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Ash disposal – mine fires – environment – an Indian dilemma

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ABSTRACT

Coal combustion ash disposal at mine sites may provide a means to deal with the serious problems of coal mine fires, orphaned mined land and coal ash disposal in India. India produces about 70 million metric tons per annum (Mta) of coal ash from the combustion of 320 Mta of domestically produced coal, the average ash content being about 30–35 per cent as opposed to an average ash content of less than 10 per cent in the U.S. In other words, India produces coal ash at about triple the rate of the U.S. Currently, 95 per cent of this ash is sluiced into gigantic slurry ponds, many located near urban areas and consuming vast amounts of premium land. Conversely, the Jharia Coalfield produces about 30 Mta of this ash and also contains the world's largest complex of underground coal mine fires. The fires occupy an aggregate surface area of about 10 square kilometres where the land surface is extremely degraded. Similarly, the Singrauli Coalfield, suffers from the environmental effects of open cast mining, overburden dumps for mine waste and an enormous coal combustion ash disposal problem, which is probably the largest such problem in India. Coal combustion ash haulback to the Jharia and Singrauli Coalfields as well as to other coalfields in India can find beneficial use by:

- Controlling mine fires through surface and underground sealing with coal combustion ash,
- Filling open-cast mine pits, depressed, and subsided areas,
- Filling abandoned underground workings to control ground subsidence,
- Reducing ground water flow through mine backfill to retard leaching of acid or metals forming constituents, and
- Serving as a soil amendment to restore soil fertility.

Placement of ash in surface and underground mines whether in the Jharia or Singrauli Coalfields or elsewhere in India, can provide an efficient, cost-effective method to remove significant quantities of ash from pond disposal while at the same time contributing to mine fire and subsidence abatement, mined land reclamation and restoration of land productivity. Wise natural resource management suggests a reasonable approach to disposal and beneficial use of coal ash is to return it to its original location – *the mine*.

INTRODUCTION

India produces approximately 70 million metric tons per annum (Mta) of coal combustion ash from the burning of 320 Mta of domestically produced coal (World Coal 1999). Future electric power generation is expected to greatly increase coal production with a resulting need for disposal or utilisation of coal combustion ash. Currently, almost all coal combustion ash is wasted in large slurry ponds. The authors report on their experiences with the Indian coal and power generating industries over the last several years. In the former, GAI provided technical assistance to Bharat Coking Coal Limited (BCCL) to assess conditions in the Jharia Coal Field, which contains the world's largest complex of underground coal mine fires. Coal ash could find beneficial use to ameliorate the mine fires, control subsidence, reclaim open cast mining pits, and help restore the agricultural productivity of the land. In the latter, GAI provided a feasibility study to the National Thermal Power Corporation to return coal ash produced by Singrauli Super Thermal Power Station to abandoned and active open cast mining pits in the northern portion of the Singrauli Coalfield. Singrauli is one of the most important power generating centres in the country. Fifteen open cast mines, enormous coal ash slurry ponds, and the impact of various heavy industries have created significant and chronic social and environmental problems. Environmentally safe management and disposal of the coal ash alone would lead the way to improve conditions in the "Power Capital of India". Based on information gained in the Jharia and Singrauli Coalfields and the author's experience with beneficial use of coal ash in the United States, recommendations are made for coal ash haulback to control mine fires, fill depressed areas, control mine subsidence, reduce ground water flow through mine backfill, and serve as a soil amendment to restore soil fertility.

Fig. 1 shows the relationship of India's coalfields to the thermal power stations throughout the country. The close proximity of some stations to the coalfields clearly shows the potential to beneficially remove very significant quantities of coal ash from the current practice of slurry pond disposal. The business ties between the coal producers, the coal consumers, and governing bodies are in place. All that remains is the wherewithal to implement a large-scale pilot project to demonstrate the potential of ash haulback in India.

