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AREA-WIDE ENVIRONMENTAL QUALITY MANAGEMENT (AEQM) PLAN FOR DHANBAD-BOKARO AREA

NC/IND/92/033

INDIA

Report

Prepared for the Government of India
under UNDP-financed TSS-1 facility

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Contents

		Page No.
	List of tables	ii
	List of figures	iii
	List of annexures	iv
	List of abbreviations	vi
Executive summary		**1**
Chapter 1	**Introduction**	**5**
	Background	5
	Objective	7
	Approach	7
	Organization of the study	10
	Organization of the report	12
Chapter 2	**Present Conditions**	**13**
	Economic and social conditions	13
	Environmental quality	23
	Summary	45
Chapter 3	**Management Strategies**	**47**
	Introduction	47
	Management Strategy I (circa 2001): planned improvements only	51
	Management Strategy II (circa 2001): planned improvements plus relocation	57
	Management Strategy III (circa 2001): planned improvements and household relocation plus fugitive dust reduction on roads	64
	Summary of capital requirements	69
	Management strategy evaluation	71
	Institutional requirements	73
Chapter 4	**Conclusions and recommendations**	**75**
	Present conditions	75
	Management strategies	76
	Cost analysis	77
	Recommendations	77
	Bibliography	79

List of tables

Page No.

2.1 Coal production in JCF and EBCF in 1992-93, Mt 16

2.2 Inventory of power generation in 1992-93 17

2.3 Performance of washeries (JCF) in 1992-93 21

2.4 Summary of 1992-93 industrial production 22

2.5 Summary of residuals discharge according to human activities - present conditions 25

2.6 Ambient condition classifications for inland waters 27

2.7 Summary of industrial and municipal liquid residuals discharged into stream segments for the post monsoon period 28

2.8 Industrial effluent facilities available 30

2.9 Ambient air quality standards (μg/m^3) 35

2.10 Concentrations of SPM, SO_2 and NO_x in JCF, 8 hour averages (μg/m^3) 35

2.11 Seasonal concentration of SPM (μg/m^3) in JCF 36

2.12 Seasonal average of SPM levels (μg/m^3) in East Bokaro area 37

2.13 Inventory of existing industrial air pollution control measures 38

2.14 Present condition (circa 1991) - estimated sectoral shares of suspended particulate matter (SPM) concentration to ambient air quality 41

2.15 Spatial distribution of households exposure to SPM - present conditions 44

3.1 Coal production plans for 2001-02 (Mt) 48

3.2 Power generation in 2001-02 49

3.3 Capacity and projected production of coal washeries in 2001-02 50

3.4 Summary of residuals discharge according to human activities, circa 2001 - Management Strategy I 53

3.5 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy I 56

3.6 Summary of residual discharge according to human activities, circa 2001 - Management Strategy II (planned improvements plus relocation) 61

3.7 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy II (planned improvements plus relocation) 64

List of tables (contd.)

Page No.

3.8 Summary of residuals discharge according to human activities, circa 2001 - Management Strategy III (planned improvements plus relocation strategy plus fugitive dust reduction on roads) 66

3.9 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy III 69

3.10 Capital requirements till circa 2001 (Million Rupees) 70

3.11 NPV for relocation costs and revenue from mining for the four sites 72

3.12 Cost analysis: NPV and cost per SPM household reduction for the three roads . 73

3.13 Agencies responsible for implementation of the AEQM plan measures 74

List of figures

Page No.

1.1 The AEQM study area 6

1.2 Concept framework for analysis for AEQM 9

1.3 The AEQM study area - structure definition and location 11

2.1 The AEQM area population distribution, 1992 14

2.2 General location of major industries and Jharia and East Bokaro coalfields 19

2.3 Spatial distribution of air quality in the AEQM area, SPM in μg/m^3, annual average, Present Condition (circa 1991) 43

3.1 Spatial distribution of air quality in the AEQM area, SPM contours in μg/m^3, annual average, Management Strategy I (planned improvements) 58

3.2 Spatial distribution of air quality in the AEQM area, SPM, contours (μg/m^3), annual average, Management Strategy II (Management Strategy I plus relocation strategy) 63

3.3 Spatial distribution of air quality in the AEQM area, suspended particulate matter, SPM in μg/m^3, annual average, Management Strategy III (total abatement measures: planned improvements plus relocation plus fugitive dust suppression) 68

List of annexures (*not attached*)

2.1 The present public roads network in the JCF
2.2 Roads constructed by BCCL under HIRAK project
2.3 Details of existing railway sidings in BCCL
2.4 Present conditions (circa 1991) - basic data cell group summaries
2.5 Present conditions (circa 1991) - basic data and residual generation - cell-wise
2.6 List of tributaries and nallas with their origins and confluence points with Damodar river and sources of pollution
2.7 Industrial effluent characteristics from coal washeries
2.8 Industrial effluent treatment facilities available
2.9 Major Cities/Towns Which Discharge Domestic Wastewater into the River Damodar
2.10 Details of fire projects in the JCF
2.11 Present conditions (circa 1991) - number of households exposed to various concentrations of air pollution (spatial distribution)
2.12 Present condition (circa 1991) - estimated sectoral shares of suspended particulate matter (SPM) contribution to ambient air quality

3.1 Alternative stowing materials
3.2 Modernization schemes under implementation
3.3 New roads planned and under construction in HIRAK project
3.4 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - basic data cell group summaries
3.5 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - basic data and residual generation - cell-wise
3.6 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - time pattern of solids handled and disposed of during time period 1991-2001
3.7 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - number of households exposed to various concentrations of air pollution (spatial distribution)
3.8 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - Mortality calculations of expected number of lives prolonged
3.9 Future conditions (circa 2001) - Management Strategy I (Planned Improvements) - estimated sectoral shares of suspended particulate matter (SPM) contribution to air quality
3.10 Future conditions (circa 2001) - Management Strategy II (Planned Improvements + Relocation) - basic data cell group summaries
3.11 Future conditions (circa 2001) - Management Strategy II (Planned Improvements + Relocation) - basic data for residual generation - cell-wise
3.12 Future conditions (circa 2001) - Management Strategy II (Planned Improvements + Relocation) - time pattern of solids generation and disposal during time period 1991-2001

List of annexures (contd.)

3.13 Future conditions (circa 2001) - spatial distribution of population exposure to air pollution, SPM, Management Strategy II (Planned Improvements + Relocation) and coamprisons with Management Strategy I (Planned Improvement) and present (circa 1991)
3.14 Future conditions (circa2001) - Management Strategy II (Planned Improvements + Relocation) - estimated sectoral shares of suspended particulate matter (SPM) contribution to air quality
3.15 Future conditions (circa 2001) - Management Strategy III (Planned Improvements + Relocation + Fugitive Dust Control) - basic data cell group summaries
3.16 Future conditions (circa 2001) - Management Strategy III (Planned Improvements + Relocation + Fugitive Dust Control) - basic data for residual generation - cell-wise
3.17 Future conditions (circa 2001) - Management Strategy III (Planned Improvements + Relocation + Fugitive Dust Control) - time pattern of solids generation and disposal during time period 1991-2001
3.18 Future conditions (circa 2001) - Management Strategy III (Planned Improvements + Relocation + Fugitive Dust Control) - number of households exposed to various concentrations of air pollution
3.19 Future conditions (circa 2001) - Management Strategy III (Planned Improvements + Relocation + Fugitive Dust Control) - Mortality calculations of expected number of lives prolonged
3.20 Future conditions (circa 2001) - Management Strategy III (Planned Improvements) - estimated sectoral shares of suspended particulate matter (SPM) contribution to air quality

List of abbreviations

a	-	annum
ACC	-	Associated Cement Companies
ACD.	-	Acidity
AEQM	-	Area-wide Environmental Quality Management
Alk.	-	Alkalinity
B	-	Boron
BAU	-	Business As Usual
BCCL	-	Bharat Coking Coal Limited
BIT	-	Bihar Institute of Technology
BOD	-	Biochemical Oxygen Demand
BSL	-	Bokaro Steel Plant
BSPCB	-	Bihar State Pollution Control Board
BTPS	-	Bokaro Thermal Power Station
Ca	-	Calcium
$CaCO_3$	-	Calcium carbonate
CCL	-	Central Coalfields Limited
CCWO	-	Central Coal Washeries Organisation
CEA	-	Central Electricity Authority
CESC	-	Calcutta Electric Supply Corporation
CFRI	-	Central Fuel Research Institute
Cl.	-	Chlorine
CMPDIL	-	Central Mine Planning and Design Institute Limited
CMRI	-	Central Mining Research Institute
CO	-	Carbon monoxide
COD	-	Chemical Oxygen Demand
CPCB	-	Central Pollution Control Board
Cr	-	Chromium
CRRI	-	Central Road Research Institute
CTPS	-	Chandrapura Thermal Power Station
Cu	-	Copper
d/s	-	down stream
DALY	-	Disability - Adjusted Life Years
DO	-	Dissolved Oxygen
DST	-	Department of Science and Technology
DVC	-	Damodar Valley Corporation
ESP	-	Electrostatic Precipitator
F	-	Flouride
FBC	-	Fluidised Bed Combustion
FCI	-	Fertiliser Corporation of India
fE	-	Iron
FTU	-	Fugitsu Turbidity Units

List of abbreviations (contd.)

GCV	-	Gross Calorific Value
GOI	-	Government of India
GW	-	Gega Watt = 10^3 mega watt
GWH	-	Gega Watt Hour
H_2S	-	Hydrogen Sulphide
ha	-	hectare
HCO^3	-	Bi-carbonate
HEMM	-	Heavy Earth Moving Machinery
I	-	Industrial
ICI	-	Imperial Chemicals Industries
IISCO	-	Indian Iron & Steel Company
IRC	-	Indian Road Congress
ISM	-	Indian School of Mines
JCF	-	Jharia Coalfields
K	-	Pottasium
kCal/kg	-	kilocalories per kilogram
kg/t	-	kilogram per tonne
kg	-	kilogram
kg/day	-	kilogram per day
km	-	kilometre
kmph	-	kilometre per hour
kWh	-	kilowatt hour
LVMC	-	Low Volatile Medium Coking
m	-	meter
m^3/hr	-	cubic meter per hour
MADA	-	Mineral Area Development Authority
mg/Nm^3	-	milligram per normal cubic meter
mg/lt	-	milligram per litre
Ml	-	Million litre
mm	-	milli meter
Mm^3	-	Million cubic metre
Mn	-	Manganese
MoEF	-	Ministry of Environment and Forests
Mt	-	Million tonne
Mt/a	-	Million tonne per annum
MW	-	Mega Watt
NA	-	Not available
NEERI	-	National Environmental Engineering Research Institute
NH	-	National Highway
NH_3	-	Ammonia
NO_3	-	Nitrate

List of abbreviations (contd.)

NO_x	-	Nitrogen Oxides
NTPC	-	National Thermal Power Corporation
OC	-	Open Cast
PAH	-	Poly Aromatic Hydrocarbons
Pb	-	Lead
PLF	-	Plant Load Factor
PM	-	Particulate matter
PO_4	-	Phosphate
ppm	-	parts per million
PWD	-	Public Works Department
R	-	Residential
R&D	-	Research and Development
S	-	South
SAIL	-	Steel Authority of India Limited
SCC	-	Semi coking coal
SiO_2	-	Silicon dioxide
SO_2	-	Sulphur Dioxide
SO_4	-	Sulphate
SPM	-	Suspended Particulate Matter
sq km	-	Square kilometer
SSF	-	Special Smokeless Fuel
t/day	-	tonne per day
t	-	tonne
t/hr	-	tonne per hour
TDS	-	Total Dissolved Solids
TERI	-	Tata Energy Research Institute
TH	-	Total Hardness
TISCO	-	Tata Iron and Steel Company Ltd.
TRC	-	Total Residual Chlorine
TS	-	Total Solids
TSP	-	Total Suspended Particulate
TSS	-	Total Suspended Solids
u/s	-	under stream
UNIDO	-	United Nations Industrial Development Organization
USEPA	-	United States Environmental Protection Agency
$\mu g/m^3$	-	microgram per cubic meter
µs/cm	-	micro siemens per centimeter
W	-	West
WBPDC	-	West Bengal Power Development Corporation
WBSEB	-	West Begal State Electricity Board
Zn	-	Zinc

Executive Summary

An Area-wide Environmental Quality Management (AEQM) plan for the Dhanbad-Bokaro area in Eastern India has been prepared to assess the impacts of industry and other human activities on environmental quality and to structure a set of management strategies to improve iti

The area studied covered approximately 2600 sq km with an estimated population of 2.2 million inhabitants. The area is characterized by large-scale coal mining operations, power generation, major industries such as steel and fertilizer, a number of small beehive coke ovens, soft coke "bhattas" and domestic coal burning. These activities have existed for many years and have resulted in wide-spread environmental degradation. The major reasons for deterioration of the environment are increased levels of economic activity (mostly coal mining), an increase in population and lack of adequate control measures. The main findings have been organized in three categories: present conditions, future conditions and conclusions and recommendations.

Present Environmental Conditions

Present economic and social conditions have created a very degraded environment. Evidence of land, air and water pollution is apparent in most parts of the area and the health risk to the local population, especially from high concentrations of suspended particulate matter (SPM) in the air, is probably serious. Industrial wastewater containing both dissolved and suspended solids pollutes the river year round; during the pre-monsoon and post-monsoon periods it is the dominant pollution source of the surface water. Non-point source runoff from both urban and rural areas combine with industrial pollution during the monsoon period.

Air quality

Major air quality problems exist in the mining areas, namely, Jharia Coalfield (JCF) and East Bokaro Coalfield (EBCF) and their immediate vicinity, where approximately 1.5 million people reside. In many locations, SPM exceeds standards with levels two to three times those allowable. However, sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) are well within the limits. The reasons for high SPM are:

- Fugitive dust caused by the movement of vehicles in open-cast mines, colliery roads and public roads;
- Poorly controlled discharges from power plants; and
- Burning of coal for domestic purposes, soft coke manufacture and other coal uses.

Water quality

Major water quality problems occur in stretches of the river Damodar and its tributaries. These arise from the discharge into the river of both dissolved and suspended solids in untreated or partially treated industrial and urban wastewater causing water-based diseases, loss of aquatic life, and increase in the accumulation of sediment. Stretches of poor river quality found near Bokaro Thermal Power Station (BTPS) and Chandrapura Thermal Power Station (CTPS) are caused by ash slurry, coal fines discharges and rejects from washeries. These stretches are characterized by high total suspended solids (TSS) and chemical oxygen demand (COD). These water quality problems are seasonal. The dominant problem during pre-monsoon and post-monsoon periods is the high TSS and COD loading from a few power plants and coal washeries. Municipal loads are not significant during these periods. Although no actual measurements of the main stream were taken during the monsoon period, a major contribution to annual river pollution is likely from non-point source runoff.

Solid wastes

Solid wastes associated with mining (overburden and extraneous matter in coal) is probably several orders of magnitude larger than that from households. The generation of waste is concentrated in one section of the study area, which contains the highest concentration of both households and mining activities. Other solid wastes are ash from power plants, rejects from washeries and domestic waste from towns. These wastes are currently scattered or dumped near the sites of production.

Land

Land surfaces in the mining areas have been degraded from past and present mining operations. The total mining area is about 130 sq km of which about 70 sq km is damaged or degraded due to fire, subsidence and overburden dumps. Additional land is occupied by washery rejects and coal stocks.

Management Strategies

Economic growth in the study area is expected in coal mining, washing, transport and power generation. Because of increased population, transportation and construction are expected to increase. A time period of ten years has been chosen for the future plan (circa 2001) and three different management strategies are proposed.

Management Strategy I confirms the need for additional abatement currently being installed, such as electrostatic precipitators for power plants and closed water circuits in washeries. Environmental degradation would be much worse without these measures because more residuals are predicted with increased coal and power production. Air quality, primarily SPM levels, will deteriorate in some sections due to increased mining. However, overall there is a marginal improvement in environmental health although the health risk to a large segment of the population would continue to be serious. Water quality problems would continue although declines in TSS are predicted in East Bokaro due to improvements in washeries, a new ash pond in BTSP and an expansion of ash pond capacity in CTPS. Household solid wastes are expected to increase in direct proportion to the population increase. The ash discharge from power stations will increase due to an expected improved performance of the plants. Solids associated with mining are not expected to change much. The net disturbed land in the area will decrease from 6800 to 4500 ha due to enhanced land reclamation.

Management Strategy II includes planned improvements (Management Strategy I) plus relocation of 75,000 households of coal company employees from the most polluted cells to colonies on the periphery of the coalfield. Improved health conditions for these people, about 375,000 in number, would be realized since proposed relocation would be in sites having reduced SPM air pollution. As a result of this relocation from atop prime coking coal seams, prime coal production would increase, leading to increased revenues. At the same time, solid waste from mining would increase marginally. Serious human health risks would continue since only a small fraction, about 12 per cent of the study area population, would be relocated. With increases in mining and associated industrial production, water quality problems would persist.

Management Strategy III includes abatement for fugitive dust in addition to activities described in Strategies I and II. Abatement includes improvement in haul roads along with water and chemical spraying in opencast mines and improved colliery and public roads. The environmental results of this strategy are very positive. There would be a drastic reduction in air pollution in the area with approximately 60 per cent of the population exposed to SPM levels of less than 200 $\mu g/m^3$ and the rest exposed only to marginally increased levels. By comparison, under Management Strategies I and II there would be only 9 per cent and 4 per cent of the population respectively, exposed to SPM levels of less than 200 $\mu g/m^3$ and 14 per cent and 8 per cent of the population respectively, exposed to levels above 500 μg/m3.

Cost Estimates

Total investment spread over ten years is estimated at Rs. 8,000 million for abatement measures in Management Strategy I, Rs. 15,000 million for relocation in Management Strategy II and Rs. 7,000 million for improved roads in Strategy III. Three measures, land reclamation, relocation and road improvement, constitute the bulk of the investments. Although costs should be reflected in the price of coal, coal prices are currently administered by the government and do not reflect social costs. Land reclamation and road improvements could be funded through a tax on coal of Rs. 14/t and Rs. 18/t of coal respectively. Population relocation (including new housing) could be funded by surplus revenues from the additional coal sales.

An NPV analysis for these measures shows that relocation (Management Strategy II) generates net positive resources and at the same time improves the environmental health of 75,000 households. Continuation of planned improvements (Management Strategy I) and fugitive dust abatement for roads (Management Strategy III) entail a cost, and their relative effectiveness, vis-à-vis reducing people-exposure to high levels of SPM, has been calculated in terms of cost per unit $\mu g/m^3$-household. The results show that merely continuing planned improvements, some of which are already underway, would result in a slight increase of overall people exposure, but would reduce exposure to the highest levels of SPM. By contrast, reducing fugitive dust would significantly improve air quality. Colliery roads improvement strategy would be most effective in reducing people-exposure, followed by PWD roads improvement and haul roads improvement.

Recommendations for Future Application of AEQM

One of the main objectives of the study was to test the AEQM approach as one way to prepare an integrated plan for a "critically polluted area". As this approach generated scientifically based management strategies for the Dhanbad-Bokaro area, it would appear to have the potential to generate management strategies for other critically polluted areas.

For a successful AEQM study and its implementation, it is of utmost importance that major players actively participate in providing data and help formulate realistic abatement measures in terms of costs and feasibility. Formulation of management strategies is fundamental to the AEQM method and this cannot be independently developed by the AEQM study team.

CHAPTER 1

Introduction

Background

Industrialization has contributed immensely to the economic development of the world, but in its wake has come serious environmental degradation. Since man lives within the environment, development should be such that environmental quality is maintained within safe limits. It is only through integration of environmental considerations into planning and management of industrial development that significant progress can be made towards a sustainable society. Solutions to complex, interrelated problems implicit in sustainability require a holistic approach beyond individual economic interests and single function environmental agencies.

Area-wide environmental quality management (AEQM) is a holistic approach to spatial environmental planning applicable to a specific region. It assesses the impacts of industrial and other human activities on environmental quality and structures a set of management strategies that reflect environmental, economics technology and institutional considerations. These strategies, in turn, should lead to actions by government, industry and the public.

The "Policy Statement for Abatement of Pollution" issued by the Ministry of Environment and Forests (MoEF), Government of India, encourages the use of innovative approaches to achieve environmental objectives. In this respect, the MoEF has targeted eighteen "critically polluted" areas in India for action; the Dhanbad-Bokaro region is one of these areas. The MoEF requested the United Nations Industrial Development Organization (UNIDO) to test the AEQM approach as one way to devise an environmental management plan for the region. UNIDO experts and the Tata Energy Research Institute (TERI) conducted the study.

