. Table 1 summarizes the estimated reserves of each coal type and shows that the supplies are expected to last only about 100 years at present rates of depletion (Tandom, 1987). Only the Northeastern and Jharia Coalfields contain coals with acceptable coking characteristics. Although the Northeastern coals have the best coking properties, they have a high organic sulfur content that cannot be reduced through standard washing techniques; this makes them unsuitable for use by the steel industry. Jharia coals are lower in sulfur (albeit higher in ash) than Northeastern coals, making them the most desirable coking coals in the country.

The Jharia Coalfield has about 19 mineable seams, labeled 0 through 19 from the bottom to the top of the stratigraphic sequence. Figure 2 shows the vertical locations, thicknesses, and spacing of the seams at the Angarpathra and Gaslitan collieries, which are typical of the mines operating in the area. The upper 11 seams (9 to 19) have less ash than the lower seams and therefore have better coking characteristics; these are the seams that have been mined most extensively to date.

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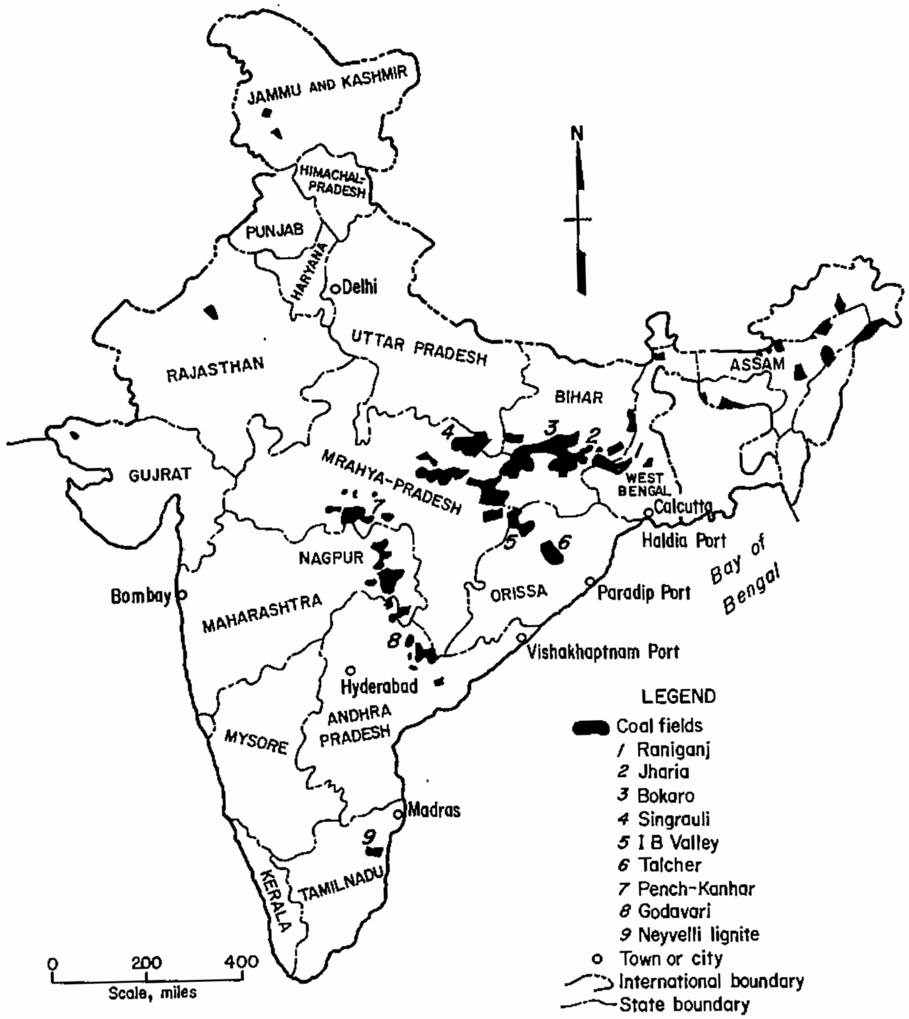

Figure 1.--Major coalfields of India.