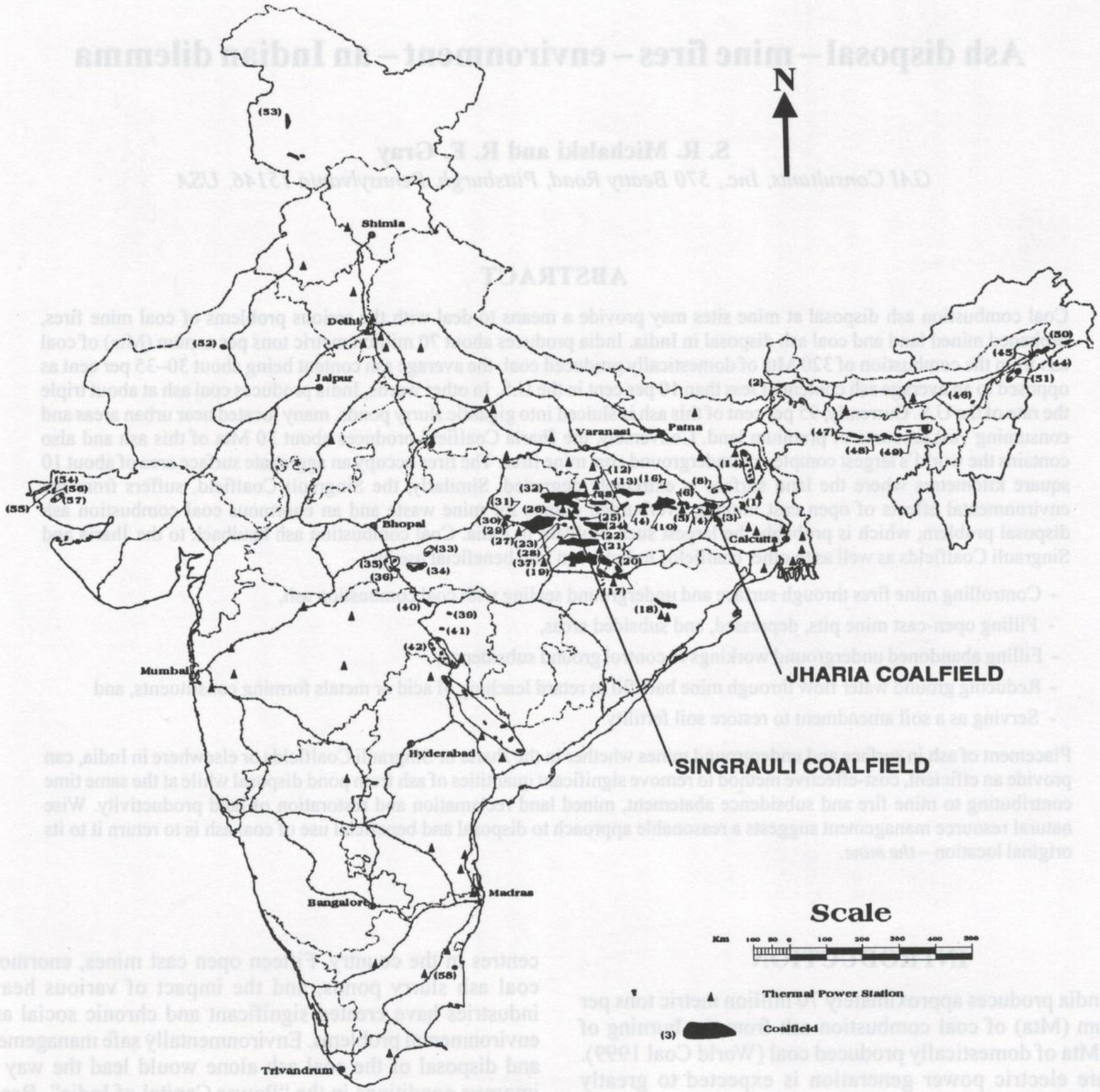

Fig. 1: Coal fields and thermal power stations of India (Based upon geological survey of India map 1976, thermal power stations added from various sources)

INDIAN COAL MINING

Coal is the dominant source of commercial energy in India (Fig. 2). Coal and lignite are likely to remain the major source of India's energy.