Special attention has been directed toward the Dhanbad-Bokaro portion of the Damodar river basin. This portion, shown in **Figure 1.1**, covers an area of approximately 2590 sq km and contains a population of about 2.2 million. This is the area covered by the AEQM study.

The Damodar river basin covers an area of 2.32 million ha and is drained by two major river systems, the Damodar and Barakar, and several minor river systems, the Usri, Konar, Bokaro and Gowai. The Damodar river basin extends over six districts of Bihar State and five districts of West Bengal. The upper catchment, containing approximately three-fourths of the river basin area, is located in Bihar, while the low-lying flood plain of the remainder lies in West Bengal state. The Damodar river basin is richly endowed with mineral resources, e.g., coal, mica and bauxite and also contains well-drained fertile lands. Because of rich reserves, the region supplies a major share of the coal mined nationally.

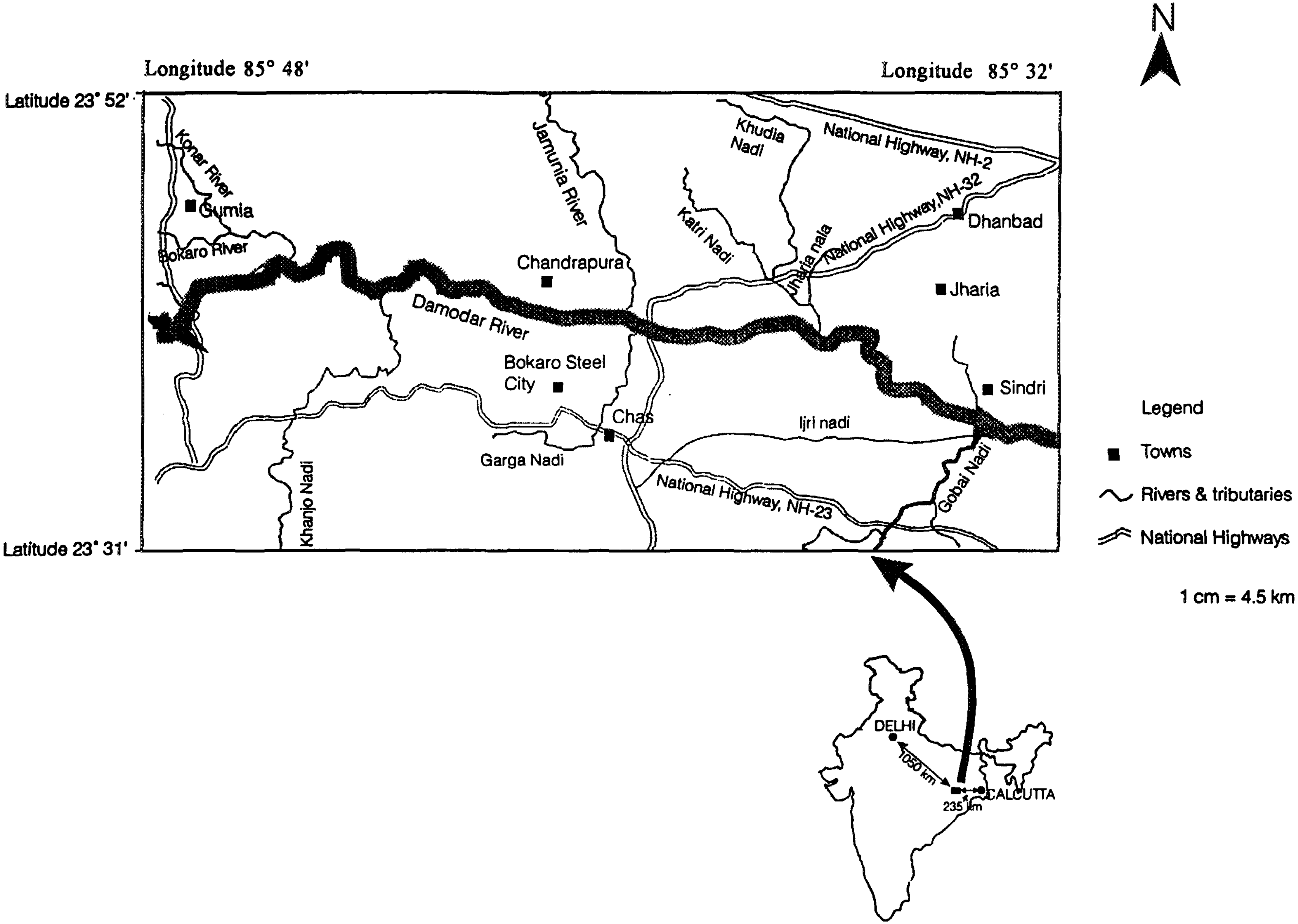


Figure 1.1 The AEQM study area

The Dhanbad and Bokaro districts of Bihar State are characterized by large-scale coal mining operations, power generation and a few major industries like steel and fertilizer manufacture. Coal mining operations have existed for almost a century and mining and associated activities have resulted in large-scale environmental degradation of the area. Land subsidence, mine fires, poor roads and unplanned urbanization dominate the landscape and there are a number of medium- and small-scale industries located there. The emission of pollutants affects air, water and land quality with ambient levels often exceeding standards. Further, there are many small, diffuse sources of pollution, such as household coke ovens and the related use of coke for family food preparation, which contribute to the deterioration of air quality. It is in this context that the present study has undertaken to identify and analyze the impacts of the various human activities on the environment in the area and to devise strategies to mitigate adverse effects.

In a recent review of environmental health at various locations, the World Bank reported in its 1993 World Development Report that two pollutants, SPM in the air and water-borne bacteria in surface and drinking waters, are linked to significant health effects in many places throughout the nation (citation). It stated that India accounted for about 290 million Disability-Adjusted Life Years (DALYs) lost in 1990, approximately 20 per cent of the global total, and that nearly one-third of these losses were due to SPM and water-borne bacteria. Both of these pollutants are abundant in the study area.

Objective

The objective of the study is to prepare an AEQM plan for the Dhanbad-Bokaro region of Bihar. An AEQM plan can guide activities of the Bihar State Pollution Abatement Board (BSPCB) in both assessing the effectiveness and efficiency of its current environmental management strategy for the Dhanbad-Bokaro region and devising alternative environmental management strategies that may be needed to protect human health and the environment. In addition, the AEQM plan can serve as a model for other state pollution control boards in devising strategies for reducing environmental impacts.

Approach

The approach used for this AEQM plan was developed and reported by Bower and others over a period of years (Bower et al 1987). "Producing Information for Integrated Coastal Zone Decisions" (Bower, 1992) was used as the principal reference for structuring the planning process.

The AEQM approach is a powerful problem solving technique for a wide range of environmental situations because it integrates concepts from the fields of ecology, environmental management, technology assessment, economics and political science to identify and evaluate alternative environmental management strategies. While most of these concepts are not difficult to understand, successful completion of an AEQM study may be quite challenging. The need for interdisciplinary analysis stretches many people and organizations, particularly where data are limited, which is often the case in environmental investigations in developing countries.

A basic understanding of the approach may be achieved by focussing on the computational framework used to generate information for AEQM decisions. A computational framework is a set of analyses, either formally linked by an algorithm or linked in the sense that the output of one or several analyses becomes the input into another analysis. A computational framework can be thought of as analogous to a critical path method (CPM) or programme evaluation and review technique (PERT) diagram, either one representing a set of connected activities to produce an output in some specified timeframe. The framework is presented in **Figure 1.2** and is elaborated upon below:

- Segment 1: Setting up the analysis. Defining objectives, making an inventory of present conditions and problems and developing scenarios for analysis;

- Segment 2: Estimating levels and spatial patterns of activities. Choosing target years (approximately 2001 for this study) and making estimates of various human activities at that time, e.g. population growth, industrial production, etc;

- Segment 3: Estimating demand for goods and services from the AEQM area, e.g. estimating the amount of minable coal, the electricity generated and the amount of land needed for population relocation;

- Segment 4: Analyzing activities. Analysis of human activities resulting in water, land and air pollution. In this planning exercise, the focus is on air pollution because it is judged to be the most serious environmental problem in the study area;

- Segment 5: Analyzing natural systems. For this study, the only natural systems modelling will be for the spatial patterns of SPM associated with industry, residences and transportation previously studied in other segments;

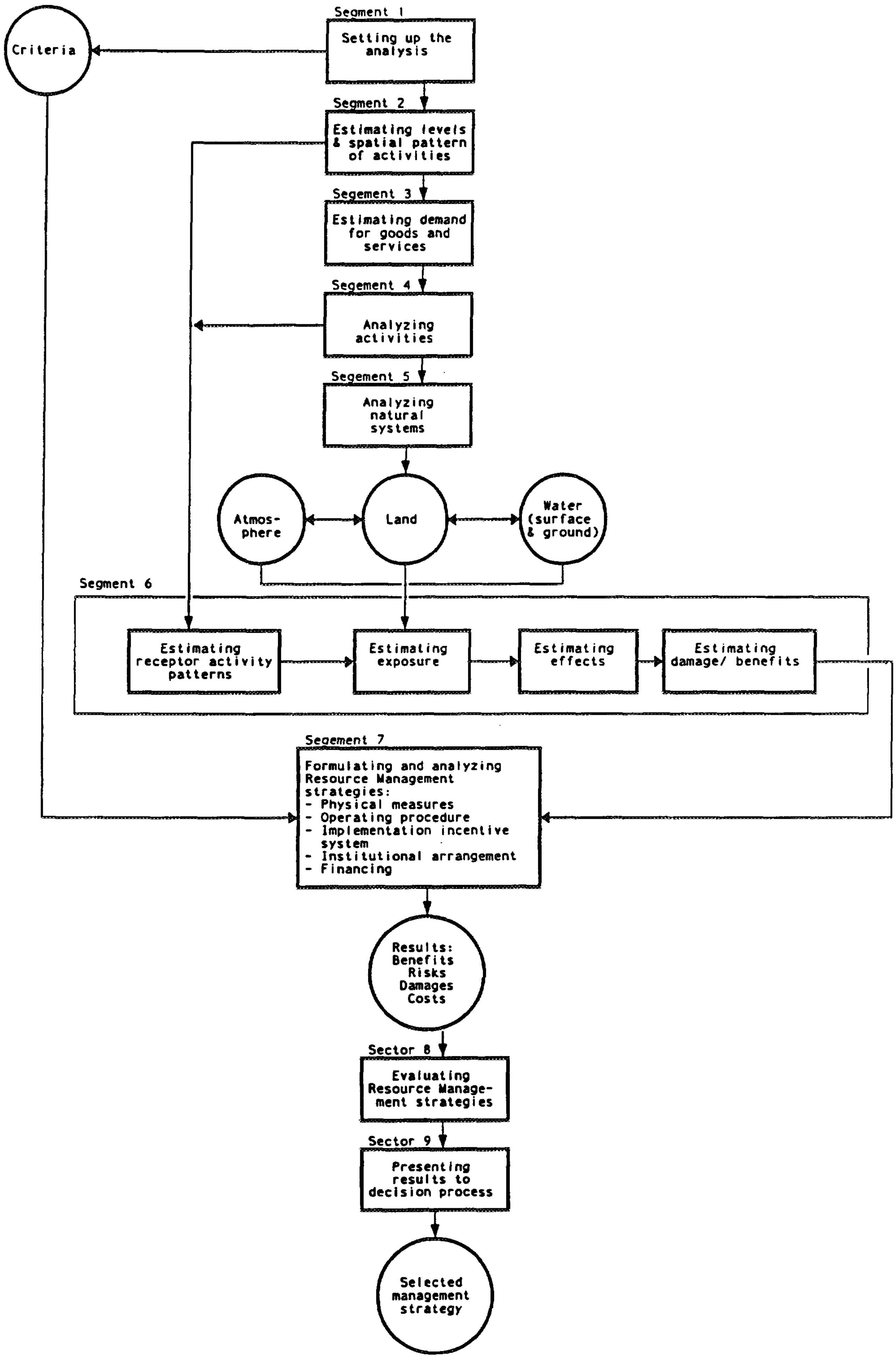
- Segment 6: Estimating receptor activity patterns, exposures, effects, damages and benefits, e.g. the morbidity and mortality of humans working and/or living in the AEQM area;

- Segment 7: Formulating and analyzing environmental management strategies. This would include pollution abatement measures, such as adding fluidized-bed combustors, as well as incentive systems for enforcing regulations, changed institutional arrangements and improved financing programmes;

- Segment 8: Evaluating environmental management strategies that would upgrade the general air, water and land environment under the impact of industry and population demands in order to improve the quality of life;

- Segment 9: Presenting results to the decision-makers in a way that would permit evaluation of the different management strategies and encourage decisions likely to improve environmental quality.

Figure 1.2 Conceptual framework for analysis for AEQM



The data assembled for the various segments of the computational framework were organized within eight primary land areas, called cells, measuring 18 km x 18 km. These were sub-divided into smaller cells wherever land use or pollution changes justified more detailed analysis. A total of twenty cells was selected for the study area of 2590 sq km. **Figure 1.3** shows the AEQM study area, cell definition and location.

By and large, the approach described above was followed, although improvisations were necessary due to data limitations. A major problem was estimating the generation of identified pollutants from many sources. For example, SPM emitted from open mine fires or fugitive dust from overburden or washery dumps cause significant air pollution in some locations, but was extremely difficult to quantify. This limitation, in turn, made it difficult to calibrate an air pollution model with existing air quality data that would be useful in predicting air quality improvements resulting from future abatement measures. Further, ash ponds/ash handling systems discharge huge quantities of ash sporadically into the river and some coal washeries discharge large quantities of coal fines intermittently. In these cases little can be gained by estimating discharges and applying a water quality model.

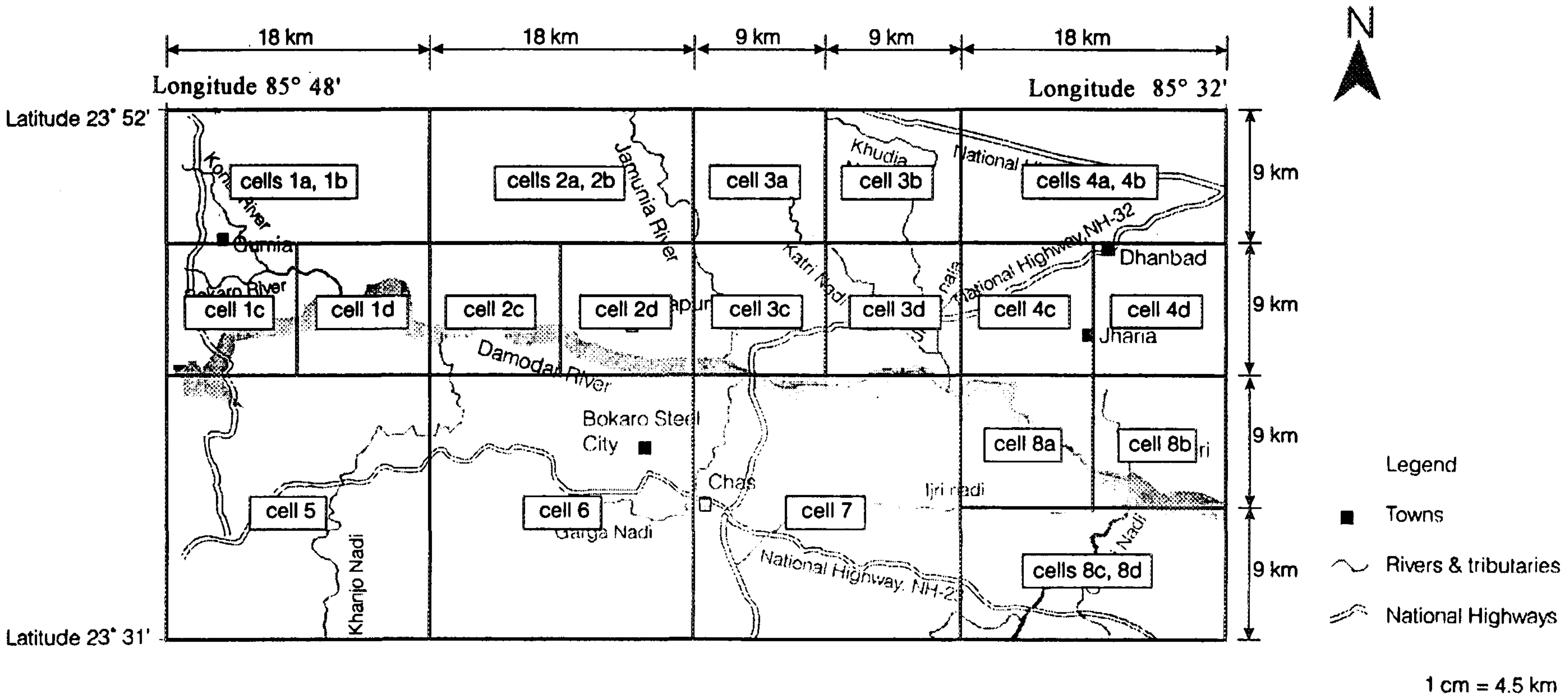
Organization of the study

A steering committee was constituted, headed by the Chairman of BSPCB, to carry out the study. The steering committee met in January, July, and September 1993 and May 1994. A draft report submitted in May 1994 was discussed in the Steering Committee meeting held the same month. A second draft was completed in January 1995. Comments received from UNIDO and other organizations were considered during preparation of this final draft report. A third and final draft was submitted to UNIDO in January 1996.

The TERI study team worked closely with BSPCB, Bharat Coking Coal Limited (BCCL), Damodar Valley Corporation (DVC), Indian School of Mines (ISM), Tata Iron and Steel Company (TISCO) and other organizations in the study region.

Preliminary visits to the study area were made by UNIDO in 1992, by the TERI staff in August 1992 and others of the study team in January 1993. Subsequently, monthly visits were made for data collection and discussions with concerned authorities. The companies visited were BCCL mines and washeries; TISCO mines, washeries and power plants; Central Coalfields Limited (CCL) mines in East Bokaro; Bokaro Steel Plant (BSL); Fertilizer Corporation of India (FCI); Associated Cement Companies (ACC); Imperial Chemical Industries (ICI); bee-hive and by-product coke ovens; briquetting plants; Damodar Valley Corporation (DVC) power plants (located at Bokaro and Chandrapura); and other industries. Also, local organizations at Dhanbad such as the Coal Mining Area Development Authority (CMADA); the Central Mining Research Station (CMRS) and the Central Fuel Research Institute (CFRI) as well as the Central Mine Planning and Design Institute (CMPDI) in Ranchi were contacted to collect relevant information. Visits were also made to DVC headquarters in Calcutta, the DVC office in Maithon and the BSPCB office in Patna.

The MoEF was kept informed of study progress and discussions were held with concerned officials about technical matters and the formulation of the proposed management strategies.



Note: The spatial analysis was organized with eight primary land areas, 18 km x 18 km, called cells. They, inturn were subdivided into smaller cells whereever the land use or pollution changes justified a more detailed analysis. A total of twenty cells were selected as shown. The study area is 2592 square km.

Figure 1.3 The AEQM study area - structure definition and location

Organization of the report

Chapter 2 describes present conditions, including economic and social features, environmental quality, and related standards for air, water and solids. The present, or baseline time period, was defined as 1989-1993.

Chapter 3 describes one future scenario ten years in the future (circa 2001) and three different management strategies. The future scenario accepted existing projections for population growth, industrial production, land use and generation of water, land and air residuals. Management Strategy I, the conventional environmental regulatory programme currently being implemented by the BSPCB, assumes that existing facilities for abatement of environmental pollution would be effective and new facilities already under construction would be completed and operated effectively. Management Strategy II includes all activities in Management Strategy I plus one major addition; approximately 75,000 households, composed of employees of two mining companies, Bharat Coking Coal Limited (BCCL) and Central Coalfields Limited (CCL), would be relocated to new communities outside the coalfields. Management Strategy III includes all activities in Management Strategies I and II plus additional measures to reduce SPM, which appears to be the most serious environmentally-induced health problem. It adds abatement of fugitive dust emanating from the three types of existing roads: haul roads (in opencast mines), colliery and public roads (PWD).

Chapter 4 summarizes the findings from the study and makes recommendations for undertaking AEQM studies in other geographic areas.