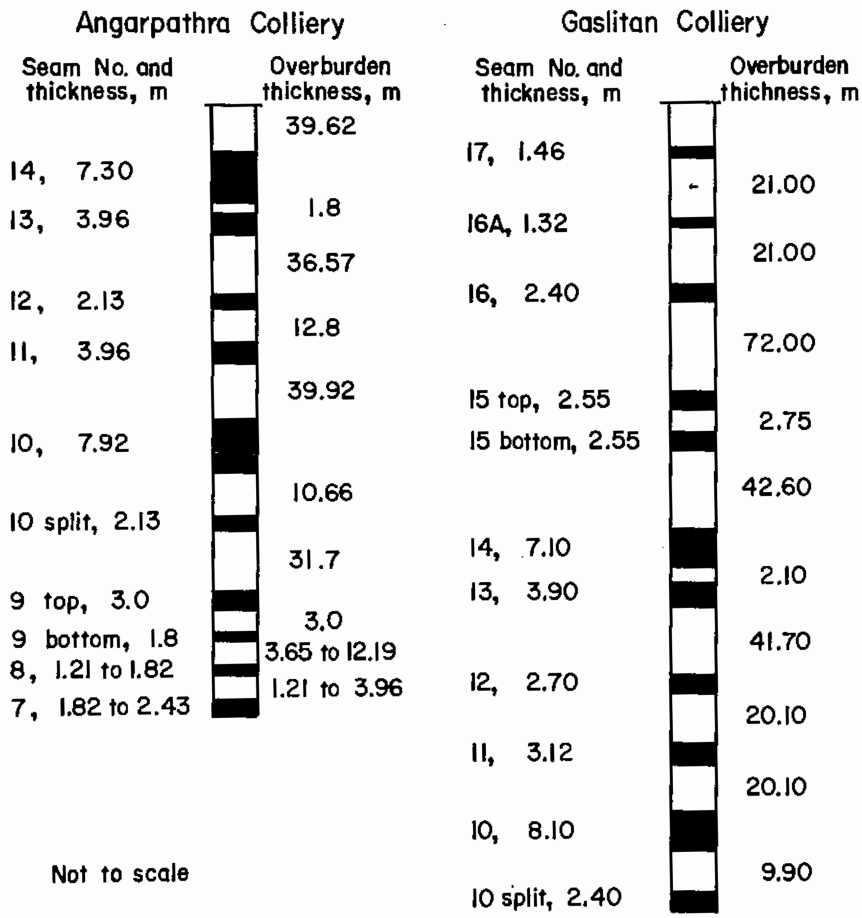

Figure 2.--Vertical location, thickness, and spacing of coal seams at the Angarpathra and Gaslitan Collieries in the Katras area.

Table 1.--Estimated reserves of coking and non-coking coal in India.[1]

Coal type	Recoverable reserves as of 1-1-80 (m.tonnes)	Depletion during 1980-94 (m. tonnes)	Life of reserves at 1994-95 level of production (years)
Coking	6,629	563	93
Non coking	32,357	2,168	116

[1]After Tandom 1987.

Unfortunately, the upper seams are very susceptible to spontaneous combustion, resulting in many mine fires during the process of extraction. It is estimated that over 60 pct of the mine fires in India have started in this manner. These fires often extend upward to the land surface because: (1) the seams are very thick with little overburden; (2) close vertical spacing between seams allows fires in lower seams to ignite higher ones; (3) old room-and-pillar workings provide a ready supply of oxygen; and (4) natural topsoil is thin and allows passage of air through subsidence cracks. Once a fire breaks through to the surface, it is very difficult to control due to the synergistic effects of underground coal combustion, strata fracture and subsidence, and passage of air from the surface through subsidence cracks.

Mine fires in the Jharia Coalfield are quite extensive and severe. The first was reported in 1916, and many have been burning for decades; a total land area of 17.3 km^2 has been damaged to date. Because the fire zones are in densely populated areas (venting has occurred within 15 m of residences), they must be controlled and the land must be reclaimed as soon as possible. In addition to heat and subsidence problems, the fires pose a significant human health hazard through the release of gaseous and particulate contaminants from surface vents. Loss of scarce and valuable coking coal reserves is another reason for immediate control of these fires. It has been estimated that 1.86 billion tonnes of coal are now inaccessible because of proximity to burning areas (Coal Lignite Working Group, 1985).

When the Indian Government took over the management of the nation's coal mines in 1971-73, it set a target date of 1995 for extinguishment of all 70 fires known to exist at that time (CMPDI, Ltd., 1986). Bharat Coking Coal Ltd., the public sector enterprise that now operates the mines of the Jharia Coalfield, is responsible for the extinguishment and land reclamation effort. This paper describes the methods, problems, and results of one of these efforts, the Jogta fire project.