Mining of coal started in India's West Bengal State in 1774. All mining was underground prior to World War II, at which time mechanical open cast mining was introduced. After India gained independence in 1947, the coal mining industry grew and technological development accelerated. National plans were developed and coal production rose form 30 to 35 million tons annually (Mta) to 72 Mta by 1972 (World Coal 1999). The coal industry was nationalised in the early 1970s. By 1998 production had grown to 320 Mta with a growth rate of 7 per cent per annum. India is now the world's third largest producer of coal. Open cast mining is responsible for almost 75 per cent of total production (World Coal 1997). Underground production has remained at 75 to 80 Mta for two decades (World Coal 1999).

INDIAN COAL COMBUSTION ASH

Electric utilities use 70 per cent of total coal production. The 220 Mta of coal used for electricity in 1997 and 1998 is estimated to increase to 447 Mta by the year 2006 or 2007. Although it is possible that coal imports may increase to

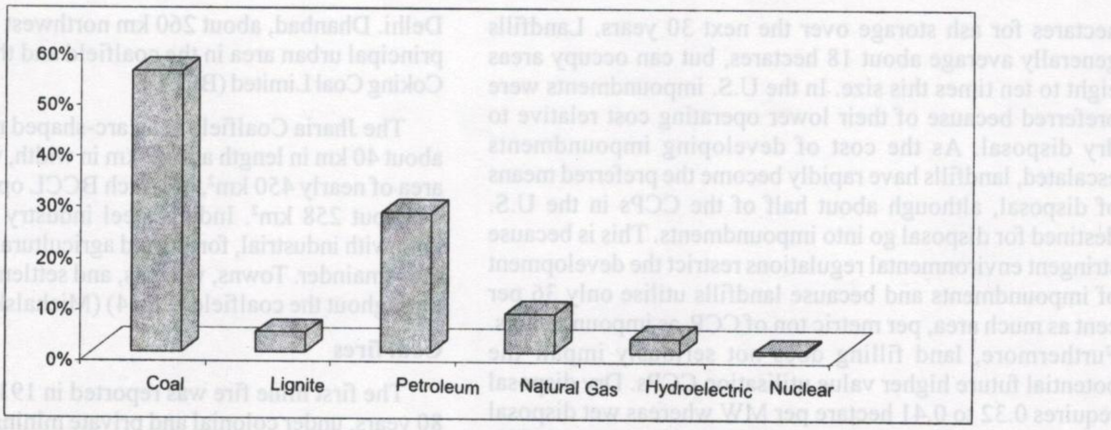

Fig. 2: Consumption pattern of primary sources of commercial energy in India (World Coal 1999)

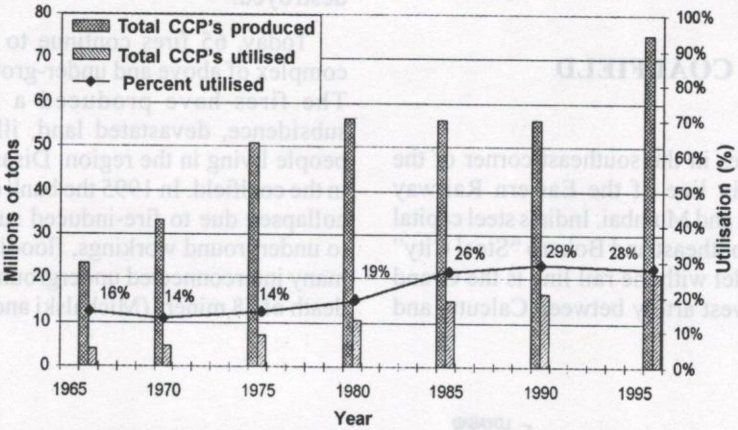

Fig. 3: CCP Production and utilisation in the U.S. 1966–1996

meet the demand, the bulk of the electricity will come from burning domestic coal (World Coal 1999).