CHAPTER 2

Present Conditions

Economic and social conditions

Population and population distribution

The study area is located in the districts of Dhanbad and Bokaro in the state of Bihar. The population was estimated at 3.4 million in 1992; it increased from 1.8 million in 1971 to 2.7 million in 1981 and to 3.4 million in 1992. The average annual growth rate for 1971-81 was 4 per cent; for 1981-92 it was 2 per cent. The share of urban population in 1992 was 46 per cent with most of the urban settlements situated in and around the mining area. There are 24 cities/towns in the area with a population of more than 25,000; of these, Bokaro Steel City, Dhanbad and Gomia have populations exceeding 100,000. The density of population (persons/sq km) in Dhanbad district increased from 480 in 1971 to 790 in 1981 and 890 in 1991. Between 1971 and 1981 there was a boom town effect in Dhanbad because of an expansion in coal mining activities resulting in a population growth rate of 4.7 per cent per annum and a population density increase of 65 per cent.

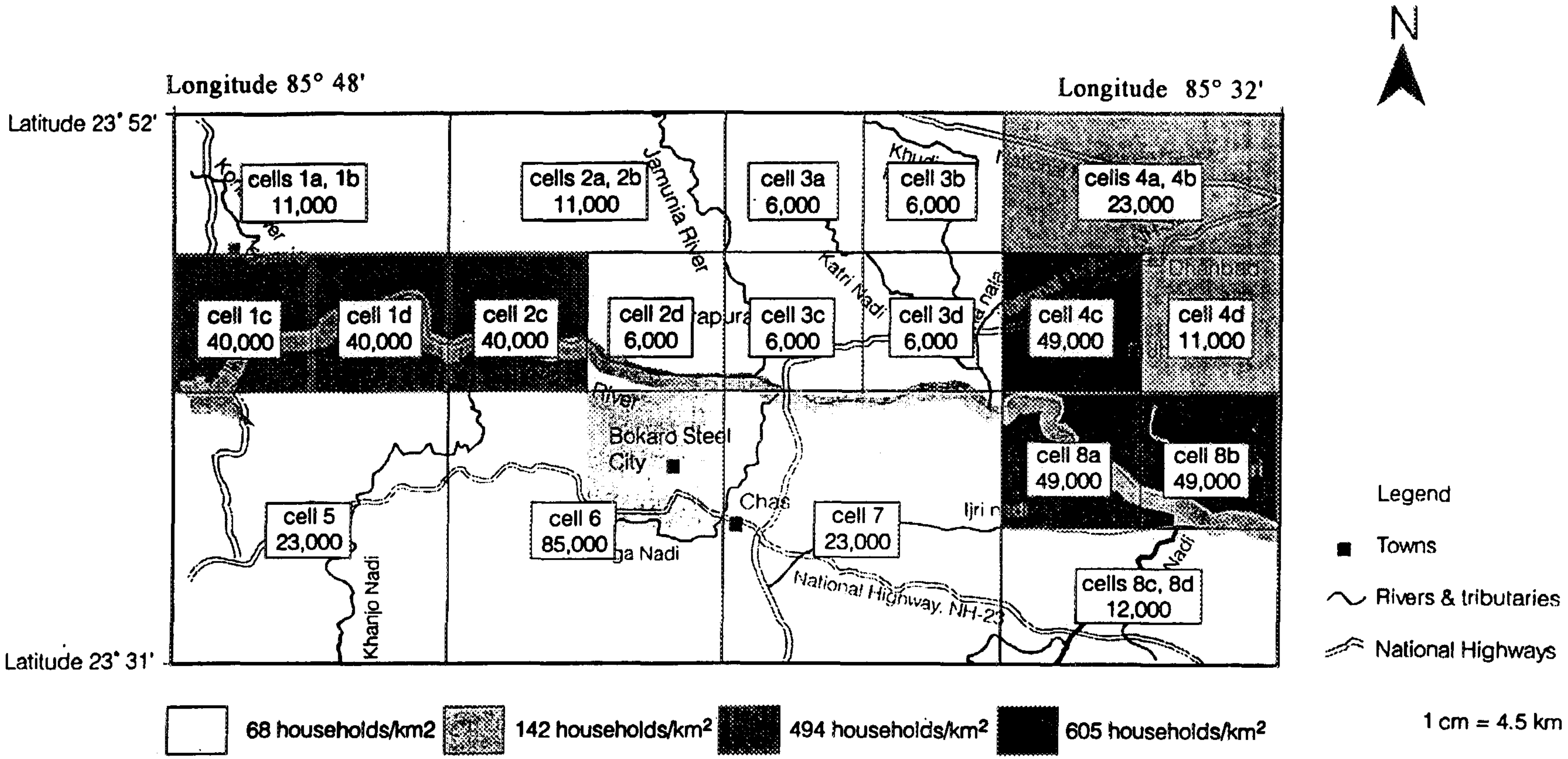
The 1992 population of the AEQM study area, a segment of the Dhanbad and Bokaro districts, was 2.2 million. The area-wide population density is shown in **Figure 2.1** with densely populated areas coinciding with coal mines and related industry.

Mining

Jharia coalfield (JCF)

Coal mining in the JCF sub-area started in the 1890s. Mining was then in the private sector and investments were low because most mining operations were in the outcrop area with coal seams close to the surface. Leaseholds were small and operations were very unscientific. Haphazard and unscientific methods used to mine the prime coking coal, with no regard to safety and conservation, compelled the government to nationalize the coal industry in two stages: coking coal mines in 1971 and all other coal mines in 1973. Now all coal mines in JCF, except captive mines under the Tata Iron and Steel Company (TISCO), are operated by BCCL, a government company. JCF produces prime coking coal for the steel industry and is the only repository of prime coking coal deposits in the country.

Figure 2.1 The AEQM area population distribution, 1992



Note: 1. See **Figure 1.1** for location map

2. Population figures are households
Estimate 1 household contains five people, or 2,480,000

3. Actual 1992 population was 2,200,000 (the difference is due to approximated spatial distributions).

The total coal reserves in JCF (up to a depth of 1200 meters) are estimated at 19,5000 Mt, with 70 per cent of these reserves in the proven category. Prime coking coal reserves are estimated at 5,300 Mt, approximately 27 per cent of the total JCF reserves.

East Bokaro coalfield (EBCF)

The development of coal mining in the EBCF sub-area started in 1908. Although the entire production was used by the railways in steam locomotives prior to independence, growth of the steel industry in the country in the post-independence era led to their use of these medium coking coals. The coalfield is managed by CCL, a government-owned company.

Total coal reserves in the EBCF are estimated at 5,685 Mt with 40 per cent of these reserves in the proven category. Medium coking coal reserves constitute 5,580 Mt, approximately 98 per cent of the total EBCF reserves.

Coal production

JCF

More than 110 collieries are operated in this coalfield by three companies, Bharat Coking Coal Limited (BCCL), TISCO and the Indian Iron and Steel Company (IISCO). BCCL has the largest number of mines (> 100) followed by TISCO (6 mines) and IISCO (2 mines). Those mines operated by TISCO and IISCO are all underground whereas BCCL operates both opencast and underground mines. The annual production of coal from this field has increased from 18 Mt in 1974-75 to about 27.6 Mt in 1992-93 with 58 per cent of the production from opencast mines (**Table 2.1**). Approximately 60 per cent of JCF's production is high ash, low volatility coking coal (unsuitable for steel making) and non-coking coal.

EBCF

There are 18 opencast and 8 underground mines operating in this coalfield with annual production more than doubling in the last two decades, from 5.4 Mt in 1974-75 to 11.9 Mt in 1992-93 (**Table 2.1**). However, the production of washery-feed, medium coking coal is unchanged and the increase is from high ash, medium coking coal, which is unacceptable for steel making. In 1992-93, about 90 per cent of the coal production was from opencast mines. Apparoximately 50 per cent of EBCF's production is high ash, low volatility coking coal (unsuitable for steel making) and non-coking coal.

River Sand

Stowing material is required to fill voids created in underground mines to prevent surface subsidence. Sand has been recognized as the best material for underground stowing due to its physical characteristics. Other materials like crushed stone, washery rejects and bottom ash from power stations have been used in small quantities in some mines. The sources of sand supply to the JCF are the Damodar and Barakar rivers. Sand winning, mining of the river bed and transportation to the mines are important supporting industries in the area ensuring underground coal production.

Table 2.1 Coal production in JCF and EBCF in 1992-93, Mt

By Technology	Underground			Opencast	Total
BCCL	9.8			15.9	25.7
TISCO	1.4			-	1.4
IISCO	0.5			-	0.5
Sub-total JCF	11.7			15.9	27.6
EBCF	1.2			10.7	11.9
Total	12.9			26.6	39.5
By Type	Coking coal			Non-coking coal	Total
	Prime	Medium washery grade	Non-washery grade		
BCCL	8.0	0.7	11.7	5.3	25.7
TISCO	1.4	-	-	-	1.4
IISCO	0.5	-	-	-	0.5
Sub-total JCF	9.9	0.7	11.7	5.3	27.6
EBCF	Nil	5.5	6.4	-	11.9
Total	9.9	6.2	18.1	5.3	39.5

Power sector

The eastern regional power system covers the states of Bihar, Orissa, West Bengal and Sikkim. The installed capacity in the region as of March 1993 was 7,758MW; 7,420 MW was thermal-based and 338 MW was hydro-based. Reliability of this power supply in the region during the last decade has been extremely poor. On average, power shortages have occurred over 15 per cent of the time, with many residential and commercial establishments relying extensively on small diesel generators to supplement power. Industries have also established captive generating units to meet shortages of power. The average plant load factor (PLF) for the region has been much lower than the national average, ranging between 35-45 per cent.

The power supply in the AEQM study area comes from two utilities and five captive power plants with a total installed capacity of 2,031 MW (**Table 2.2**). In addition, BCCL has about 40 MW of diesel generating capacity at washeries and mines to meet power shortages.

The Bokaro Thermal Power Station (BTPS) of DVC is situated on the banks of Konar river and has a total installed capacity of 820 MW at two stations, Bokaro 'A' and Bokaro 'B'. Bokaro-A has 3x50 MW units and a fourth unit being derated to 40 MW, with a total generating capacity of 190 MW. The first three units were installed in the early 1950s and the fourth in 1960. Bokaro A generated 1,288 GWh in 1992-1993 and consumed 0.53 Mt of coal. The average PLF for the plant declined from 50 per cent in 1984-85 to 37 per cent in 1992-93. According to plant authorities, this decline could be arrested or reversed through renovation and modernization. Bokaro-B has three units of 210 MW each, commissioned between 1986 and 1993. Two units must still be stabilized and the PLF in 1992-93 was only 37 per cent. It generated 688 GWh in 1992-1993 and consumed 1.0 Mt of coal. Since these are new units, performance is expected to improve and PLF to increase to 60 per cent.

Chandrapura Thermal Power Station (CTPS) of DVC is on the eastern edge of the JCF on the banks of the Damodar river. It has six units with a total generating capacity of 780 MW. The first three units were installed in the 1960s and the remaining three units were added between 1974 and 1979. The plant generated 2,011 GWh in 1992-93 and consumed about 1.44 Mt of coal. The average PLF for the plant has declined from 53 per cent in 1984-85 to 29 per cent in 1992-93 with age and operational problems the major reasons for the low PLF. Renovation and modernization are underway to improve performance.

The area has five captive power plants at three locations with a total installed coal-based capacity of 431 MW. TISCO operates three of these captive power plants. Power Houses (PH) 1 and 3 are at Jamadoba and PH-2 at Sijua. PH-1 was installed in 1940 and is the oldest in the area. Its boiler will be replaced in stages by Fluidized Bed Combustion (FBC) boilers. PH-3 is a new plant based on an FBC boiler using washery rejects. The Fertilizer Corporation of India (FCI) operates one captive power plant that was installed in the early 1950s with a total capacity of 80 MW from seven boilers. In 1992-93, the plant generated 194 GWh of power at a PLF of 28 per cent. Coal consumption was 0.4 Mt with a high specific coal consumption of 2 kg/kWh; performance is extremely poor due to age of the plant. Lastly, BSL operates one captive power plant that was installed in the 1970s. It has an installed capacity of 325 MW and generated 806 kWh of power in 1992-93 at a PLF of 28 per cent. In addition, captive power plants based on FCB technology and consuming washery rejects have been installed at Kathara Washery (2 x 10 MW) and at Moonidih Washery (2 x 10 MW). Construction has been completed and trials are underway, but they are not yet fully operational. For this reason they are not included in the inventory.

Table 2.2 Inventory of power generation in 1992-93

Power station	Installed capacity (MW)	Generation (GWh)	Plant Loading Factor (%)
BTPS A	190	688	37.0
BTPS B	630	1288	37.0
CTPS	780	2011	29.0
TISCO (Captive)	26	90	57.0
FCI (Captive)	80	194	28.0
BSL (Captive)	325	806	28.0
Total	**2031**	**5077**	

Industrial sector

Major industries in the study area are an explosive factory at Gomia, an integrated steel plant at Bokaro steel city, fertilizer and cement units at Sindri, and 14 coal washeries at various locations. In addition, there are four by-product coke ovens, more than 100 bee-hive coke ovens, one special smokeless fuel (SSF) plant and many coal briquetting plants. Locations of the major industries are shown in **Figure 2.2.**

Explosive factory, Imperial Chemical Industries (ICI), Gomia

This explosives unit situated at Gomia has the following units: sulphuric acid plant, nitric acid plant, ammonium nitrate plant, explosives plant and steam generation plant. It manufactures explosives, detonators, safety fuses and nitro-cellulose. In the steam generation plant there are three coal-fired boilers with a capacity of five t/hr. Coal consumption in 1992-93 was 15,000 Mt.

Bokaro Steel Plant

This is an integrated iron and steel plant with a design capacity of 4.6 Mt of hot metal, 4 Mt of ingot steel and 3.2 Mt of saleable steel. In 1992-93, hot metal production was 3.8 Mt, crude steel 3.6 Mt and saleable steel 3 Mt. It has the following major units: refractory material plant, sinter plant, coke oven plant, blast furnaces, steel melting shop, steel rolling and hot strip mills and power plants.

Fertilizer unit, Fertilizer Corporation of India, Sindri

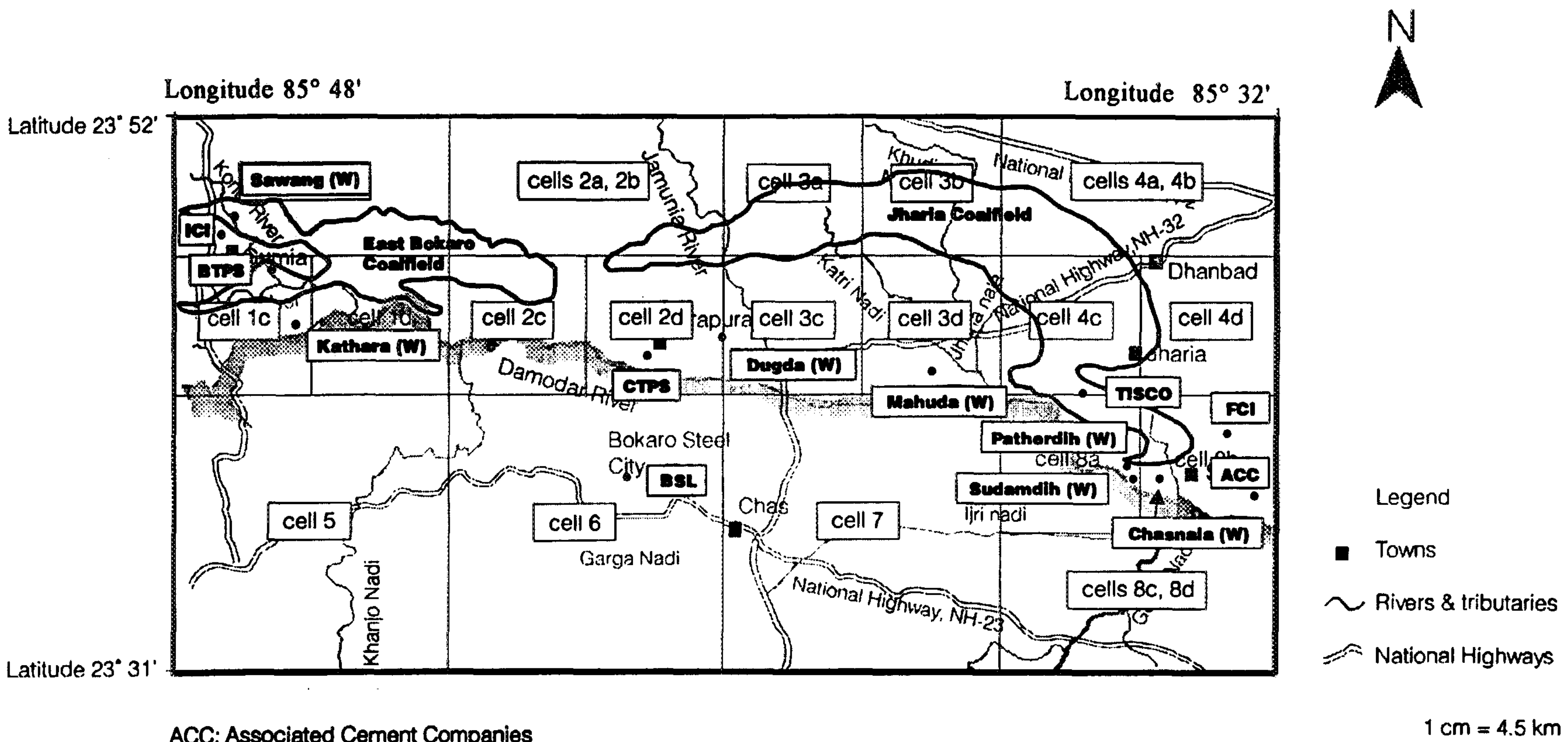
This fuel-oil based fertilizer plant was commissioned in 1953 and modernized in 1979. The steam generation plant has three boilers and total coal consumption during the year was about 350,000 Mt.

Cement plant, Associated Cement Companies (ACC), Sindri

This factory was commissioned August, 1955 with its main product slag cement. Clinker was manufactured at this plant until January 1993 when raw material, particularly calcium carbonate sludge, became unavailable. Clinker is now obtained from another plant. Kilns formerly used to produce clinker have been dismantled and it functions only as a grinding unit with four grinding mills. There are no liquid discharges from the plant. Production capacity is 0.3 Mt per year and during the year 1992-93 the unit produced 0.3 Mt.

Coke manufacturing

Coke production is a major industry in the area, supplying hard coke to the iron and steel industry. Coal is converted into hard coke in both by-product and bee-hive coke ovens.



ACC: Associated Cement Companies
BSL: Bokaro Steel Plant
BTPS: Bokaro Thermal Power Plant
CTPS: Chandrapura Thermal Power Plant
FCI: Fertilizer Corporation of India
ICI: Imperial Chemical Industries
TISCO: Tata Iron and Steel Company (Power Plants & Washery)
W: Washery

Figure 2.2 General location of major industries and Jharia and East Bokaro coalfields

Bee-hive ovens are less capital intensive than by-product ovens and can easily be started or shut down as required. At the time of coal mine nationalization, there were many bee-hive coke ovens and four by-product coke plants in the area. Over the years, a number of bee-hive coke ovens have closed and at present about 100 are operated. Bee-hive coke ovens produced about 1.1 Mt of hard coke during 1992-93. The four by-product coke oven plants are old and are managed by BCCL; they produced about 0.15 Mt of hard coke in 1992-93.

Soft coke is produced in the area by the conventional bhatta method, i.e. open stack burning, with about 1.3 Mt of raw coal required to manufacture 1 Mt of soft coke. Production of soft coke in the JCF area has declined from 1.12 Mt in 1975-76 to 0.12 Mt in 1992-93, mainly due to the unfavourable economics of soft coke manufacture and accompanying environmental pollution. There is one special smokeless fuel (SSF) unit in the Dhanbad area and about 65 briquette units. These produced about 0.8 Mt of smokeless coal fuel in 1992-93.

Coal washeries

Raw coal from the mines contains impurities of two types, external or free dirt and inter-mixed or fixed dirt. The free dirt is comprised of shales, stones, etc., which mix with the coal during mining or may be present in the coal seams as distinct bands of varying thickness. Fixed dirt is inorganic mineral (ash) in the coal. Indian coals are high in ash, therefore, they need to be cleaned to reduce the ash content before being supplied to consumers such as steel plants. In India, coal washing has hitherto been confined mainly to coking coal in order to reduce the ash to the required level for use in steel plants. The products of washing coking coal include (1) clean, low ash coal varying in ash from 17 per cent to 20 per cent for conversion to coke in a steel plant; (2) middling coal, with ash in excess of 35 per cent, used for steam generation in power plants and industrial units; and (3) rejects, with ash in excess of 55 per cent, usually discarded in external dumps and having an adverse impact on the environment. With the development of FBC boilers, rejects are finding use for power generation.