JOGTA FIRE PROJECT

Fire Site

The Jogta fire started in 1941 due to spontaneous combustion of coal in a pillar extraction section of a mine operating in seams 13 and 14, about 20 to 50 m below the land surface. Attempts were made first to extinguish the fire using underground seals to cut off the air supply to the panel. These were ineffective, and by 1953 the fire had reached the surface. It spread to the north, east, and west and began to threaten neighboring mines, railways, roads, streams, and residences (Sinha and Malhotra, 1980). By the time control measures were begun in 1980, the fire had spread over an area of 18.72 ha, with an east-west strike length of about 1 km. The District Board road and some residences had subsided, and the fire was within 30 m of a stream and other residential areas.

The surface areas affected by the fire had some of the most hazardous environmental conditions imaginable, which greatly hindered the extinguishment and reclamation effort. Soil temperatures (when any soil was present) in areas where the fire had penetrated the surface were 250° to 650° C (Malhotra, 1986). Subsidence cracks as wide as 2 m occurred throughout the area, discharging steam, smoke, and flames which sometimes shot as high as 6 m above the surface. Subsidence was particularly common and unpredictable during the monsoon season when the water added weight and lubrication to the strata. Pollutants such as carbon monoxide and particulates were severe; vegetation was practically nonexistent. In areas away from the damaged surface, but above the underground fire zone, the temperature 1 m below the surface was 40° to 50° C. Vegetation occurred sporadically, and only during the monsoon season.

Extinguishment and Reclamation Plan

Given the extreme environmental conditions at the fire site, remedial measures had to be precise and thorough yet cautious and deliberate; the former was to ensure that the fire would be completely extinguished, and the latter to protect the workers' health and safety. The general approach toward reclamation consisted of (Malhotra and Banerjee):

1. Excavating the subsidence cracks and filling them with impermeable material to prevent oxygen from reaching the fire;

2. Leveling, compacting, and sealing the entire surface to prepare it for the use of heavy, rubber-tired equipment;

3. Hauling in quarry refuse to establish a subsoil base with a slope of 5 to 10 pct to minimize erosion by rainfall;

4. Hauling in topsoil to further seal the surface and provide a medium for plant growth;

5. Irrigating the area and planting with over 30 hardy species of vegetation;

6. Creating ponds to take advantage of the surface profile resulting from backfilling operations.

The procedures, problems, and results of various aspects of the reclamation effort are described below.

Equipment Selection and Site Preparation

The intense heat of the surface and the constant threat of subsidence were the two major constraints governing the selection and operation of equipment. For the initial phase of crack excavation and sealing, comparatively light (21-tonne), track-mounted bulldozers were chosen. The lighter weight and greater bearing area of these machines lessened the danger of equipment-induced subsidence. If this did occur, the bulldozers were better able to retrieve themselves from the sunken area than heavier, tire-mounted equipment. In addition, the engines and fuel tanks of the bulldozers were relatively high off the ground, making them less susceptible to damage from the hot soil surfaces. Even so, digging time was limited to 3 hours at a stretch to protect the lubrication of the bulldozer undercarriage. In areas of intense heat release, the excavated surface had to be covered with about 600 cm of topsoil before heavier, rubber-tired vehicles could be used.

After the bulldozers had stabilized and sealed the surface, quarry refuse for the subsoil base and topsoil for the final cover were hauled in by 35-tonne dump trucks. The fill material was compacted by the truck tires and special compacting equipment with an impact load of 20 tonnes. The quarry refuse initially was leveled to a maximum slope of 10 pct; however, in several areas this proved to be insufficient to prevent gully formation during the monsoon season. Maximum slopes were subsequently reduced to 5 pct before topsoil was emplaced. In areas where higher slopes had to be maintained, such as against a rail head where a 25 pct profile was required, biological soil binders were used to prevent erosion, and dense planting of Agave Sisalana and grass was employed to improve stability. In other areas, large sandstone pieces in the upper 2 m of subsoil fill material resulted in highly permeable zones that allowed venting to redevelop. These had to be reexcavated, refilled, and recompacted before further reclamation could take place.

Topsoil in the Jharia Coalfield area was very scarce, which greatly increased the time and cost associated with the reclamation effort. Topsoil thickness varied according to sealing and plant growth requirements; the initial topsoil thickness was limited to 15 cm wherever possible. Sealing was considered to be effective if the subsurface oxygen content was 3.5 pct or lower.