Although the United States burns 800 Mta to generate electricity (almost 4 times as much as India), both countries produce approximately the same quantity of Coal Combustion Products (CCPs), about 70 million tons per year. Indian coal is generally of poor quality in terms of ash content. Indian coals may have as much as 30–35 per cent ash with net calorific value less than 3,000 kcal/kg, whereas U.S. coals average about 10 per cent ash with net calorific values between 5,200 and 8,200 kcal/kg. Coal cleaning circuits remove ash from sources external to the coal seam (i.e., shale partings, overburden, etc.), which are characteristics of U.S. coal. The ash in Indian coal is very finely disseminated within the matrix of the coal itself rendering it very difficult to remove by standard U.S. coal cleaning technology. India's installed power generating capacity of 60,000 MW is projected to increase to 200,000 MW by the year 2007 to meet demand (Thakur et al. 1995). To further compound the problem, only 2 to 3 per cent of the total ash produced in India (Water and Earth Sciences Associates Ltd. 1996a) is currently being used for productive purposes as opposed to 28 per cent utilisation in the U.S. (Fig. 3).

Most coal-fired power generating stations in India collect ash with electrostatic precipitators. A very small quantity of this ash is stored in a dry state to be used as a raw material for the manufacture of cement products and brick. CCPs not used are placed in utility-owned and operated impoundments or landfills*, which are typically located near the power plant. Impoundment storage restricts utilisation options. Ash must be stored dry, as in landfills, to be suitable for higher value uses (Brendel and Dube 1998).

In the U.S. impoundments typically vary from 12 to 160 hectares, although some encompass areas of 340 hectares or greater and have storage capabilities of 80 million cubic meters. In India, the impoundments are even larger. The Ramagundam Super Thermal Power Station (STPS) in Andhra Pradesh uses approximately 700 hectares for ash pond storage whereas Chandrapur STPS has acquired 2,700

*The CCP dry landfill at the Dadri National Capital Power project, operated by the National Thermal Power Corporation is located near New Delhi and is probably the largest such site in all of India (Brendel and Dube 1998).

hectares for ash storage over the next 30 years. Landfills generally average about 18 hectares, but can occupy areas eight to ten times this size. In the U.S. impoundments were preferred because of their lower operating cost relative to dry disposal. As the cost of developing impoundments escalated, landfills have rapidly become the preferred means of disposal, although about half of the CCPs in the U.S. destined for disposal go into impoundments. This is because stringent environmental regulations restrict the development of impoundments and because landfills utilise only 36 per cent as much area, per metric ton of CCP, as impoundments. Furthermore, land filling does not seriously impair the potential future higher value utilisation CCPs. Dry disposal requires 0.32 to 0.41 hectare per MW whereas wet disposal requires about 0.81 hectare per MW (Sengupta 1995). Nevertheless, disposal of CCPs in ponds remains the preferred means of disposal in India and will likely remain so well into the future.

JHARIA COALFIELD

Location

The Jharia Coalfield lies in the southeast corner of the state of Bihar on the main line of the Eastern Railway stretching between Calcutta and Mumbai. India's steel capital of Jamshedpur lies to the southeast and Bokaro "Steel City" to the west. Roughly parallel with the rail line is the Grand Trunk Highway, the east-west artery between Calcutta and Delhi. Dhanbad, about 260 km northwest of Calcutta, is the principal urban area in the coalfield and the home of Bharat Coking Coal Limited (BCCL).

The Jharia Coalfield is an arc-shaped reserve measuring about 40 km in length and 12 km in width, which occupies an area of nearly 450 km², of which BCCL operates a leasehold of about 258 km². India's steel industry holds another 22 km², with industrial, forest, and agricultural areas comprising the remainder. Towns, villages, and settlements are scattered throughout the coalfield (Fig. 4) (Michalski et al. 1997a).