There are 14 washeries with a total installed capacity in 1992-93 of 22.2 Mt. Nine of these are operated by BCCL, three by CCL, one by TISCO and one by IISCO. Four are pithead washeries captive to the coal produced by specific mines, but coal from other mines in the area is also processed to close the gap between mine production and washing capacity. Existing washeries were designed for coking coal that is relatively easy or only moderately difficult to wash and with a maximum ash of up to 26 per cent. Coal supplies have changed over the years, deteriorating in quality as measured by ash content and washability. The yield of clean coal is poor causing a high cost of beneficiation. These problems have been further aggravated due to increased production from lower coal seams with higher ash content in JCF, increased supplies from opencast mines with large amounts of free dirt, boulders and other extraneous materials and increased proportions and deteriorating quality of coal fines smaller than 0.5 mm.

Poor quality raw coal supplied to the washeries has affected yield and quality of washed coal. In addition, capacity is low due to age, inadequate maintenance, power failures and poor management of fine coal. Washeries performance in 1992-93 is given in **Table 2.3**.

Table 2.3 Performance of washeries (JCF) in 1992-93

Washery	Year of commissioning	Capacity (Mt)	Raw coal feed (Mt)	Capacity utilization (per cent)	Clean coal		Middling production (Mt)	Rejects (Mt)
					Production (Mt)	Yield (per cent)		
Prime coking								
Dugda 1	1961	1.8	1.1	58.8	0.5	46.2	0.3	0.2
Dugda 2	1968	2.0	1.1	56.0	0.5	48.3	0.4	0.0
Bhojudih	1962	1.7	1.5	87.3	0.9	63.4	0.0	0.6
Patherdih	1964	1.6	1.0	59.7	0.5	53.6	0.4	0.1
Lodna	1991	0.4	0.7	72.9	0.2	52.2	0.1	0.1
Sudamdih	1981	1.7	0.9	52.9	0.4	48.2	0.4	0.0
Moonidih	1983	1.6	0.9	56.9	0.5	50.0	0.3	0.2
Jamadoba	1952	1.7	1.4	81.4	0.9	65.7	0.2	0.3
Chasnalla	1968	2.0	1.1	55.0	0.6	57.3	0.2	0.2
Total		**14.5**	**9.3**		**5.1**		**2.3**	**1.7**
Medium coking								
Barora	1982	0.4	0.3	67.5	0.1	46.4	0.1	0.1
Mahuda	1990	0.6	0.4	61.9	0.3	71.3	0.1	-
Total		1.1	0.7		0.4		0.2	0.1
JCF		**15.5**	**10.0**		**5.5**		**2.6**	**1.8**
Medium coking								
Kargali	1960	2.7	2.5	92.0	1.4	54.0	0.7	0.5
Kathara	1963	3.0	1.9	64.0	0.9	46.0	0.6	0.5
Sawang	1970	1.0	1.1	-	0.7	65.0	0.3	0.1
Total EBCF		**6.7**	**5.5**		**3.0**		**1.5**	**1.1**
Total		**22.20**	**15.5**		**8.5**		**4.1**	**2.9**

In summary, production of major industrial products in 1992-93 from the various industrial activities is given in **Table 2.4**.

Table 2.4 Summary of 1992-93 industrial production

Plant and location	Major items	Production (Mt)
Coke-Ovens	By-product coke	0.15
	Beehive coke	1.12
Soft coke	Bhatta method	0.12
	SSF/Briquette	0.80
Coal washeries	Clean coal	8.48
	Middling coal	4.12
ICI, Gomia	Explosives	0.04
	Detonator (million nos.)	69.00
ACC, Sindri	Cement	0.30
FCI, Sindri	Ammonia	0.30
	Urea	0.33
Bokaro Steel Plant, Bokaro City	Hot metal	3.85
	Crude steel	3.59
	Saleable steel	3.00

Transport sector

After nationalization, there was a substantial increase in coal production and transport. To facilitate bulk transport in the JCF area, the Indian Railways changed from a system of piece-meal placement of wagons at the numerous colliery sidings (where manual loading of coal was done) to full train (rake) loading from selected sidings. Numerous small sidings were removed and a number of new facilities created by reconstructing old sidings. This resulted in increased road transport of coal from pit-head to railway sidings, washeries, etc. and increased movement of materials (cement, bricks, steel, etc.) into the collieries. In addition, there has been a substantial increase in the population of the area resulting in increased passenger and freight traffic. In the East Bokaro area, increased coal production has increased road transport, moving coal from pithead to washeries and railway sidings.

Road network in JCF

The road network in the area can be broadly categorized into mine and public roads. The mine roads (mostly unpaved) are mainly used to move coal from production point to dispatch or consumption points and to move men and material within the mining area. The total length of mine roads is estimated to be about 200 km. Public roads are classified as National Highways, State Highways and Public Works Department (PWD) and district roads. The public road network within the study region is about 347 km in length; there are three national highways and the rest are PWD roads. Details of the public road network are presented in **Annexure 2.1**.

In the 1980's, BCCL began construction of new ring roads around the coalfield to facilitate movement of vehicles to operating mines. In addition, construction was begun on some existing roads. The Border Roads Organization of the government of India was given responsibility for construction of these roads under the project code "HIRAK." A total length of 104 km was constructed up until 1992-93, at an estimated cost of Rs. 384 million. Details are given in **Annexure 2.2**.

Railway network in JCF

JCF is encircled by railway tracks, namely Grand Chord (Eastern Railway between Gomoh - Dhanbad) on the northern side, Jharia Extension (South-Eastern Railway between Bhojudih - Talgoria) on the southern side, Pradhankhanta - Patherdih Chord on the east and Gomoh - Chandrapura on the west. About 73 railway sidings cover the collieries to facilitate loading of coal. Details are given in **Annexure 2.3**.

Environmental quality

Introduction

Since the nationalization of mines in 1971-73, the area has sustained a high rate of growth in coal production. In addition, a steel plant was constructed in Bokaro steel city in the 1970's which reached a production of almost 4 Mt of crude steel in 1992-93. The increase in coal and steel production has increased many related activities like coal transportation, coal washeries, workshops and garages for vehicle repair and maintenance, public and private transport and other commercial establishments. This rapid growth has been accompanied by a deterioration in the quality of the environment (air, water and land), particularly in the urban areas. The generation of residuals from various activities has increased many times in the last two decades causing serious pollution problems.

Climate

The general climate of the area may be broadly described as that of the tropical monsoon belt. The four seasons are Winter (December to February), Summer or Pre-Monsoon (March to May), Monsoon (June to September), and Post-Monsoon (October to November). The temperature ranges from as low as 5°C in January to 48°C in May-June. The relative humidity is highest during the monsoon months when it varies between 60 and 100 per cent, but in summer the relative humidity is as low as 14 per cent. The predominant wind direction in January is from the West, in April it is from South-West and West, in July from South-East and in October the predominant winds are North-Westerly. The average wind speed ranges from 6.1 km/h in December-January to 9.2 in May-June-July. The annual rainfall varies from 1,197 mm to 1,382 mm and 80 to 85 per cent of the rain occurs during the monsoon months.

Topography and drainage

The general location of the Jharia and East Bokaro coalfields is shown in **Figure 2.2**. In the Jharia coalfield, the ground elevation varies from 240 m above sea level in the western part to 140 m in the south-east. The general slope is towards the south and south-east. The peripheral region of the coalfield is characterized by small sandstone ridges and rather uneven topography; the rest of the coalfield, although uneven in topography, is characterized by a general absence of hilly terrain or ridges. The original topography of the area now occupied by the coalfield has changed considerably due to mining, including surface subsidence, opencast mining, overburden dumps and fires. As a consequence, depressed local elevations, some major, occur all over the coalfield. The Damodar river, which receives the drainage of the Jharia coalfield, flows along the southern periphery. A number of streams, namely Jamunia, Khudia, Katri, Ekra, Tisra, etc. which join the Damodar at different points, also effect the drainage.

The East Bokaro coalfield is drained by three prominent rivers, the Bokaro, Konar and Damodar. A major part of the area is drained by the Bokaro river which flows along the central part of the coalfield and joins the Konar river near the BTPS. These are fed by a network of small streams and nallahs (drainage ditches), among which the Karo and the Godo nallahs figure prominently. A dam is located on the river Damodar at Tenughat at the south-western side, supplying the water requirements of Tenughat Power Station and Bokaro Steel Plant.

Further characterization of the environmental situation is organized according to the three types of pollutant receptors -- water, land and air. **Annexure 2.4** describes the level of household, mining and industrial activities in each of the twenty cells described in **Figure 1.3**. **Annexure 2.5** is a detailed inventory of activities and residuals discharge. A summary of the information in these two annexures is presented in **Table 2.5**.

Water

Ambient water quality standards

There are both national and state standards for water; state standards may not be less stringent than the national standards. There are both discharge and ambient standards for surface water. The one for ambient conditions for inland water reflects different use patterns (**Table 2.6**).

Water quality in the study area

The Damodar river and its tributaries (Bokaro, Konar, Jamunia) are major sources of water in the study area (see **Figure 1.1**). Most industries draw from these rivers. The list of tributaries and nallahs with their origins and confluences with the Damodar and sources of pollution are given in **Annexure 2.6**. The Damodar valley receives intense rainfall during the monsoon, causing large runoff and vigorous stream flows. Soil erosion from this runoff and quantities of fly ash and coal fines discharged from thermal power stations and coal washeries have resulted in heavy silting in the river bed. In several stretches, the river has become very shallow due to deposits of soils, fly ash and coal fines.

Table 2.5 Summary of residuals discharge according to human activities - present conditions

Cell Group Number	Water borne solids				Solids				SPM in air		Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
1 1a-1b 2a-2b (324 km²)	0	0	0	0	40	0	0	0	10	0	IMPACTED STREAM LENGTHS Zero river lengths DOMINANT SOURCES Household solids Ground level emissions Minimal industrial activity Households=22,000; density=70/km2
2 1c, 1d, 2c (243 km²)	10200	700	500	80	240	2800	1200	0	150	210	IMPACTED STREAM LENGTH Bokaro 5km; Konar 2km; Damodar 15km DOMINANT SOURCES Washery, power plant & mines Stack emissions + ground level emission Household solids Households=120,000; density=500/km2
3 2d (81 km²)	1310	630	0	0	10	0	0	0	0	330	IMPACTED STREAM LENGTH Damodar 10 km DOMINANT SOURCES Washery & mines Household solids Poweer plant stack emissions Households=6000; density=70/km2
4 3a, 3b, 3c 3d,4a-4b, 4d (567 km²)	160	0	0	0	120	850	4040	1720	200	0	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Washery & mines Household solids Ground level discharges Households=58000; density=100/km2

... Contd ...

Table 2.5 contd.

Cell Group Number	Water borne solids				Solids				SPM in air		Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
5 4c, 8a-8b (243 km²)	1340	50	620	190	290	4030	3980	760	130	70	IMPACTED STREAM LENGTH Damodar 20 km DOMINANT SOURCES Mines, power plants, fertiliser plant Household waste Mineland Stack & ground emissions Households=150,000; density=600/km2
6 6 (324 km²)	440	0	0	0	170	0	0	0	40	0	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Steel mill Household waste Stack emissions very high (No data released): 50 stacks Ground level discharge Households=85,000; density=260/km2
7 5, 7, 8c-8d (810 km²)	340	0	0	0	110	0	0	0	40	0	IMPACTED STREAM LENGTH Damodar 2 km DOMINANT SOURCES Mines in cell 4b Household waste Ground level discharge Households=58,000; density=70/km2

Note: Total suspended solids (TSS) was selected as the indicator of waterborne solids since it was the dominant type of load.

Table 2.6 Ambient condition classifications for inland waters

Characteristics	A	B	C	D	E
Dissolved oxygen (mg/l), min.	6	5	4	4	-
Biological oxygen demand (mg/l),	2	3	3	-	-
max.	50	500	5000	-	-
Total coliform (MPN/100 ml), max.	500	-	1500	-	2100
Total dissolved solids (mg/l), max.	250	-	600	-	500
Chloride as Cl (mg/l), max.	10	300	300	-	-
Colour, Hazen units, max.	-	-	-	-	26
Sodium absorption ratio, max.	-	-	-	-	2
Boron as B (mg/l), max.	400	-	400	-	1000
Sulphates as SO_4 (mg/l), max.	20	-	50	-	-
Nitrates as NO_3 (mg/l), max.	-	-	-	12	-
Free Ammonia as N (mg/l), max.	-	-	-	1.0	2.25
Conductivity at 25°C (us/cm), max.	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.0
pH	0.05	0.2	0.2	-	-
Arsenic as As (mg/l), max.	0.3	-	50	-	-
Iron as Fe (mg/l), max.	1.5	1.5	1	-	-
Fluorides as F (mg/l), max.	0.1	-	0.1	-	-
Lead as Pb (mg/l), max.	1.5	-	1.5	-	-
Copper as Cu (mg/l), max.	15	-	15	-	-
Zinc as Zn (mg/l), max.					

A: Drinking water source without conventional treatment but after disinfection
B: Outdoor bathing, organized
C: Drinking water source with conventional treatment followed by disinfection
D: Propagation of wildlife and fisheries
E: Irrigation, industrial cooling, etc.

Source: Central Pollution Control Board, Government of India, 1990

River measurements were obtained as part of the National Environmental Engineering Research Institute (NEERI) study (1994) at several locations during three seasons of the year - pre-monsoon, monsoon, and post-monsoon. The locations included both industrial and municipal point sources and measurements included TSS, COD and biological oxygen demand (BOD). They also included stream flow measurements in cubic meters per hour, but unfortunately Damodar flow measurements were taken only during the post-monsoon period. Consequently, data analysis is restricted to this period. A geographic summary of liquid residuals for this period is presented in **Table 2.7**.

Table 2.7 Summary of industrial and municipal liquid residuals discharged into stream segments for the post monsoon period

Cell	Site description	Discharge (m^3/hr)	TSS (kg/day)	COD (kg/day)	BOD (kg/day)	Comments
1d	Damodar U/s Bokaro	11000	84000	30000	300	Sample S10
1c	Bokaro thermal power	70	500	230	130	Munic. sullage
1d	Damodar D/s Bokaro	48600	5770000	1647000	2000	Sample S11
1c	Konar U/s Bokaro	7700	36000	5000	100	Sample T5
1c	Bokaro D/s Bokaro power station	21200	1357000	714000	700	Sample T7
1d	Damodar U/s Kargali coal washery	34500	1700000	868000	900	Sample S12
2c	Phusro township	400	900	530	30	Munic. sullage
2c	Damodar at Phusro bridge	55800	1291000	647000	1500	Sample S13
6	Garga D/s Bokaro steel plant	129000	437000	63000	900	Sample T11
2d	Damodar U/s Chandrapura power station	128000	683000	349000	1800	Sample S14
2d	Damodar U/s Dugdha coal washery	48100	627000	190000	2500	Sample S16
3c	Dugdah township	350	24400	104000	20	Munic. sullage
3c	Damodar at Telmachu bridge	104000	132000	71000	5400	Sample S18
7	Damodar D/s Katri	92500	340000	115000	3060	Sample S19
8a	Damodar at Jamadoba water works	334000	722000	124000	2400	Sample S20
8a	Sudamdih township	8700	10700	3400	500	Munic. sullage
4c	Jharia township	10	80	130	30	Munic. sullage
8b	Damodar at Domgarh water works	323000	607000	142000	10200	Sample S21

Notes:

1. Data based upon the average of four 8-hourly flow composite samples collected during January
2. U/s - Up stream, D/s - Down stream
3. See NEERI (1994) report (pages 74-89) for river data
   See NEERI (1994) report (pages 202-206) for municipal-sullage data
   See NEERI (1994) report (page 14, Figure I-3) for locations.

Source: *National Environmental Engineering Research Institute (1994)*

Industrial loads to the river dominate during the post monsoon period with TSS and COD values consistently representing more than 90 per cent of the total river load and in many locations, more than 99 per cent of the total. Concentrations of TSS and BOD at many locations of the river system are far in excess of standards set for class C waters by the Central Pollution Control Board. Six of the industrial point sources account for more than 50 per cent of the load, which suggests that abatement conducted at only a few locations would be cost effective.

Sub-area 2 (cells 1c, 1d and 2c), which covers less than 10 per cent of the total AEQM area, is the dominant site of liquid residuals discharge. The impact of the monsoon season on the total river system is probably significant since over 80 per cent of the annual runoff occurs then. During this period, a combination of sediments accumulated in the stream bed throughout the year, especially deposits from industrial sources, and sediment eroded from higher elevations, such as overburden, roads, crop land and urban areas, is flushed downstream into the reservoirs. The volume of useful storage in the reservoirs is likely reduced more rapidly than originally estimated, so that the useful life of the dams decreases. A reduction in industrial pollution would improve the river ecosystem in two ways; the reduction in sediment would tend to stabilize the morphology of the river network and the reduction in oxygen demand would help restore a natural aquatic ecosystem.

While the municipal contribution to river pollution is evidently small compared to industrial loads at this time, a successful industrial pollution abatement programme could make municipal loads more important, relatively speaking, in the future. Water-borne diseases from discharge of untreated sewage may be an important factor in environmental health in the area, particularly because surface water is a source of drinking water. Field data, including river flows, would be important for planning a more comprehensive water pollution abatement programme, but for now attention to industrial point sources seems merited.

Although no data have been located documenting ground water quality of the region, some comments can be made based on personal communication. Some mines operate below ground water level and pumping is necessary to allow operations to continue. Ground water pumped from the mine is released on the surface where it supplements the natural flow of the river system. Because a number of shallow wells exist at the fringes of the urban areas, surface water intrudes into the ground water in many mine areas. Polluted water exists in the shallow aquifer which could have an impact on human health from both bacteria and dissolved minerals.

Inventory of industrial and municipal waste water treatment facilities

An inventory of existing industrial waste water treatment facilities and related collection facilities is presented in **Table 2.8.** Eleven out of the 16 industrial facilities have inadequate treatment facilities or facilities that need improvements. Of these 11, seven are judged to be causing a significant impact on the river. Regarding 14 the major cities and towns, waste water treatment facilities are virtually non existent and the discharge from five of these cities and towns is judged to be causing a significant impact on the river (See **Annexure 2.9**).

Estimating water residuals

Liquid residual loads were not estimated for specific industrial point sources due to lack of data. Comments on liquid residuals made earlier in this chapter were based upon actual stream loads at various locations. However, general comments can be made on the two industries that are the primary polluters of the river: power plants and washeries.

Table 2.8 Industrial effluent facilities available

Status of Pollution Control Measures Adopted by Industries in the Damodar Basin

No.	Industry	Type of Treatment	Adequacy of Treatment	Major Pollutants	Receiving body of Wastewater	Impact on the River
1.	Kargali washery	Settling tanks adopted. Recirculation of final effluent. Presently no discharge to river Damodar	Treatment is not satisfactory	SS, COD	River Damodar	Insignificant
2.	Sawang washery	Settling tanks. Final effluent to an abandoned quarry	Treatment is satisfactory	SS, COD	Surface water body	Insignificant
3.	CTPS	Settling ponds exist	Inadequate	SS, COD	River Damodar	Significant
4.	Dugdha I & II washeries	Settling ponds adopted closed circuit system	Treatment is satisfactory	SS, COD	River Damodar	Insignificant
5.	Kathara washery	5 Settling ponds have been provided for the recovery of coal fines	Inadequate	SS, COD	River Damodar through river Konar	Significant
6.	BPTS A & B	Wastewater from demineraliser plant is neutralised in reinforced concrete lined pit. Thermal power cooling tower blow down water, floor washing and condenser blow down water is used for ash slurry. Fly ash slurry is discharged into flyash pond	Effluent treatment plant is not effective	SS, COD	River Damodar through river Konar	Significant
7.	Mahuda Washery	True floc is added in the thickener for better solid recovery. The effluent is recycled and therefore system acts as a closed circuit	Needs proper operation	SS, COD	River Damodar	Insignificant

...Contd ...

Table 2.8 contd.