Worker Health and Safety Hazards

The initial excavation and sealing of the surface fire zones was an extremely hazardous task. For each bulldozer operator, at least three helpers were required to stand at a distance and warn him of impending subsidence. Poor visibility due to dust (dry season) and steam (wet season) made this process even more difficult. Operators and helpers were all endangered if a ground collapse did occur and the machine had to be retrieved from the hole.

Carbon monoxide poisoning was a constant threat; work was limited to 3 hours per day, 2 days per week for each crew to prevent excessive exposure. Even with these restricted hours, workers commonly developed headaches which remained for 3 days after each day of work (Malhotra, 1987).

Revegetation Efforts

The scant topsoil available for revegetation was usually of poor quality due to: (1) extreme heat and salt deposition by steam moving upward from burning underground areas; and (2) erosion and leaching by rainfall. Table 2 lists the soil nutrients typical of intensely vented areas (Malhotra, 1987). The high conductivity (salinity) of these soils inhibited the germination and growth potential of plants intended for revegetation. This problem was compounded by the high salinity of the subsoil layer of quarry refuse (conductivity of 4.5 to 29 mmhos/cm). The nutrient content of the topsoil was enhanced by the addition of chemical fertilizers at rates of 150 kg/ha during transplantation and 100 kg/ha per stage in three stages at 3- to 4-week intervals after planting.

Before planting began in 1981, the entire area to be reclaimed was irrigated for one year in order to allow topsoil to seal minute cracks and to delineate areas requiring further sealing. Irrigation water was pumped in from a neighboring mine and from a dammed intermittent stream on the east side of the fire zone. Depending on weather conditions, the area was irrigated at 1- to 3-week intervals.

The first few planting seasons were not very successful; for example, of the 2,500 saplings planted during 1981, only 52 plants of Gmelina Arborea survived. This suggested that heat and pollutants from the subterranean fire zone were still reaching the surface. In subsequent years, however, survival rates of other species increased considerably, up to 95 pct in some cases. Subsurface oxygen content in most of the revegetated areas was reduced to below 2 pct. Initial plant species included Eucalyptus, Pongammia, Jacaranda, and Peltophorum, with diversification carried out in later plantings. Over 30 plant species were introduced, with greater survival rates for species that were relatively insensitive to saline soils. As mentioned earlier, Agave Sisalina was successful in stabilizing areas with steep slopes.

Table 3.--Typical soil characteristics and nutrients in intensely vented areas.[1]

Sample	pH	Conductivity (mmhos/Cm)	Organic carbon (%)	P (kg/ha)	K (kg/ha)
1	5.1	0.10	0.29	5.1	907.2
2	5.5	0.08	0.50	3.8	201.6
3	6.4	0.30	1.44	3.2	179.2
4	4.7	4.50	1.31	3.8	358.4
5	5.3	1.50	0.87	3.2	156.8
6	7.6	29.0	0.54	10.3	168.0
7	7.5	25.0	0.78	6.6	1,120.0

[1]After Malhotra 1987.

Ecological Development

The reclaimed and revegetated fire areas are now green and capable of supporting ecological development, a welcome contrast to the scenes of devastation that existed in 1980. In two areas the original land profile was used in the reclamation process to create ponds capable of supporting aquatic life. The ponds were developed by creating two embankments with fill, repeatedly compacting the fill to decrease permeability, emplacing a thick layer of topsoil mixed with organic matter, and providing supplemental food for fish until natural aquatic biota were established. Microorganisms began to grow in the ponds within a year, and fish were added during the 1985 growing season. Although fish growth during the first year was lower than normal, the growth in subsequent years has been satisfactory. Carp stocked in 1985 have attained a weight of around 1 kg, about normal for this locality. Wildlife has also been introduced satisfactorily, even though the specie of deer (black buck) is known to be sensitive to conditions of captivity.

SUMMARY

The Jogta fire project has shown that it is possible to completely reclaim an area of the Jharia (India) Coalfield that had been devastated by underground and surface mine fires. The ecosystem of the locality has been returned to the premining state, and efforts are now underway to improve the situation by establishing green belts, zoological parks, and fisheries. In addition, the reclamation effort has completely eliminated a severe source of gaseous and particulate air pollution and alleviated the threat of subsidence damage to nearby residences.

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