Coal fires

The first mine fire was reported in 1916 and for the next 80 years, under colonial and private mining, the fires spread. The landscape is now so severely scarred that it is clearly visible from space, and the productivity of the land virtually destroyed.

Today, 65 fires continue to burn, creating the largest complex of above and under-ground coal fires in the world. The fires have produced a legacy of uncontrolled subsidence, devastated land, ill health, and death to the people living in the region. Disasters are also not unknown in the coalfield. In 1995 the bank of a monsoon-swollen river collapsed due to fire-induced subsidence. Water rushed in to underground workings, flooding the Gaslitand Mine and many interconnected underground galleries, resulting in the death of 78 miners (Michalski and Gray 1997b).

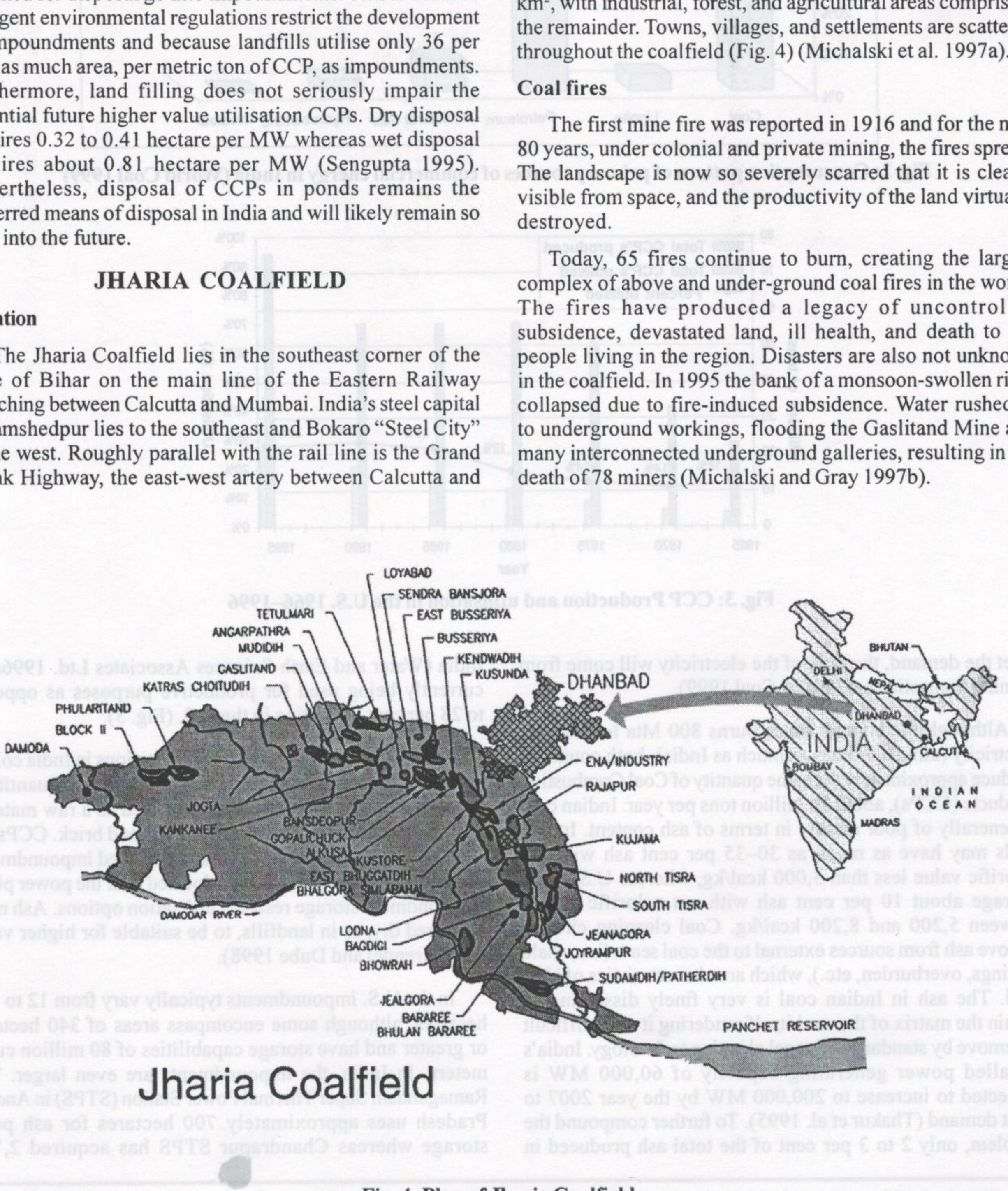

Fig. 4: Plan of Jharia Coalfield

Throughout the early 1990s, nearly 40 Mt of coal has been consumed by fire, resulting in staggering financial losses and isolating nearly 1500 Mt of coal from further development. However, this is not the only issue. The health and well being of people living on or near the burning mine lands, the stability of railroad rights of way and river (jore) channels, and associated impacts on future coal mining are all important factors (GAI/Met-Chem 1996).

One third of the collieries (12) contain a single fire. The remaining two-thirds contain two to four fires each. Eighty-five per cent of all fires involve a series of burning underground coal seams partially exposed in open pits. Twenty-two fires involve a single coal seam, 19 fires burn in two seams, 13 fires burn in three seams, 5 fires burn in four seams, and 2 fires burn in six seams. Individual fires occupy areas of 0.007 to 1.79 km² with an average 0.29 km² per fire. Fires extend up to 140 m below ground surface with an average depth of 50 m (GAI/Met-Chem 1996).

Environmental impact

The Jharia Coalfield is a severely disturbed and polluted area with serious environmental impacts due to its poor air and water quality and unreclaimed land disturbance. However, direct contribution of Bharat Coking Coal Limited to pollution through its mining activities is relatively small and it does not have control on other factors which contribute to the poor environmental quality, including dense population; other industrial facilities; poor roads; and poor land management.