No.	Industry	Type of Treatment	Adequacy of Treatment	Major Pollutants	Receiving body of Wastewater	Impact on the River
8.	Moonidih Washery Station	The effluent is discharged into 8 settling ponds in series. The effluent from settling tanks is discharged into cultivated land. The runoff from the land reaches river Damodar.	Inadequate	SS, COD	River Damodar through cultivated fields	Significant
9.	Jamadoba washery	Installed centrifugal and settling ponds. Effluent recycled	Treatment adequate	SS, COD	River Damodar	Insignificant
10.	Jamadoba Power House No. 1	Settling ponds are constructed for fly ash control	Treatment facilities needs improvement	SS, COD	River Damodar through Joria Nullah	Insignificant
11.	Jamadoba Power House No. 3	No treatment provided. Water finds its way to river Damodar through natural drain	Treatment is inadequate	SS, COD	River Damodar through Dogri Nullah	Significant
12.	Loyabad Coke Oven Plant	Settling tanks	Inadequate	SS, COD	River Damodar through Katri Nullah	Significant
13.	Patherdih washery	The effluent is discharged through settling tanks on the lands	Adequate	SS, COD, Oil & grease	River Damodar	Insignificant
14.	Sudamdih washery	Pucca/kutcha settling tanks, it proposes effluent recirculation	Inadequate	SS, COD, Oil & grease	River Damodar	Insignificant
15.	Chasnala washery	Settling tanks. Effluent recirculated. A portion goes out as seepage	Inadequate	SS, COD, Oil & grease	River Damodar	Insignificant
16.	Bhowra Coke Plant	No treatment at present. Settling tanks under construction	Inadequate	SS, COD	River Damodar	Significant

Source: *Feasibility Report on Pollution Abatement of Damodar River (December 1994), NEERI*

The ash-water slurry from the power plants is discharged into ash ponds and the overflow then runs into the Damodar river. Because the ash ponds are full, daily discharges of TSS at BTPS and CTPS are very high. Although an effort has been made to raise the height of the ash ponds, the structures were poorly constructed and have collapsed in some places so that the ash slurry continues to flow directly into the rivers. New ash ponds are not being constructed due to lack of land.

Because the discharge of ash slurry into the river was sporadic, it was impossible to derive a pollutant generation co-efficient. With direct and uncontrolled discharges of ash slurry into the river, however, this discharge would be several orders of magnitude greater than permissible in terms of TSS.

Inefficient fine-coal management and old technology have resulted in the escape of coal fines and tailings from reject ponds into the river. Since there is an on-going industry of coal recovery from the river bed (downstream), a certain indifference to these discharges appears to exist because their recovery translates directly into improved earnings for some parties. Discharges of fines into the river differ from washery to washery and even for a given washery from day to day. Therefore, it was not possible to estimate a discharge co-efficient. As in the case of power plants, the coal fines discharged are most likely much greater than permissible for discharge of solids into water bodies.

The most common effluent treatment technique used in the washeries is sedimentation; most have settling tanks with flocculators. **Annexure 2.7** gives the effluent characteristics from Moonidih, Jamadoba, Sudamdih, Patheridih, and Chasnalla coal washeries. Both TSS and COD levels exceed class C effluent standards from all the washeries. The reasons for this are: (1) they have had difficulty handling lower quality coal mined in recent years because most of the washeries were commissioned in the Sixties and were designed for a superior quality of coal. Heavy media cyclones were introduced and fine crushing was adopted wherever possible. Recent washeries include cyclones in their designs; (2) fine coal management is a major problem in the washeries. Where the ash of fines is more than approximately 25 per cent, the froth flotation process is often utilized. However, froth flotation has not performed optimally due to inconsistent feedstock and the presence of oxidized coal. A major problem associated with beneficiation of fine coal is dewatering, normally done with vacuum disc filters. This equipment requires high maintenance and in many washeries becomes a process bottleneck. These filters could be replaced with screen bowl centrifuges (as in Jamadoba washery), pressure filters, or horizontal belt filters; and (3) dewatering of tailings from the fine coal treatment plant is also neglected and tailings are allowed to settle in ponds to dry and are subsequently excavated. In other countries tailings are dried in a bath filter press or solid bowl centrifuge, so that washery effluents are clear of solids. These improvements need to be incorporated into the washeries.

Older washeries are being fitted with facilities for fine coal treatment and in some, new technologies for fines recovery are being tried. Spirals have been installed in Chasnalla washery; pneumatic flotation trials have been conducted at Kargali washery; the fine coal washing system at Moonidih is being improved; a horizontal belt filter is being tried at Sudamidih/ Moonidih and screen bowl centrifuges are functioning satisfactorily at Jamadoba. Recently, closed-water circuits employing the concept of zero discharge have been installed in Dugda, Jamadoba and Chasnalla washeries.

Land

Solids residuals include household solid waste and the wide range of solids associated with industrial activities, especially mining. Comments on land use in both the JCF and EBCF are provided as an overview of solids generation and disposal in the AEQM study area. Comments on the impact of mining in different cells of the study area are also provided.

Land use in the JCF

In JCF, the total coal bearing area is 450 sq.km. Of this, 44 per cent is used for mining and settlements, 40 per cent for agriculture, 12 per cent for cultivable wasteland, 3 per cent for water body and river sand and 1 per cent for forest land.

The JCF area has suffered severe damage to its land and land-related environmental attributes due to unplanned opencast and underground mining operations. Earlier, mining was in the hands of private entrepreneurs with limited resources and opencast areas were not back-filled, leaving behind large voids. Extraction by caving of thick upper seams at shallow depths has caused ground surface subsidence, leading in some cases, to spontaneous heating and combustion of the coal seams. Surface and underground coal seam fires are a noticeable feature of JCF.

Land use in the EBCF

In EBCF, the total coal bearing area is 226 sq. km. Of this, 55 per cent is used for forests and agricultural, 37 per cent is used for mining activity and townships and 8 per cent for cultivable wasteland.

In this coalfield, more opencast mines were operated leading to more serious land degradation. Mining was carried out with little planning with regard to land reclamation and this has resulted in overburden dumps and voids over large areas of land. A number of external overburden dumps (soil and rocks) are scattered over the coalfield and sometimes over the forest land where there was no other choice. They are of various sizes and shapes and have not been reclaimed. The total area covered by these dumps is about 720 ha. Apart from external overburden dumps, voids were created in the area in the past due to selective mining of seams. The area covered by these voids is about 240 ha, but because there are virgin seams lying under them back filling has not yet been done.

Land reclamation

Land reclamation conducted in damaged areas in the coalfields includes quarry filling, bulldozing, terracing and soil conservation measures such as plantings in residential colonies, barren land, etc. About 2,600 ha of land (BCCL - 2,500 and TISCO - 100) have been restored and vegetated.

Projects to deal with fires in the coal seams have been undertaken in JCF. The objectives of the fire projects are: (1) to prevent the spread of fire by limiting air access; (2) to extinguish the fire and release coal reserves; and (3) to reclaim land affected by fire through plantations. Details of fire projects including counter-measures are given in **Annexure 2.10**.

Estimating solid residuals

Urban solid wastes are those generated from residences together with those not classified as hazardous from commercial and industrial activities. The disposal of urban solid waste is under the jurisdiction of municipalities or district administrations and at present wastes are deposited in open dumps. The discharge co-efficient has been derived based on a per capita consumption/day; a discharge of 0.4 kg/person/day of solid waste or 2 kg/household is assumed. The recommended treatment and disposal is by sanitary landfill because this method is environmentally satisfactory and has the potential to create useful land.

The general inventory of activities and estimated residual loadings is presented in **Annexure 2.5,** and summary table, **Table 2.5**. The spatial distribution has been organised in the cell structure shown in **Figure 1.3**. Solid waste generation is greatest in the two sub-areas of highest population density, i.e. sub-area 2 (cells 1c, 1d, 2c) and sub-area 5 (cells 4c, 8a and 8b). Household solids generated in these two sub-areas are 240 and 290 MT per day, respectively, and these two sub-areas, representing one-fifth of the land, produce one-half of the household solids. There are no regulations for collection and disposal of these solid residuals and most, after sorting by rag pickers for recyclable items, are dumped on the roadsides and eventually end up in abandoned mine pits.

The spatial distribution of solid residuals associated with mining is assumed to match the location of past and present mining activities. Accordingly, two sub-areas, sub-area 4 (cells 3a, 3b, 3c, 3d, 4a, 4b, 4d) and sub-area 5 (cells 4c, 8a and 8b), contain most of the wastes. These two sub-areas, representing about one-third of the AEQM study area, contain over 80 per cent of the disturbed mine land.

In summary, three comments can be made about the solid residuals. First, the generation of industrial solids associated with mining is much larger, probably several orders of magnitude larger than that from the households. Second, the generation of wastes is concentrated in a small fraction of the total study area; sub-area 5 (cells 4c, 8a and 8b) contains the highest concentrations of both household and mining related wastes. The inclusion of other industrial solid residues, e.g., power plant ash, would change the inventory slightly, but the general results would remain the same. Third, there are no regulations for disposal of solid residuals at this time.

Air

Ambient air quality standards

Ambient air quality standards are categorized into three classes - industrial and mixed, residential and rural areas and sensitive areas. **Table 2.9** shows the eight-hour concentration limits for SPM, SO_2 and NO_x. The concentration of pollutants should be within these prescribed limits 95 per cent of the time.

Table 2.9 Ambient air quality standards (μg/m^3)

Category	SPM	SO_2	NO_x
Industrial and mixed	500	120	120
Residential and rural	200	80	80
Sensitive	100	30	30

Source: *Central Pollution Control Board, Government of India, 1990.*

Air quality in the study area

The BSPCB monitors and records ambient air quality data in seven locations in the JCF area. Air quality data for the BSPCB stations were available from December 1991 to November 1992. Therefore, all analysis of air quality is based on one year's data, taken as representative for the study area (a robust analysis would require data for a minimum of seven years).

The 8-hour concentration of SPM, SO_2, and NO_x for seven stations of BSPCB is given in **Table 2.10**. As can be seen, apart from the Bihar Institute of Technology (BIT)- Sindri and Govindpur, SPM levels exceed the uppermost permissible standards (500 μg/m3 for industrial and mixed areas). In fact, maximum values in some cases exceed 1,000 μg/m^3, an exceedingly high level. SO_2 and NO_x are below residential and rural standards.

Table 2.10 Concentrations of SPM, SO_2 and NO_x in JCF, 8 hour averages (μg/m^3)

Location	SPM		SO_2		NO_x	
	95 Percentile	Max	95 Percentile	Max	95 Percentile	Max
Bank More	530	880	70	250	70	130
Dhanbad	720	1180	60	140	70	150
Jharia	700	1030	80	310	80	470
BIT - Sindri	330	730	50	260	60	110
Nirsa	680	5900	40	150	80	130
Gobindpur	160	460	30	420	70	140
Mugma	600	850	50	160	100	180

Notes:

1. Data for all stations relate to December 1991 to November 1992 except Gobindpur where data are from August 1991 to July 1992.
2. Data for SO_2 and NO_2 values have been converted from a 4-hourly to an 8-hourly basis using Larsen's model (Larsen, 1967 and 1973) for comparison.
3. Values have been rounded off.

Source: *BSPCB.*

The 28 BCCL monitoring stations are in the mining area. Sources of emission include captive power plants, fugitive dust from haul roads and external dumps, exhaust from mining equipment and other vehicles and coal burning for domestic and other uses. The average, maximum and minimum concentrations of SO_2, NO_x and SPM were observed during three-month periods from January 1988 to September 1989. However, observations from each site are not available for all the quarters. The seasonal SPM levels for a selected number of the stations are given in **Table 2.11**. The station at Indian School of mines, located 10 km away from the active mining area, is taken as the reference point. As seen from the table, SPM levels are very high for the three colliery offices and the officers' club, with averages 2 to 3 times greater than the 95 per cent allowable. SO_2, and NO_x were generally below standards, but in a few places, winter NO_x levels were fairly high. On an annual basis, however, they appear to be within acceptable limits.

Table 2.11 Seasonal concentration of SPM ($\mu g/m^3$) in JCF

	Sampling station	SPM $\mu g/m^3$		
		March to June (1988 & 1989)	July to October (1988 & 1989)	November to February (1988 & 1989)
1.	Lodna Colliery Office	910 790	620 670	830 900
2.	Officers Club, Bagdigi	760 830	670 660	790 740
3.	Bararee Colliery Office	820 810	650 630	820 820
4.	Joyrampur Colliery Office	790 750	660 630	740 700
5.	I.S.M. Office	160 230	120 180	230 220

Note: Values have been rounded off.

Source: *Central Mining Research Institute (1994).*

Although BSPCB has no air quality monitoring stations in the EBCF area, companies like CCL, BTPS and ICI have stations for monitoring ambient air quality on an irregular basis. The ambient air quality in this area is mostly dominated by pollution from mining and allied activities and Bokaro TPS, with fugitive dust from opencast mines and transport major contributors.

Ambient air quality data over the EBCF area, monitored at 12 locations by CCL, are available for the year 1991. The majority of the stations are located near the mines, while some are in residential areas. The seasonal average ground level concentrations of SPM for these 12 stations are given in **Table 2.12** and these levels exceeded standards in most of the residential and industrial areas. SO_2 and NO_x were found within standards.

Table 2.12 Seasonal average of SPM levels ($\mu g/m^3$) in East Bokaro area

No.	Station	Area	Seasons			
			PM	W	S	M
1.	Jarangdih underground mine	I	440	710	670	190
2.	Kathara Guest House	R	200	300	520	100
3.	Bokaro Colliery	R	230	250	390	80
4.	Bokaro Excav. Workshop	I	560	600	320	180
5.	Chalkari village	R	320	430	490	130
6.	Karo Infer. underground mine	I	200	250	460	130
7.	Karo Spl. underground mine	R	210	340	530	160
8.	Govindpur underground mine	R	60	210	320	100
9.	Kathara Colliery	I	370	410	430	140
10.	Saram village	R	150	200	140	70
11.	Khudgara village	R	230	230	200	90
12.	Tenughat	R	130	240	200	60

Note: I - Industrial; R - Residential; PM - Post monsoon; W - Winter; S - Summer; M - Monsoon

Source: *CCL*

Inventory of industrial air pollution control measures

An inventory of existing industrial air pollution control measures in presented in **Table 2.13**. There are four manufacturing establishments, two utilities and five capitive power plants, all with mechanical or electrostatic precipitators. Unfortunately, most of these are not operated at their design efficiencies. Some measures are also in use at the other types of establishments, but here again they are not adequate.

Table 2.13 Inventory of existing industrial air pollution control measures

Industry	Major pollutants	Type of treatment	Adequacy of treatment	Air impact
Manufacturing - ICI Gomia	SPM, SO_2, NO_X and NH_4	Scrubbers, absorption columns	Adequate where employed	Reduction in air emissions
- Bokaro steel plant	SPM, SO_2, NO_X and CO	Cyclones, wet scrubbers, bag filters and electrostatic precipitators, tree planting	Adequate where employed	Reduction in air emissions
- FCI, Sindri	SPM, SO_2 and NO_X	Electrostatic precipitators	Adequate where employed	Reduction in air emissions
- ACC, Cement plant at Sindri	SPM	High efficiency pulse jet dust filters, tree planting	Adequate	Reduction in air emissions
Cola production - BCCL - TISCO - IISCO - EBCF	Fugitive dust, SPM	Settling road dust with water or chemicals, dust extraction, green space allocation	Where fully operational, quite effective	Reduction in air emissions
Power generation - Tenughat - BTPS-A - BTPS-B - CTPS - Kathara washery - Moonidih - TISCO washery (captive) PH1 & 3 (Jamadoha) PH 2 (Sijua) - FCI (captive) - BCCL (captive)	SPM, SO_2, NO_X	Mechanical and electrostatic precipitators	Where fully operational, quite effective	Reduction in air emissions
Special smokeless fuel plant, Dhanbad	SPM, SO_2, NO_X, CO	Venturi scrubber	Adequate where employed	Reduction in air emissions
Smokeless fuel open stack burning	SPM, SO_2, NO_X, CO, NH_3, benzene, xylene, phenol, napthalene, PAHs	No controls	-	-
Beehive coke ovens	SPM, SO_2, NO_X, CO, NH_3, benzene, xylene, phenol, napthalene, PAHs	Improved oven design and single taller chimneys	Very effective where employed	Reduces air emissions
By-product coke ovens	SPM, SO_2, NO_X, CO, NH_3, benzene, xylene, phenol, napthalene, PAHs	Tar recovery	Effective where employed	Reduction in air emissions

Note: The first two cells in the last two rows in the table refer to hard-coke production and not washeries as the earlier table indicated.

Estimating air residuals

The sources of emission affecting air quality in the area are as follows: (1) fugitive dust from opencast mining operations e.g. movement of heavy earth moving machinery, drilling and blasting, etc; (2) exhaust from dumpers and dozers; (3) emissions from thermal power stations; (4) dust generation from overburden dumps, coal dumps, and washery rejects dumps due to wind erosion; (5) emissions from hard coke ovens, bee-hive coke ovens and soft coke bhattas; (6) emissions from the Bokaro steel plant, explosive factory, and fertilizer unit; (7) fugitive emissions due to movement of vehicles; and (8) emissions from domestic cookstoves.

Developing reasonable estimates for source discharge co-efficients was difficult because very little actual emission data were available. This problem is not unique here; emission data are generally unavailable for most activities in India. Therefore, these values in no way represent a "robust" estimate, but rather a first approximation.

Estimates for fugitive dust from mining were based on literature from coal mining in the Powder River Basin, Arizona (Dyke and Stuckel, 1976), which has a terrain that is similar to the Dhanbad-Bokaro study area, and experiments conducted at the Indian School of Mines, Dhanbad (Banerjee and Sinha, 1993). The major share was due to haul road traffic. Figures for the Powder River Basin reflect dust generation of 6 kg/vehicle-km-travelled. This number, along with actual haul road movement, was used to determine pollutant generation.

Abatement in opencast mines includes watering haul roads and other roads at regular intervals, dust extraction in drills and dust proof cabins in heavy equipment. In addition, green belts (bands of vegetation) have been provided around some mines, colonies, etc. to trap dust. Water spraying is the main method to suppress fugitive dust emitted from various sources in opencast mines. During hot summer months, however, water alone evaporates fast and thus is ineffective as a dust suppressant. Hence the discharge co-efficient is assumed to be the same as the generation co-efficient.

In the power sector, source generation estimates were based on the specific fuel consumption for individual power plants and the ash content of the coal. Discharge co-efficients assumed an average operating efficiency of 90 per cent for electrostatic precipitators (ESP) and 75 per cent for mechanical precipitators, although these are much lower than design estimates. These figures reflect actual average operating efficiency, including the times when ESPs are not operating e.g. during start-up, etc,.

Hard coke manufacture results in large quantities of emissions. The smoke contains gaseous and particulate matter including SPM, carbon monoxide (CO), hydrogen sulfide (H_2S), SO_2, ammonium (NH_3), benzene, xylene, toluene, phenol, naphthalene and PAH (poly-aromatic hydrocarbons). The emission standard for bee-hive ovens is 325 mg/Nm^3 for SPM, but for new plants the limit has been set at 150 mg/Nm^3 for SPM and 25 ppm for hydrocarbons. Measured values for conventional bee-hive ovens show a range from 1,700 to 1,900 mg/Nm^3 SPM after the charging process and an average emission level of 400-500 mg/Nm^3 SPM over the entire cycle.

Based on operating data monitored by BSPCB, SPM emissions from bee-hive coke ovens range between 1 and 5 kg/t of coal charged, with an average of 3.6 kg/t. Most emissions occur in the initial hours after charging. This figure was used to determine the discharge co-efficient.

SPM emissions from KUMBHRAJ ovens (improved design) were reported to range between 64-184 mg/Nm^3. Moreover, the KUMBHRAJ design is being further improved to meet the new standards (150 mg/Nm^3) as well as to reduce emissions significantly during charging. Because there are only a few installations of improved design, they do not make a significant difference in the total discharges of SPM from bee-hive ovens.

Since the plants did not meet pollution standards in 1992, the BSPCB directed that all bee-hive coke ovens convert from the existing multiple chimney system to the single chimney system connected by a tunnel to a stack with a minimum height of 20 m. This single chimney system enables a greater residence time for exposure of combustion gases to high temperatures, thereby allowing the heavier and toxic particles to burn completely. Although more than 60 per cent of the units have converted to the single chimney system, no monitored results from these units were available. A 30 per cent reduction in the total amount of SPM emitted from bee-hive coke ovens is assumed as a result of the single chimney system.