The estimated 1991 population of the Jharia Coalfield was 1.1 million with a population density of approximately 2,400 people per km². To provide a perspective, this contrasts with the 1991 population density of 497 per km² for the State of Bihar and 274 per km² for India (Schori and Scrymgeour 1997).

The entire coalfield, including unmined areas, suffers from accelerated rates of soil erosion due to severe overgrazing. Subsidence is a problem in the Jharia Coalfield, principally in areas of old mining (pre-nationalisation era before 1973). In these areas, mining was at shallow depths where the mine roof can suddenly collapse into the mine voids or the coal pillars left for support have proven to be unstable. Failure of these pillars causes the overlying area to subside. In fire-affected areas, pillars burn, also resulting in subsidence. The areas disturbed by past mining activities are extensive and are summarised in Table 1.

Beneficial use of coal ash

Coal combustion ash has many beneficial uses applicable to India (Water and Earth Sciences, Ltd. 1996a). All of the utilisation options with the exception of ash haulback have low likelihood to consume large quantities of CCPs in India, at least in the foreseeable future (Chugh 1996, Michalski et al. 1998). Mining applications, including surface mine disposal, are similar to land filling, but are considered more beneficial since the CCPs are used to backfill open cast mining pits made to recover coal. Power stations located in the coalfields may find surface mine disposal as an economic alternative (Roy 1997).

Under certain circumstances, disposal in underground mines may also be an option. The technology for underground disposal of CCPs are derived from the technologies used for disposal of coal mining process wastes in underground mine workings. Fly ash, because of the size and shape of the particles, is an ideal material to stow in underground mines. The fly ash may be placed in the inactive portions of active mines or used to completely fill abandoned mines. The fly ash may be placed by hydraulic or pneumatic methods, although the former is generally much cheaper, particularly for long term, high volume operations (Tonet 1970).

A large ash haul-back demonstration project for the purpose of returning coal ash to the Jharia Coalfield could benefit BCCL and the coal ash producer. The material could be used to:

- control mine fires through surface and underground sealing, reclaim mined land,
- serve as a soil amendment to restore soil fertility,
- stow in underground workings for subsidence control,
- fill mined pits, depressed and subsided areas,
- reduce ground water flow through mine backfill to retard leaching of acid or metals,
- reduce the demand for impoundment storage capacity,
- minimise or eliminate ash discharge to the rivers and reservoirs, and
- fabricate lightweight block for the rapid construction of stoppings.

A pilot project could demonstrate the usefulness to both the utility in search of coal combustion waste disposal and to BCCL for fire control, pit backfilling, stowing and reclamation purposes.

Table 1: Areas disturbed by past mining activities (After BCCL in GAI/Met-Chem and Norwest 1997)

Type	Area (ha)	Per cent
Subsided areas	3,500	56
Fire affected areas	1,730	27
External OB dumps	640	10
Old pits	430	7
Total	**6,300**	**100**

SINGRAULI COALFIELD

Location and background

The Singrauli region, otherwise known as the "Energy Capital of India", does not suffer from coal mine fires, but does suffer from major environmental problems created by open-cast coal mining, coal combustion ash disposal, coal ash disposal ponds, alienation of land, and from pollution caused by ancillary industries.

The Singrauli Region lies across the common border of Uttar Pradesh and Madhya Pradesh and is located approximately 800 km southeast of New Delhi and 200 km south of Varanasi (Fig. 1). The region occupies an area of about 3,500 km^2. The Govind Ballagh Pant Sagar (GBPS) or Rihand Reservoir is the centrepiece of the region and occupies an area of about 460 km^2. The GBPS was formed in the early 1950's for the purpose of constructing the Rihand Dam and hydroelectric generating facilities and was strongly supported by Jawaharlal Nehru, India's first Prime Minister. The region is characterised by low hills to the northwest and southeast of Rihand Reservoir. The fertile Waidhan Plain lies just southwest of the upstream end of the reservoir. Just over half of the region is covered by degraded semi-deciduous woodland, and about 17 per cent is currently under some form of agriculture (GHK/MRM International 1994).

Prior to the 1960's, Singrauli was an isolated rural area. The landscape was characterised by forests and small farms. The indigenous people of the region practised subsistence agriculture and collection of minor forest products. Today, Singrauli is one of India's largest and most important centres of coal mining and power generation, with a landscape that is dominated by the Rihand Reservoir, massive open-cast coal mines, five super thermal power stations, hydroelectric generation facilities and a number of energy dependent heavy industries. These industries include the production of aluminium, cement, carbon and chemicals. Expansion of these industries is planned for the near term. Singrauli, therefore, has become one of the most important power generating centres in the country and an area of strategic importance to the economy of India.

Extensive coal deposits were discovered on the western bank of the Rihand reservoir in the Moher Half Basin and the Singrauli Main Basin with an estimated 10,850 million tons of reserves. Opencast mining began in 1963 with the Juingurdah Mine in the Moher basin. Since then, 15 opencast mines have been opened to produce 50 million tons per annum for the purpose of thermal power generation. Nearly 52 million tons are projected for the year 2000, with further expansion to the west in the Moher Half Basin (GHK/MRM International 1994).

Northern Coalfields Ltd. (NCL) operates 11 opencast mines occupying nearly 200 sq. km. NTPC, Uttar Pradesh State Electricity Board (UPSEB) and private sector operators currently produce nearly 6,800 MW at six thermal power stations in the region. The Singrauli Coalfield is estimated to be capable of supporting 20,000 MW of installed generating capacity for over 130 years. Currently approved and funded investments in the power industry will increase current installed capacity by 40 per cent in the next 5 to 10 years. Planned expansion beyond this amount is anticipated (GHK/MRM International 1994).