Factors such as heavy traffic congestion ensure that vehicles constantly use the unpaved road shoulders, which generate a large amount of fugitive dust. Secondly, there is a lot of coal dust and sand spillage from the trucks. Thirdly, most of the roads are in extremely bad condition. The discharge co-efficients for fugitive dust from passenger and freight transport are rough estimates based on the relative condition of roads and freight and passenger movement in the area.

Some new roads have been constructed by BCCL in JCF. Routine repairs and maintenance of existing roads are carried out sporadically by the concerned agencies, but due to lack of a proper plan for improvement of roads, there is no significant reduction in fugitive dust emissions.

In the domestic sector, approximately 1.5 t of coal are consumed per year for a family of five persons. Literature on emissions from coal-based stoves indicates a range of 10-50 kg of SPM/t of coal burned, but because actual emissions data were not available, a figure of 30 kg/t has been assumed. No abatement measures exist to reduce generation and discharge of pollutants from the manufacture of soft coke in open Bhattas and in cookstoves for domestic use of coal.

Table 2.5, based on the above emission discharge factors for SPM for the above activities, summarizes SPM discharges in 1992-93. **Annexure 2.4 and Annexure 2.5** provide more detailed information.

As can be seen in **Table 2.14**, the coal mining and transport sectors are major contributors to SPM followed by household cooking, industry and power stations. Although open mine fires contribute significantly to the SPM load, data were not available to provide a quantitative estimate. Fugitive dust from overburden, coal and washery reject dumps also contribute significantly to the SPM load, but these could not be reasonably estimated.

Table 2.14 Present condition (circa 1991) - estimated sectoral shares of suspended particulate matter (SPM) contribution to ambient air quality

Cell	Annual average ambient concentration ($\mu g/m^3$)	Percentage contribution of SPM to ambient air quality				
		Coal mining	Household cooking	Truck traffic	Power stations	Other
la-lb	225	0	22	66	12	0
lc	225	46	11	36	5	2
ld	325	41	13	41	5	0
2a-2b	275	0	23	70	7	0
2c	375	45	7	26	4	18
2d	425	0	31	63	6	0
3a	500	71	2	22	3	2
3b	450	62	4	31	3	0
3c	525	0	10	82	8	0
3d	525	23	4	63	2	8
4a-4b	350	0	5	37	2	57
4c	600	34	9	50	1	6
4d	325	54	5	31	1	9
5	250	0	21	71	8	0
6	275	0	26	69	5	0
7	350	0	15	78	7	0
8a	375	24	13	58	3	2
8b	350	0	27	72	1	0
8c-8d	225	0	23	69	8	0

To conclude this section, SPM ambient concentrations are extremely high with certain sub-areas experiencing levels two to three times over standards. Both SO_2 and NO_x levels, however, are usually within acceptable limits.

Air quality modelling

To assess current and future exposure to SPM in the region, it is necessary to model the distribution of SPM over the grid structure of the study area (**Figure 1.3**). Long-term estimates based on seasonal/ annual concentration give the best representation of ambient conditions because they include diurnal/ seaonal variations due to changes in meteorology and emissions. Thus, a long-term model is better than a short-term model requiring hourly meteorological data for the whole year and repeated model runs. The Climatological Dispersion Model (CDM-2), an operational US EPA Model, was used to determine the annual SPM concentration using average emission rates from point and area sources and a joint frequency distribution of wind direction, wind speed and stability (Mersch, 1989).

For this modelling exercise, power plant emissions were treated as point sources, while the emissions in each cell from other sources, domestic, transport, mining and others (like coke-ovens), were treated as area sources. The existing point sources considered were Bokaro A & B, Chandrapura, TISCO and FCI power plants. Proposed power plants at Kathara, Madhuban, Sudamdih, Moonidih and Bhujidih were also included in the modelling exercise. Area source emissions in each cell were adjusted to account for changes in sectors like domestic, transport, mining and others. Annual meteorological data for Bokaro were assumed representative of the whole area. The modelling domain considered was 72 km x 36 km with individual grids of 9 km x 9 km, and the concentration at receptor points at the centre of each grid was considered representative of the entire cell.

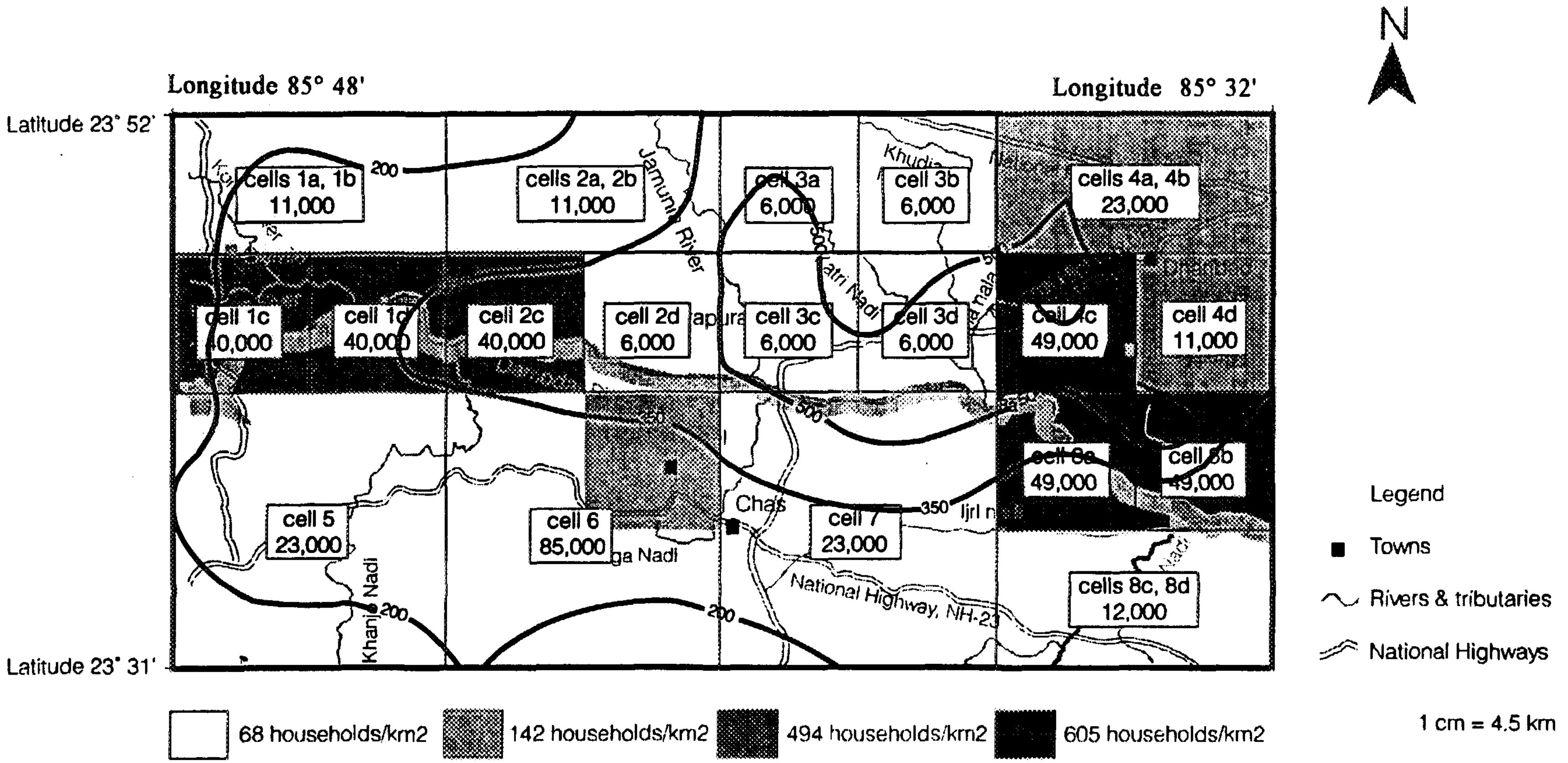
The CDM model was used to predict present concentrations as well as concentrations associated with each of the three management strategies to be described in Chapter 3. The ratio of the model-predicted future to existing concentrations was used to scale monitored concentrations to estimate future values. Concentration contours were plotted corresponding to present conditions as well as conditions resulting from the three management strategies in each cell. The concentration contours for present conditions are displayed in **Figure 2.3**.

Exposure Assessment

The exposure assessment for the present condition is presented in **Table 2.15**. (**Annexure 2.11** shows the number of households exposed to various levels of SPM in each cell.) Approximately 90 per cent of the present population lives in an unhealthy environment with SPM concentrations greater than those recommended.

To estimate the state of the environment of the people in an area with respect to SPM, an exposure index of "SPM ($\mu g/m^3$) - households" has been used. A value is derived for each cell by multiplying the number of households exposed to the average air quality for one of the four categories. The averages for each category were taken as: 175 for concentrations of less than 200, 275 for concentrations of 200 to 350, 425 for concentrations of 350 to 500, and 550 for concentrations greater than 500 $\mu g/m^3$ SPM.

Figure 2.3 Spatial distribution of air quality in the AEQM area, SPM in $\mu g/m^3$, annual average, Present Condition (circa 1991)



Notes: (1) Population figures are households.
Estimate 1 household contains five people, or 2,480,000
(2) Actual 1992 population was 2,200,000 (the difference is due to approximated spatial distribution

Table 2.15 Spatial distribution of households exposure to SPM - present condition

Cell groups	SPM concentration ranges (μg/m³)				Comments
	< 200	200 ≤ 350	350 ≤ 500	> 500	
1 [1a-1b,2a-2b] (324 km²)	6500	13000	2500	0	Sparsely populated. Minimal industrial activity.
2 [1c, 1d, 2c] (243 km²)	14000	65000	41000	0	Dominant sources: mining, power plant, and traffic
3 [2d] (81 km²)	0	0	6000	0	Dominant sources: CTPS and traffic
4 [3a, 3b,3c, 3d, 4a-4b, 4d] (567 km²)	2000	5000	38500	12500	The areas where SPM associated with mining activity and traffic
5 [4c, 8a, 8b] (243 km²)	3000	44000	43000	57000	Dominant sources: mines, mine fires, power generation, traffic and domestic activity
6 [6] (324 km²)	5000	20000	60000	0	Dominant sources: Bokaro Steel plant and neighbouring CTPS
7 [5,7,8c-8d] (810 km²)	13000	36000	9000	0	Sparsely populated. Minimum industrial activity
Total number of households	43500	183000	200000	69500	
Household distribution (per cent)	9	37	40	14	
Percentage of households (›)	91	54	14		

Health effects assessment

Mortality studies done elsewhere in the world were used to estimate changes in mortality health effects resulting from changes in exposure to SPM (World Bank, 1994). These studies suggest that a reduction in 10 μg/m³ of respirable particulates results in a 1.25 per cent decrease in the mortality rate. These numbers have been applied by the World Bank to estimate the benefits of SPM reductions in New Delhi, where the average annual SPM level is approximately 300 μg/m³. A reduction by one third to 200 μg/m³, would reduce New Delhi's mortality rate by about 3.75 per cent because approximately one-third of the 100 μg/m³ reduction would be particulates in the size range causing respiratory problems. This reduction would prolong about 2,400 statistical lives.

Diarrhoeal diseases are the second largest identifiable cause of DALY losses in India, (respiratory infections are first) and these diseases may be reduced by 15 to 40 per cent through improvements in water supply and sanitation. As this study focused primarily on air pollution related health effects, no attempt was made to make a quantitative estimate of these diseases in the study area.

Summary

The Dhanbad-Bokaro region has been identified by the MoEF as one of the most polluted areas in the nation. This chapter has reviewed the environmental conditions that have caused the region to receive this dubious distinction. Existing reports on the water, air and solids have been collected and analysed and some general conclusions can be reached from the review.

Air pollution, as measured by SPM, is dangerously high in the majority of the study area and is probably causing serious human health problems. Ambient air pollution due to SPM is particularly severe in sub-area 5 (cells 4c, 8a and 8b), where there is a combination of mines, industry and high density population.

Surface water pollution during the non-monsoon seasons is dominated by less than six industrial point sources that contribute the majority of the TSS and COD loads. Municipal sullage and sanitary loads during these seasons are less than 10 per cent of the totals. Loadings during the monsoons are not quantified, but probably contain most of the annual non-point source runoff, both urban and rural. The river sediment load during this season must be very high and most of it must be deposited into the first reservoir of the first dam downstream, either the Tenughat or the Panchet reservoir.

Proposed plans to expand industrial production and current pollution abatement efforts are such that the environmental quality of the region is not likely to improve in the immediate future. Additional abatement efforts appear to be necessary. The current effort as well as other efforts are characterized and evaluated in the next chapter.

CHAPTER 3

Management Strategies

Introduction

Whereas an inventory of existing conditions was provided in Chapter 2, this chapter is directed to describing and evaluating three environmental management strategies:

- **Management Strategy I** is the conventional point-source environmental regulatory programme currently being implemented by BSPCB. It assumes that existing facilities for abatement of environmental pollution would be effective and that new facilities for abatement already under construction would be completed and operated effectively;

- **Management Strategy II** is based upon all activities included in Strategy I with one important addition. Approximately 75,000 households, those of the employees of two mining companies (BCCL and CCL), would be relocated to new communities outside the coalfields. This would decrease the air pollution experienced by the relocated families, while opening new mines to increase coal production. Relocation is assumed to occur over a period of ten years, beginning in 1997, four years before expanded mining operations begin in 2001. Mining is estimated to continue for 25 years, but no additional pollution abatement is assumed other than the reduced air pollution experienced by relocated mine employee households.

- **Management Strategy III** builds upon Strategies I and II with the focus on reducing SPM levels with non-point source abatement measures. These measures would reduce fugitive dust eminating from haul (in opencast mines), colliery and public roads.

In addition to the three management strategies, this chapter describes the one scenario that underlies the three management strategies. The future scenario is based on existing projections for population growth, industrial production and land use. A period of approximately ten years has been chosen for the scenario, i.e. circa 1992-2002.

Overview of future economic activities (circa 2001-2002)

The major features of the future scenario in comparison with present conditions are:

- Population increases from 2.2 to 3.2 million;
- Power generation increases 2.5 times through improved performance of existing units and new capacity, and installation of FBC plants based on washery rejects;
- Coal mining quantity increases from 39.5 Mt to 42.8 Mt;
- Coal washing quantity increases from 15.5 Mt to 22.1 Mt.

Economic activities which will grow in the future are coal mining, coal washeries, coal transportation and power generation from existing and new plants. Because of increased population, transportation and construction would increase in the future. The fertilizer unit at Sindri and the steel plant at Bokaro have no expansion plans. Hard coke production from bee-hive coke ovens in the area would remain the same. Details by sector are discussed below.

Coal mining

Coal production in the area is projected to increase from 39.5 Mt in 1992-93 to 42.8 Mt in 2001-02. Details of coal production in 2001-02 by company and type of mining are given in **Table 3.1**.

Table 3.1 Coal production plans for 2001-02, Mt

Company	Underground	Opencast	Total
BCCL	13.9	15.5	29.4
TISCO	1.7	-	1.7
IISCO	0.5	-	0.5
Total JCF	16.1	15.5	31.6
EBCF	1.2	10.0	11.2
Grand Total	17.3	25.5	42.8

Sand mining

Required stowing material for the JCF in 2001-02 is estimated at 15.75 Mt. Sand from internal resources would decline and may become nil by 2001-02. Colliery ropeways would carry about 0.4 Mt/a. Due to reduced availability, only 2 Mt/a of sand would be transported by trucks from the Damodar and Barakar rivers compared to about 3 Mt/a in 1992-93. The following alternate schemes are being considered for sand collection/transportation: (1) from Durgapur barrage by rail [10.8 Mt/a]; (2) from Maithon dam by road [1.5 Mt/a]; and (3) use of alternative materials like crushed stone, washery rejects, ash from power plants, etc. [2.5 Mt/a].

The status of experiments using alternative materials for stowing is given in **Annexure 3.1**.

Power generation

The projected generation of power in 2001-02 by plant is given in **Table 3.2**. West Bengal State Electricity Board is planning 2 x 210 MW units at Tenughat, which will be in operation by 2001-02. Power generation at Chandrapura and Bokaro plants is projected to improve through renovation and modernization. WBSEB is planning 2 x 210 MW units at Tenughat, which will be in operation by 2001-02. TISCO plans to convert the boilers of power plant No. 1 to FBC boilers. BCL plans to install four captive power plansts based on FBC boilers, consuming washery rejects, at Dugda (50 MW), Sudamdih (20 MW), Madhuban (20 MW) and Bhojudih (10 MW). The fertilizer plant at Sindri (FCI) plans to replace the existing captive plant with a new 38 MW (2 x 19 MW) plant. Total power generation is projected to increase from 4,271 GWh in 1992-93 to 11,340 GWh in 2001-02, an increase by a factor of 2.6 in ten years.

Table 3.2 Power generation in 2001-02

Plant	Capacity (MW)	Generation (GWh)	PLF (per cent)	Remarks
Tenughat	420	2210	60	New
BTPS A	190	830	50	-
BTPS B	630	3310	60	-
CTPS	780	3420	50	-
Kathara & Moonidih Washeries (Captive)	40	280	80	New
TISCO (Captive)	26	180	80 for PH1 & 3 60 for PH2	-
FCI (Captive)	38	270	80	New
BCCL (Captive)	120	840	80	New
Total	**2224**	**11340**		

Coal washeries

Modernization and effluent abatement are under implementation in the washeries and, once completed, the production of washed coal meeting the quality requirements of steel plants would increase. The capacity and projected production from washeries in 2001-02 are given in **Table 3.3**. Two new washeries are under construction in JCF - Madhuban: 2.5 Mt/a and Bhelatand (TISCO): 0.80 Mt/a. The capacity of Jamadoba washery, however, is likely to be derated to 0.90 Mt/a in the future. Details of these schemes by washery are given in **Annexure 3.2**. The total quantity of rejects likely to be generated from these washeries would be more than 3.0 Mt in 2001-02.

Table 3.3 Capacity and projected production of coal washeries in 2001-02

Washery	Capacity (Mt)	Raw Coal feed (Mt)	Capacity Utilization (per cent)	Clean Coal Production (Mt)	Coal yield (per cent)
Prime Coking					
Dugda 1&2	3.80	3.10	80	1.20	39.0
Bhojudih	1.70	1.70	100	1.00	57.0
Patherdih	1.60	1.70	100	0.90	52.0
Sudamdih	2.00	1.70	90	0.80	48.0
Moonidih	2.00	1.70	80	0.80	50.0
Lodna	0.50	0.40	90	0.20	50.0
Madhuband	2.50	2.30	90	1.00	45.0
Jamadoba	0.90	0.80	90	0.50	65.0
Bhelatand	0.80	0.70	70	0.50	65.0
Chasnalla	2.00	0.40		0.90	65.0
Subtotal	**17.70**	**15.50**		**7.80**	
Medium Coking					
	0.40	0.40	90	0.20	47.0
Barora	0.60	0.50	80	.30	68.0
Mahudo	**1.00**	**0.80**		**0.50**	
Subtotal					
JCF Total	18.80	16.30	-	8.30	-
Medium Coking					
Kargali	2.70	2.40	90	1.00	40
Kathara	3.00	2.40	80	1.10	50
Sawang	1.00	1.00	100	0.50	52
EBCF Total	**6.70**	**5.80**		**3.60**	
Grand Total	**25.50**	**22.00**		**12.00**	

Transport sector

Plans have been drawn up by the State Government for development of national highways and PWD roads, and BCCL plans to construct new roads under the HIRAK project. Details of new roads under the HIRAK project are given in **Annexure 3.3**. The PWD plans include widening and strengthening sections of road between Dhanbad and Sindri, Rajganj and Jamidha and Pootki and the Phus bungalow link road. The total length of these sections is 59 km and the cost is estimated at Rs.52 million.

Due to increased coal production in the area, coal transport would increase marginally. However, sand transport would decline in the JCF area from 3 Mt/a to 2 Mt/a due to lack of available sand in the Damodar river.

Management Strategy I (circa 2001): planned improvements only

Overview

The major environmental changes resulting from this strategy are:

- In spite of an effective traditional point-source control programme, SPM levels increase in most sub-areas with an impact on more people;
- Stream pollution from industrial sources is reduced due to abatement measures, but the water-borne bacterial disease level probably increases due to population growth; and
- Reclaimed land from old mines increases, and the net disturbed land decreases.