The construction of Rihand Dam and subsequent development of opencast coalmines, super thermal power stations and various energy intensive heavy industries have created significant and chronic social and environmental problems. These developments have resulted in the forced relocation of over 100,000 people over the past 30 years. Many people have been relocated several times as a result of their relocation sites being required for additional development and creation of ash disposal sites. Major environmental problems have been created by opencast coal mining, coal ash disposal ponds, and from pollution caused by ancillary industries. Industrial development has had an effect on air and water quality, the regional ecology and biodiversity, land use and public health.

One of the most severe environmental impacts is the alienation of land through its use for:

- opencast mining,
- mine waste dumps, and
- slurry pond construction for coal combustion ash disposal.

It is estimated that thousands of hectares of land will be required for coal ash slurry pond construction every 25 years. Fulfilling this requirement will only aggravate existing environmental and social problems in the region (GHK/MRM International 1994).

Implementing coal combustion ash haulback will minimise required disposal area and maximise the utility of already disturbed lands in the Singrauli Coalfield by:

- providing a disposal option that will use large quantities of coal ash outside the normal slurry
- pond disposal method;
- filling open cast mine pits; and
- manufacturing soil amendments and synthetic soils from coal ash for the purpose of reclaiming mined land, supporting vegetative cover, and creating plantations for agricultural purposes.

Placement of ash in opencast mines has the potential to provide an efficient, beneficial cost-effective and environmentally sound method of coal ash management, while simultaneously restoring the agricultural productivity of disturbed lands.

CONCLUSIONS

Coal combustion ash can be disposed of in a beneficial and an environmentally acceptable manner in the abandoned or active opencast mines within the Jharia and Singrauli Coalfields and elsewhere in India. The proximity of thermal power stations to the coalfields is apparent and, in many cases, can be used to advantage to economically dispose of the ash in an environmentally safe manner (Fig.1). Furthermore, an aggressive ash management programme with ongoing research will permit the use of coal ash for mine closure and reclamation of mine spoil areas.

Now is the time for India to implement an ash haulback demonstration project. In the short term, the government of India should sanction a large demonstration project in the implementation/transport and disposal of coal combustion products in one of India's coalfields. Such a demonstration could be implemented near existing large thermal power stations as in the Singrauli or in the Jharia Coalfields to help abate the disastrous effects of surface mining and underground coal mine fires. The purpose of the demonstration would be to improve and implement handling procedures that allow the haul-back method to be economically attractive to both the coal provider and the coal consumer. Results could find wide application throughout India in developing environmentally safe and sound procedures to manage, dispose and utilise the anticipated high volumes of coal ash.

Reclamation of active and inactive mine sites offer benefits beyond that of ash disposal. The ultimate goal is to restore the land to its former productivity. Ash haulback provides an economical and environmentally safe means to achieve that goal. Restored land is an important tool in maintaining a region's eco-balance. Reclamation will provide two long-term benefits: forests and vegetation that will serve as a sink for greenhouse gases, and provide sustainable economic resources for local people. These benefits result from the creation of optimal soil conditions and the establishment of forest cover as the final step in reclamation of the mine sites. The use of coal ash blended soils is a proven technology for improving the quality of the impoverished or poor-quality mine spoils, with the result of increased vegetative productivity (Gray and Gray 1998).

Placement of ash in open cast and underground mines can provide an efficient, cost-effective method of disposal while at the same time contributing to mine fire abatement, subsidence abatement, mined land reclamation and restoration of the productivity of the land. Returning coal ash to the mines is the *only* presently available technology that can significantly contribute to reducing the quantity of ash otherwise destined for slurry ponds, rivers, and occupied land. Wise natural resource management suggests a reasonable approach to disposal and beneficial use of coal ash is to return it to its original location – *the mine* (Beaver 1987).

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