Abatement measures

Water

Because the ash ponds in CTPS and BTPS are full, a large quantity of ash slurry overflows into the river, carrying heavy loads of TSS. The immediate solution is to construct properly designed, new ash ponds. The overflow of clean water can then be reused for ash slurry operations or for agriculture. With ponds properly constructed and managed, the large TSS loads from power plant effluents flowing into the river would be stopped.

The washeries plan closed water circuit operation to permit recovery of coal fines and reuse of the water. A few washeries (e.g., Jamadoba, and Dugda) already have a closed water system in operation. The washeries' plans for reorganization and modernization include better management of the fine coal circuit which would result in a decrease in the TSS load now entering the river.

The other major source of pollution is waste water discharge either directly or through open drains or nallahs from the many towns along the river. Most of these towns are either not sewered or are partially sewered and six have been identified for installation of pollution abatement measures. Stabilization ponds for BOD abatement and settling ponds for TSS abatement would be built.

Land

The major impact of mining is on land, and therefore land reclamation of affected areas and overburden dumps is essential. These measures are being implemented in phases.

Washeries generate about 3 Mt/a of rejects, which occupy large areas of land and pollute air and water through wind and water erosion. The plan is to use 1.7 Mt of rejects in FBC power units, generating about 1.0 Mt/a of ash, to be stored in ash ponds and used as mine fill in opencast mines or in underground mines for stowing. In addition, bottom-ash from captive thermal power stations would be used as underground stowing material in conjunction with sand (e.g., Chasnalla mine).

Urban solid waste would be deposited in sanitary land fills.

Air

Actions have been taken to install and/or upgrade ESPs on all power plants, both utility and captive. The captive power unit at FCI is to be replaced by a new unit.

Environmental quality

Table 3.4 (along with **Annexures 3.4 to 3.9**) summarizes the predicted environmental outcome of Management Strategy I. Considering all changes, it is clear that environmental quality, including health, improves only marginally in the ten year period with. Detailed comments follow, organized according to water, land and air.

Water

There is an overall change in industrial loads to the river system. Declines in water borne solids are predicted in sub-areas 2 (cells 1c, 1d and 2c), 3 (cell 2d) and 5 (cells 4c, 8a and 8b) due to improvements in washery closed circuits, a new ash pond for BTPS and expansion of the ash pond capacity at the CTPS. (Compare **Table 3.4** and **Table 2.5**.)

Environmental health problems caused by discharge of raw sewage would probably increase in the AEQM area because of population increase especially during the moonsoon season.

Land

Insights into changes expected in solids generation associated with Management Strategy I may be gained by review of the data presented in **Table 3.4** and **Annexure 3.6**. Household solid wastes are expected to increase in direct proportion to the population for the entire AEQM area, from the present approximately 1,000 t/day in 1992/1993 to about 1,200 t/day in circa 2001. Power plant solids i.e., bottom ash and trapped fly ash, are expected to more than double, in proportion to the power generated, rather than in proportion to the increase in capacity, which is less than one half, due to improved performance and installation of ESPs. Little change is expected in solids associated with direct mining. Coal production would increase from 39 Mt/yr to 43 Mt/year, but sand mined from the river would decline from 3 Mt/yr to 2 Mt/year.

Table 3.4 Summary of residuals discharge according to human activities, circa 2001 - Management Strategy I

Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
1 [1a-1b,2a-2b] (324 km²)	0	0	0	0	60	0	0	0	10	0	IMPACTED STREAM LENGTH Zero stream lengths DOMINANT SOURCES Household solids Ground level emissions Minimum industrial activity Households=28,000; density=90/km²
2 [1c, 1d, 2c] (243 km²)	9040	290	290	0	290	2920	1750	900	140	250	IMPACTED STREAM LENGTH Bokaro 5km; Konar 2km; Damodar 15km DOMINANT SOURCES Washery, power plant & mines Stack emissions + ground level emission Household solids Households=147,000; density=600/km²
3 [2d] (81 km²)	2610	1260	0	0	10	0	0	0	0	190	IMPACTED STREAM LENGTH Damodar 10 km DOMINANT SOURCES Washery & mines Household solids Power plant stack emissions Households=7,000; density 90/km²
4 [3a, 3b, 3c 3d,4a-4b,4d] (567 km²)	160	20	0	0	140	2470	4660	2820	230	20	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Washery & mines Household solids Ground level discharges Households=70,000; density=120/km²

... Contd ...

Table 3.4 contd.

Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
5 [4c, 8a-8b] (243 km²)	960	100	490	0	360	5140	4110	2360	100	90	IMPACTED STREAM LENGTH Damodar 20 km DOMINANT SOURCES Washery & mines Household solids Ground level discharges Households=180,000; density=740/km²
6 [6] (324 km²)	440	0	0	0	210	0	0	0	50	0	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Steel mill Household waste Stack emissions very high (No data released): 50 stacks Ground level discharge Households=105,000; density=260/km²
7 [5,7,8c-8d] 810 km²	340	0	0	0	140	0	0	0	50	0	IMPACTED STREAM LENGTH Damodar 2 km DOMINANT SOURCES Mines in cell 4b Household waste Ground level discharge Households=71,000; density=70/km²

Note: Total suspended solids (TSS) was selected as the indicator of waterborne solids since it was the dominant type of load.

Major changes are expected, however, in solids generated from the indirect effect of mining, i.e. washery rejects, land disturbed, reclaimed land, net reclaimed land and the volume of overburden. The annual amount of washery rejects is expected to increase about one-third, primarily due to expanded capacity and higher efficiency of the washeries. The accumulated amount of land disturbed is expected to increase from 9,300 to 10,500 ha, but a tripling of land reclaimed is also anticipated accumulating from 2,500 to 6,000 ha. The net disturbed land is thus reduced from 6,800 to 4,500 ha.

Additional insight can be gained from a spatial review of the data with primary attention drawn to three areas that contain the coal mines and most of the power plants. The major changes are:

- In sub-area 2 (cells 1c, 1d and 2c) power plant activities would include installation of an ESP on the Bokaro A facility and an improved PLF, with both contributing to an increase in the amount of solids generated. Mining would remain about constant and no river mining of sand occurs in this sub-area. The indirect effects of mining are expected to change from 1,250 to 1,750 ha with the accumulated amount of land disturbed due to the expansion of mining. Land reclamation would increase from zero to 900 ha resulting in a net decline in disturbed land from 1,250 to 850 ha. The volume of overburden generated each year would decrease slightly and the annual generation of washery rejects is expected to increase marginally.

- In sub-area 4 (3a, 3b, 3c 3d and 4d) captive power plants with a total capacity of 70 MW, based on FBC technology and using washery rejects as fuel, would be commissioned. Coal mining would be expected to increase about 20 per cent, from 17 to 21 Mt/year, and no river mining for sand would occur in this sub-area. The indirect effects of mining would be similar to sub-area 2 except for solids generated by the coal washeries. New washeries would be built and older ones operated more efficiently to account for the increased output of washed coal. As a result, the annual amount of washery rejects would triple from about 850 to 3,000 Mt/day. The accumulated amount of land disturbed by mining and related activities would increase from about 4,000 to 4,700 ha, but land reclamation would be expected to increase from about 1,700 to 2,800 ha. The accumulated net area of disturbed land would decline from 2,300 to 1,900 ha with the annual generation of overburden expected to decline slightly, from 27 to 24 Million m^3/year.

- In sub-area 5 (cells 4c, 8a and 8b), power plant capacity would increase due to the installation of a 50 MW FBC boiler and a 38 MW power plant in Sindri. Generation of solids would also increase. There would be no increase in coal mining activity, but sand mining would decline from 3 to 2 Mt/year. The indirect effect of mining has the same pattern as in the other two sub-areas. The accumulation of disturbed land would marginally increase from 4,000 to 4,100 ha. The land reclaimed would increase from 800 to 2,400 ha and the net disturbed land would decline from 3,200 to 1,700 ha. The annual amount of overburden generated would decline from 16 to 6 million m^3/ year due to proportionately more underground mining. The annual production of washery rejects would increase about 25 per cent from 4,000 to 5,100 t/day, due to improved washery performance.

Air

As indicated in the overview, the number of households exposed to air pollution would rise due to increased population, mining and power generation. However, the percentage of households exposed to very high SPM levels (> 500 μg/m³) would decrease from 14 to 8 per cent and to high SPM levels (350-500 μg/m³) would decrease from 40 to 35 per cent (**Table 3.5**). But households exposed to low SPM levels (200-350 μg/m³) would increase from 37 to 53 per cent. The net effect is a reduction in mortality rate and it is estimated that about 270 lives would be prolonged (see **Annexure 3.8**).

Table 3.5 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy I

Cell Number	< 200	200 ≤ 350	350 ≤ 500	> 500
1 [1a-1b, 2a-2b] (324 km²)	5000	17000	6000	0
2 [1c, 1d, 2c] (243 km²)	15000	108000	24000	0
3 [2d] (81 km²)	0	0	7000	0
4 [3a, 3b, 3c, 3d, 4a-4b, 4d] (567 km²)	0	27000	16500	26500
5 [4c, 8a, 8b] (243 km²)	0	95000	65000	20000
6 [6] (324 km²)	0	20000	85000	0
7 [5, 7, 8c-8d] (810 km²)	5000	54000	12000	0
Total number of households	25000	321000	215000	46000
Household distribution (per cent)	4	53	35	8
Percentage of households (›)	96	43	8	

A comparison of **Figure 2.3** and **Figure 3.1** helps to further understand the narrative. The major differences by sub-areas (aggregates of cells) are as follows:

- Sub-area 2 (cells 1c, 1d and 2c) shows a slight decline in air quality even though ESPs are installed on Bokaro A TPS. The reasons are increased power generation, an increased number of cook-stoves due to a rise in population and a minor increase in opencast mining. However, the number of households exposed to high SPM levels (350-500 $\mu g/m^3$) decreases from 41,000 to 24,000. No part of this area experiences SPM values > 500 $\mu g/m^3$;

- Sub-area 4 (cells 3a, 3b, 3c, 3d, 4a, 4b and 4d) has a net decline in air quality with more households exposed to very high (> 500 $\mu g/m^3$) and moderately high (> 200 ≤ 350 $\mu g/m^3$) SPM levels than at present. The number of households affected by the moderately high level increases from 5,000 to 27,000 and those affected by the very high level increase from 12,500 to 26,500. A decline occurs in the number of households impacted by the other two air quality levels. Mining activities and related traffic are the primary causes for these changes;

- Sub-area 5 (heavily populated cells 4c, 8a and 8b) shows an improvement with households exposed to very high SPM levels (> 500 $\mu g/m^3$) decreasing from 57,000 to 20,000. This is primarily due to reduced opencast mining and related lower transportation activity;

- Sub-area 6 (cell 6) is also predicted to experience a decline in air quality. The Bokaro Steel Plant, for which there are no emission data, is located in this area. Therefore, the values shown here are very uncertain. The CTPS power station located nearby in cell 2d may also be a factor; and

- Sub-area 7 (cells 5, 7, 8c, and 8d) is also predicted to experience a decline in air quality. Although this area is relatively clean because of minimal industrial activity, air quality deteriorates because of population growth.

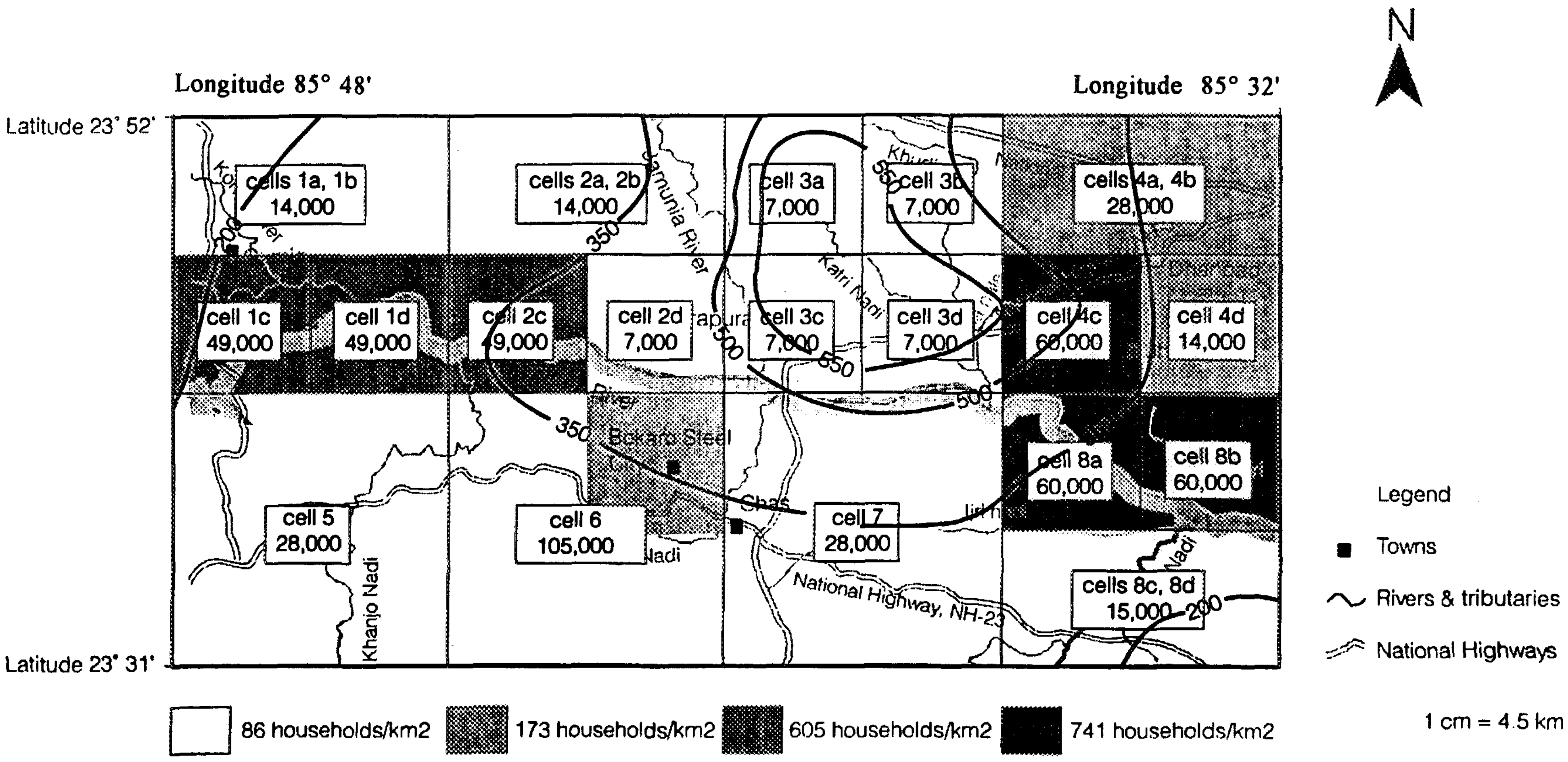
Management Strategy II (circa 2001): planned improvements plus relocation

Overview

Major changes from Management Strategy I to Management Strategy II are:

- a total of 75,000 households, 30,000 during a four year period leading up to the year 2001 and the remainder during the following six years, are relocated from areas of higher to those of lower SPM levels;
- coal mining increases slightly in areas vacated due to relocation of infrastructure;
- increase in transport activities due to increased mining;
- all other economic activities are unchanged;
- minor changes in the level of residuals generated throughout the AEQM area; and
- a reduced number of households living in high SPM areas, resulting in health improvements.

Figure 3.1 Spatial distribution of air quality in the AEQM area, SPM contours in $\mu g/m^3$, annual average, Management Strategy I (planned improvements)



Notes: (1) Population figures for each cell are households.
Estimate household contains five people
(2) Total population figure in circa 2001 is
3,04,000 people an increase of about 23% over 1992 levels

Abatement measures

A large segment of the population currently resides over vast amounts of coal reserves, living on subsidence prone land and exposed to high levels of air pollution. Therefore, several government commissions have recommended that these people be relocated to colonies outside the coalfield, where the environment is relatively safer and cleaner. This would provide access to vast quantities of prime quality coking coal now under residences. Revenue from coking coal sales should offset the costs of rehabilitation, thereby improving the environment for a large segment of population at little or no additional cost.

The Master Plan for JCF, the Banerjee Committee Report (1987) and the Expert Committee for EBCF (1992) have all suggested shifting of employees and non-employees residing on coal bearing and environmentally polluted areas to new colonies to provide a better quality of life for those people.

According to the Master Plan for JCF, seven satellite townships were to be set up outside the coal mining area for this rehabilitation. BCCL has already begun construction of three new townships, and up until 1992-93 about 10,000 houses had been completed.

The coal companies face problems of land acquisition for the new townships, therefore, the Banerjee Committee suggested construction of multi-storied houses to avoid excessive land requirements. An extract from the Committee's report on this issue is reproduced below:

> "Immediate improvement in production in higher grades of prime coking coal in significant quantities can be achieved if BCCL is placed in a position to vacate certain crucial surface areas presently occupied by its own buildings. The BCCL's buildings comprise mostly of workers houses and a few larger old fashioned bungalows, and on the basis of rough census their total number would be 50,000".

Similarly in EBCF, the Expert Committee reported 560 Mt of coal blocked under surface buildings, roads, rail, and other structures. Three to four relocation colonies have been proposed with 25,000 houses for shifting coal company employees and three villages. Shifting the population would release locked-up reserves of coal for the Kargali and Bokaro mines operating in the area. Shifting of a rail line is almost complete, resulting in the release of 6 Mt of coal reserves. Also, a feasibility report for diversion of the Damodar river (3.6 km stretch) is under consideration by the central government because this would release about 100 Mt of blocked coal reserves. It would displace about 4,000 families.

Therefore, in this strategy, shifting has been proposed for 75,000 households [BCCL (50,000) and CCL (25,000) employees] because they would benefit from shifting to satellite towns on the periphery of the coalfield. The shifting or relocation would be as follows:

- From cell 8d to 4a-4 - 5,000 households
- From cell 4c to 4d -30,000 households
- From cell 8a to 8b -15,000 households
- From cell 1d to 1c -25,000 households

The benefits of shifting of worker population are: (1) relocated families would be exposed to low and moderate levels of SPM from the present high and very high levels; (2) release of prime coking coal in JCF and medium coking coal in EBCF under company buildings, structures, etc.; and (3) better fire abatement and recovery of coal from coal seams under fire-affected areas in JCF.

Environmental quality

Table 3.6 (along with **Annexures 3.10 to 3.14**) summarizes the predicted environmental outcome of Management Strategy II. The net effect of Management Strategy II compared with Management Strategy I is positive. Additional revenue from the sale of coal will more than pay for household relocations with reduction in exposure to air pollution a plus.

Water

There are no significant differences between Management Strategy I and II.

Land

Household relocations are proposed from four different areas, each the site of additional coal mining. A total of 30,000 households is expected to have been relocated by 2001 and the remainder by 2010. The relocation of population results only in modest changes in the quantity of household waste generated in particular sub-areas as can be seen by comparing **Table 3.4** and **Table 3.6**.

Mining on land released by relocations is expected to commence in 2001 with a production of 0.7 Mt, increasing to 3.5 Mt by 2005 and stabilizing there. The present level is 39.5 Mt/year (see **Table 2.1**). After Strategy I, the level of mining is 42.8 Mt/ year, as shown in **Annexure 3.4**. Total output would increase to 43.5 Mt/year under Management Strategy II.

Air

The spatial distribution of SPM shown in **Figure 3.2** is similar to that of Management Strategy I with minor changes due to household relocations and expanded mining. The significant change is the improvement in environmental health. The reduced number of households living in high SPM areas results in a reduction in mortality with approximately 320 lives prolonged (see **Annexure 3.19**). This comparison further suggests that the environmental health experienced by a population of 3.2 million in the time period circa 2001 would not be any more severe than that experienced by 2.2 million presently living in the region. Details of areas where improvements occur are shown in **Table 3.7** and **Figure 3.2**. The effects of changes are clarified using the table and figure together. The percentage of population exposed to very high SPM levels (> 500 $\mu g/m^3$) declines from 8 to 5 per cent and the percentage of population in areas with high SPM levels (300-500 $\mu g/m^3$) marginally declines from 35 to 34 per cent.

Table 3.6 Summary of residual discharge according to human activities, circa 2001 - Management Strategy II (planned improvements plus relocation)

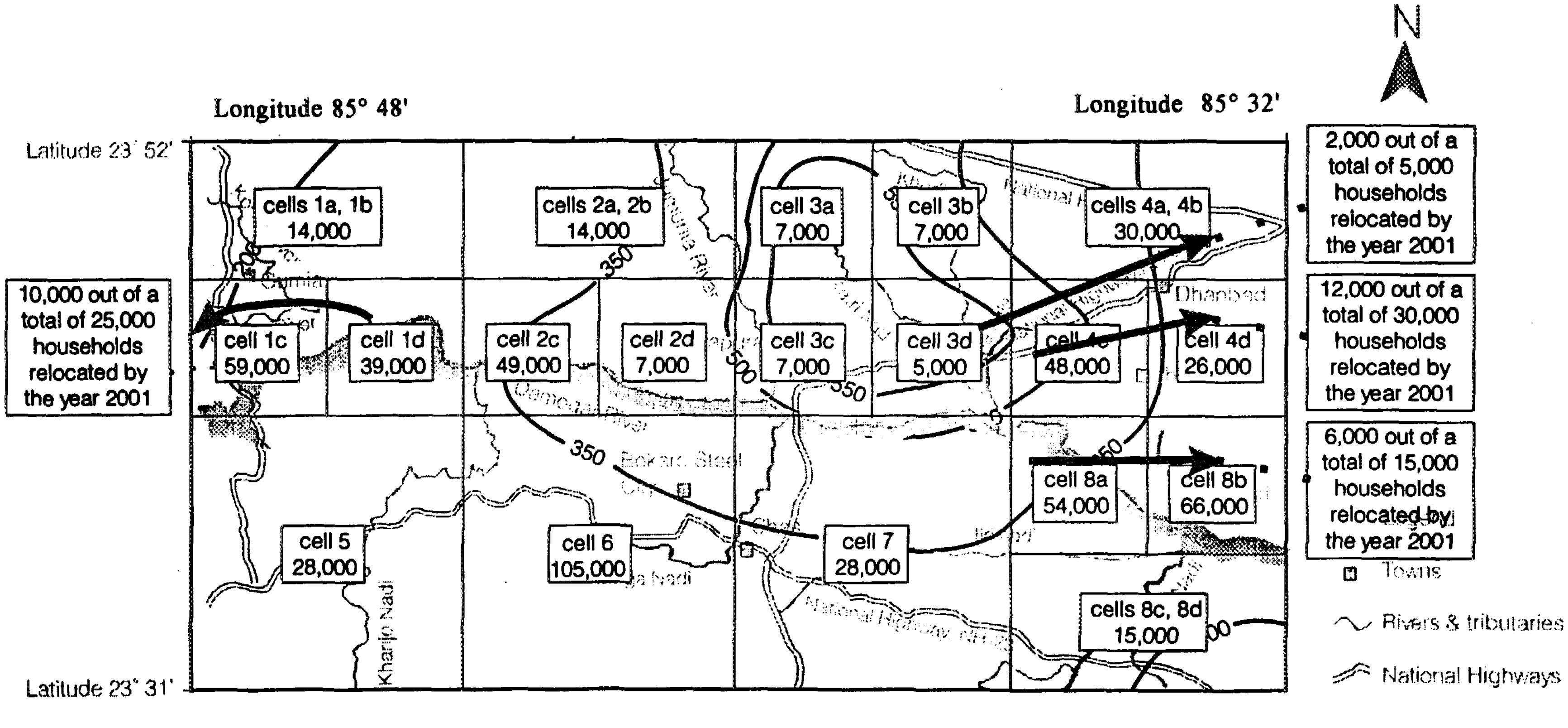
Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
1 [1a-1b 2a-2b] (324 km²)	0	0	0	0	60	0	0	0	10	0	IMPACTED STREAM LENGTH Zero stream lengths DOMINANT SOURCES Household solids Ground level emissions Minimum industrial activity Households=28000; density=90/km²
2 [1c, 1d, 2c] (243 km²)	9040	290	290	0	290	2920	1750	900	140	250	IMPACTED STREAM LENGTH Bokaro 5km; Konar 2km; Damodar 15km DOMINANT SOURCES Washery, power plant & mines Stack emissions + ground level emission Household solids Households=147000; density=600/km²
3 [2d] (81 km²)	2610	1260	0	0	10	0	0	0	0	190	IMPACTED STREAM LENGTH Damodar 10 km DOMINANT SOURCES Washery & mines Household solids Power plant stack emissions Households=7000; density=90/km²
4 [3a,3b,3c 3d,4a-4b,4d] (567 km²)	160	20	0	0	160	2470	4670	2820	230	20	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Washery & mines Household solids Ground level discharges Households=82000; density=140/km²

... Contd ...

Table 3.6 contd.

Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
5 [4c,8a-8b] (243 km²)	960	100	490	0	340	5100	4120	2360	100	90	IMPACTED STREAM LENGTH Damodar 20 km DOMINANT SOURCES Washery & mines Household solids Ground level discharges Households=168,000; density=690/km²
6 [6] (324 km²)	440	0	0	0	210	0	0	0	50	0	IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Steel mill Household waste Stack emissions very high (No data released): 50 stacks Ground level discharge Households=105000; density=320/km²
7 [5,7,8c-8d] (810 km²)	340	0	0	0	140	0	0	0	50	0	IMPACTED STREAM LENGTH Damodar 2 km DOMINANT SOURCES Mines in cell 4b Household waste Ground level discharge Households=71000; density=90/km²

Note: Total suspended solids (TSS) was selected as the indicator of waterborne solids since it was the dominant type of load.



Notes: (1) Population figures for each cell are households.
Estimate household contains five people
(2) Total population figure in circa 2001 is
3,04,000 people an increase of about 23% over 1992 levels

Figure 3.2 Spatial distribution of air quality in the AEQM area, SPM, contours ($\mu g/m^3$), annual average, Management Strategy II (Management Strategy I plus relocation strategy)

Table 3.7 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy II (planned improvements plus relocation)

Cell Number	< 200	200 - 350	350 - 500	> 500
1 [1a-1b, 2a-2b] (324 km^2)	4500	17500	6000	0
2 [1c, 1d, 2c] (243 km^2)	25000	98000	24000	0
3 [2d] (81 km^2)	0	0	7000	0
4 [3a, 3b, 3c, 3d, 4a-4b, 4d] (567 km^2)	0	41000	16500	24500
5 [4c, 8a, 8b] (243 km^2)	0	101000	59000	8000
6 [6] (324 km^2)	0	20000	85000	0
7 [5, 7, 8c-8d] (810 km^2)	5000	54000	12000	0
Total number of households	34500	331500	209500	32500
Household distribution (per cent)	6	55	34	5
Percentage of households (›)	94	39	5	

Management Strategy III (circa 2001): planned improvements and household relocation plus fugitive dust reduction on roads

Overview

Major changes from Management Strategy II to Management Strategy III are:

- haul road improvement in opencast mines including proper construction, better water sprinkling and/or chemical spraying;
- two hundred km of colliery roads to be made pucca (semi-metalled);
- PWD roads to be strengthened and maintained in good condition;
- all other activities are unchanged; and
- drastic reduction in SPM levels in ambient air quality in most cells, especially in those most degraded.

Abatement measures

Additional non-point source abatement measures would be implemented to reduce fugitive dust generation from roads, drastically reducing SPM levels. One set of measures would improve public and colliery roads. Because the present roads are extremely bad conditions, the management strategy includes plans to strengthen, reinforce and widen most roads. The other set of measures would improve haul roads in opencast mines. Fugitive dust from mining operations (blasting, loading and transport) in opencast mines is the major source of air pollution in the area. Apart from regular measures like water sprinkling and use of dust extraction equipment, chemical spray on haul roads can result in suppression of fugitive dust in the mining area. A combination of measures, including proper design and construction of haul roads, and water and chemical spraying are suggested.

Environmental quality

Table 3.8 (along with **Annexures 3.15 to 3.19**) summarizes the predicted environmental outcome of Management Strategy III. The net of Management Strategy III is positive compared to Management Strategy II because there is a drastic reduction in air pollution.

Water

There are no significant differences in water quality when compared with Management Strategies I and II.

Land

No change in solid wastes when compared to Management Strategies I and II.

Air

The spatial distribution of SPM as shown in **Figure 3.3** is very different from **Figures 2.3, 3.1** and **3.2** (present conditions and Management Strategies I and II). Virtually no population is exposed to very high (> 500) and high (>350-500) levels of SPM as against 54 per cent in present conditions, 43 per cent in Management Strategy I and 39 per cent in Management Strategy II. As a result, the population living in areas with < 200 $\mu g/m^3$ SPM levels increases to 58 per cent as against 4 per cent in Management Strategy I. **(Table 3.9)** There is an overall improvement in air quality in most of the study area, resulting in a drastic improvement in environmental health. The mortality rate declines further and approximately 1930 lives would be prolonged (see **Annexure 3.19** for details).

Table 3.8 Summary of residuals discharge according to human activities, circa 2001 - Management Strategy III (planned improvements plus relocation strategy plus fugitive dust reduction on roads)

Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
1 [1a-1b 2a-2b] (324 km^2)	0	0	0	0	60	0	0	0	5	0	Ground level emissions decrease drastically IMPACTED STREAM LENGTHS No river lengths DOMINANT SOURCES Household solids Minimum industrial activity Households=28000; density=90/km^2
2 [1c,1d,2c] (243 km^2)	9040	290	290	0	290	2920	1750	900	80	250	Ground level emissions decrease drastically IMPACTED STREAM LENGTH Bokaro 5km; Konar 2km; Damodar 15km DOMINANT SOURCES Washery, power plant & mines Power plant stack emissions + ground level emission Household solids Households=147,000; density=600/km^2
3 [2d] (81 km^2)	2610	1260	0	0	10	0	0	0	0	190	IMPACTED STREAM LENGTH Damodar 10 km DOMINANT SOURCES Washery & mines Household solids Stack emissions Households=7000; density=90/km^2
4 [3a,3b,3c 3d,4a-4b,4d] (567 km^2)	160	20	0	0	160	2470	4670	2820	150	20	Ground level emissions decrease drastically IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Washery & mines Household solids Households=82000; density=140/km^2

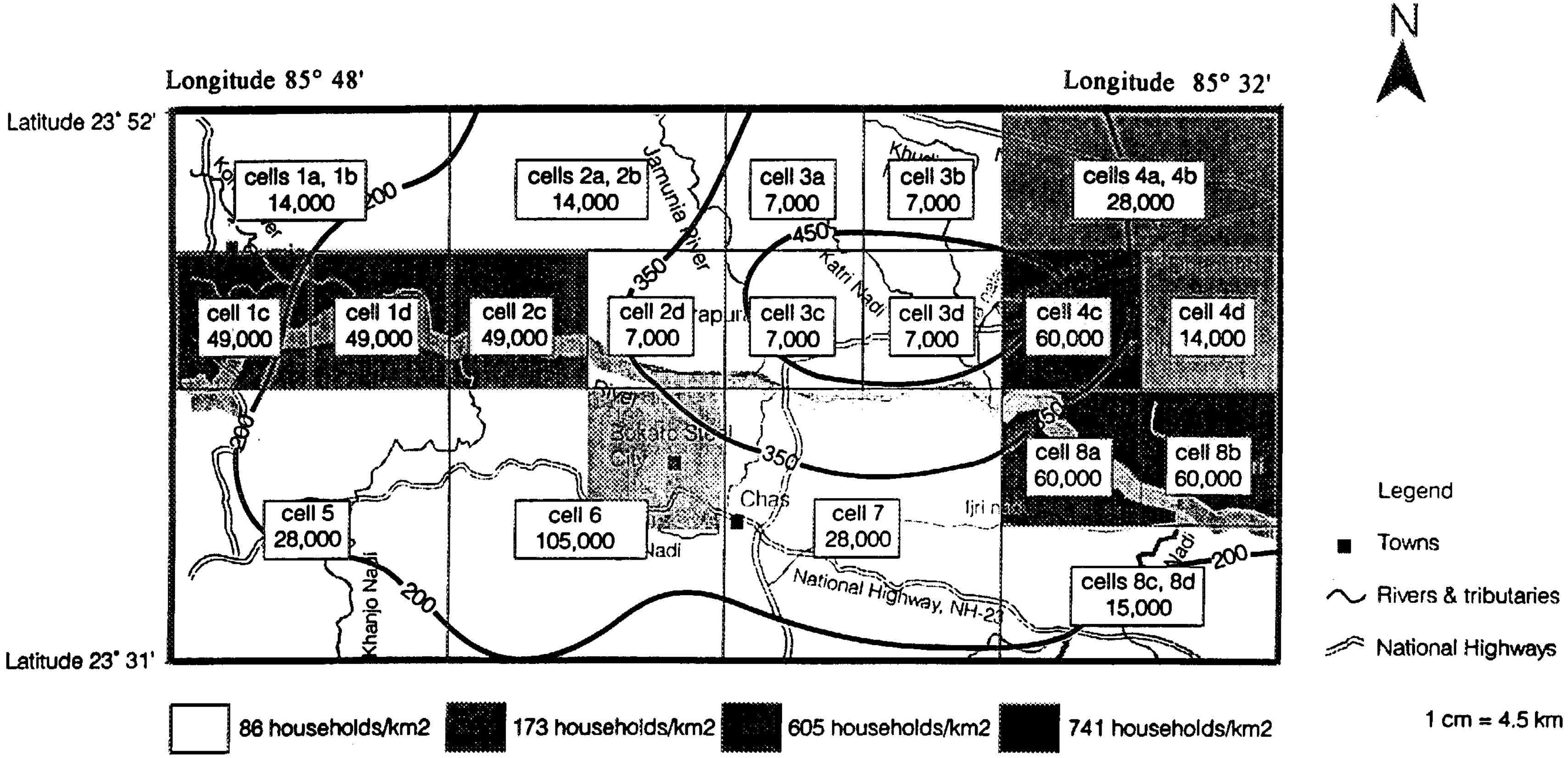
... Contd ...

Table 3.8 contd.

Cell Number	Water borne solids				Solids						Comments
	TSS in river (t/day)	Ash power plants (t/day)	Spills washeries (t/day)	Coal spills (t/day)	Household (t/day)	Washery rejects (t/day)	Past & present mineland (ha)	Reclaimed land (ha)	Low elevation discharge (t/day)	High elevation discharge (t/day)	
5 [4c,8a-8b] (243 km²)	960	100	490	0	340	5100	4120	2360	60	90	Ground level emissions decrease drastically IMPACTED STREAM LENGTH Damodar 20 km DOMINANT SOURCES Washery & mines Household solids Households=168,000; density=690/km²
6 [6] (324 km²)	440	0	0	0	210	0	0	0	20	0	Ground level emissions decrease drastically IMPACTED STREAM LENGTH Damodar 3 km DOMINANT SOURCES Steel mill Household waste Stack emissions very high (No data released): 50 stacks Households=105,000; density=320/km²
7 [5,7,8c-8d] (810 km²)	340	0	0	0	140	0	0	0	30	0	Ground level emissions decrease drastically IMPACTED STREAM LENGTH Damodar 2 km DOMINANT SOURCES Mines in cell 4b Household waste Households=71,000; density=90/km²

Note: Total suspended solids (TSS) was selected as the indicator of waterborne solids because it is the dominant pollutant load.

Figure 3.3 Spatial distribution of air quality in the AEQM area, suspended particulate matter, SPM in $\mu g/m^3$, annual average, Management Strategy III [total abatement measures: planned improvements plus relocation plus fugitive dust suppression



Notes: (1) Population figures for each cell are households. Estimate household contains five people
(2) Total population figure in circa 2001 is 3,04,000 people an increase of about 23% over 1992

Table 3.9 Spatial distribution of annual population exposure to SPM, circa 2001 - Management Strategy III

Cell Number	< 200	200 - 350	350 - 500	> 500
1 [1a-1b, 2a-2b] (324 km^2)	24000	4000	0	0
2 [1c, 1d, 2c] (243 km^2)	123000	24000	0	0
3 [2d] (81 km^2)	0	7000	0	0
4 [3a, 3b, 3c, 3d, 4a-4b, 4d] (567 km^2)	37000	43400	1600	0
5 [4c, 8a, 8b] (243 km^2)	90000	78000	0	0
6 [6] (324 km^2)	20000	85000	0	0
7 [5, 7, 8c-8d] (810 km^2)	57000	14000	0	0
Total number of households	351000	255400	1600	0
Household distribution (per cent)	58	42	0	0
Percentage of households (›)	42			

Summary of capital requirements

For Management Strategy I, the total capital investment required up to the year 2001-02 is estimated at Rs.8,536 million; the amount already provided for ESP's and closed circuit washeries is estimated at Rs.1,229 million, leaving a balance of Rs.7,307 million (**Table 3.10**). Out of this, land reclamation costs predominate (Rs.5,500 million).

The investment costs for pollution abatement measures like ESP's, closed-circuit washeries and fugitive dust abatement for haul roads in opencast mines should be reflected in coal prices because these are part of the cost of production. Since the government has taken over the coal mines, they have set coal prices on an arbitrary basis without including pollution abatement costs. Regarding investment for land reclamation, an expert committee of the government suggested in their 1987 report that adequate funds be provided by the government because land damage is due to past mining operations and costs cannot be borne by current mining operations. Since the government has not as yet made funds available, an alternative is to charge a cess on coal production to raise the resources required for land reclamation. The cess is included as part of Management Strategy I because BCCL is partially carrying out this activity. The cess to be charged is estimated at Rs.14/t.

Table 3.10 Capital requirements till circa 2001 (Million Rupees)

ACTIVITY	1992-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	2000-01	2001-02
Management Strategy I										
Chandrapura ESP	273	273								
Bokaro A ESP	-	67	67							
Chandrapura Ash Pond	37	36	73							
Bokaro A Ash Pond	16	-	16							
Bokaro B Ash Pond	-	104	104							
Close Circuit Washery	200	350	350	300	300	300				
Stabilization/ sedimentation ponds for town waste water	43	43	43							
Sanitary Land Fill for Solid Wastes	3	3	4	4	4	4	4	4	5	5
Land reclamation	503	503	521	540	558	576	576	576	576	576
Total	**1075**	**1379**	**1178**	**844**	**862**	**880**	**580**	**580**	**581**	**581**
Funds already provided	473	690	67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net requirement	**602**	**689**	**1110**	**843**	**862**	**880**	**580**	**580**	**580**	**581**
Management Strategy II										
Net requirement for Strategy I options	602	689	1110	843	862	880	580	580	580	581
Relocation						1500	1500	1500	1500	1500
Total	**602**	**689**	**1110**	**843**	**862**	**2380**	**2080**	**2080**	**2080**	**2081**
Management Strategy III										
Requirement for Strategy II options	602	689	1110	843	862	2380	2080	2080	2080	2081
Dust abatement on haul roads					259	257	255	255	255	255
Improving colliery roads					106	106	106	106	106	106
Improving PWD roads					333	333	333	333	333	333
Total	**602**	**689**	**1110**	**843**	**1560**	**3076**	**2774**	**2774**	**2774**	**2774**
Coal mining requirements								**500**	**500**	**500**

Note: Capital requirements continue beyond the planning horizon and were considered when calculating NPV in Tables 3.10 (d) and 3.11. Investments for coal mining refers to additional coal mined under Strategies II and III. This is phased in over 7 years starting from circa 1999 up to 2005, when the incremental capacity of 3.5 Mt is achieved

Urban sanitation is totally neglected and lack of available funds is often mentioned as a major constraint. Per the Eighth Plan document of the Government of India, the outlay for urban sewerage, sewage treatment and urban waste management is Rs. 54,940 million for the five year period. Sharing this among the Indian urban population, it is assumed that 0.7 per cent (the ratio of urban population in the study area to the urban population of India) of the total outlay of Rs.54,940 million i.e., Rs. 385 million, should have been provided for sanitation improvement in the study area, using allocations in the 8th Plan. This amount, Rs. 385 million, would be sufficient to meet the investment requirement indicated in **Table 3.10**.

For Management Strategy II, a total of Rs.15,000 million spread over 10 years is required, ie., approximately Rs.1,500 million annually. Since the relocation of households would be a business venture with a postive return, finances should be raised by the private sector.

For Management Strategy III, approximately Rs.700 million is required annually. The Eighth Plan document provides Rs. 132,100 million (State roads, Rs. 106,100; central roads, Rs. 26,000) for construction and maintenance. Again, if we assume that 0.7 per cent of this amount is earmarked for road construction/improvement in the study area, the amount available would be Rs. 925 million for five years or about Rs. 185 million annually. Because this amount (specified in the Eighth Plan) is either not made available to the concerned government agencies in the area or there is improper utilization of the funds by the agencies, road conditions remain in deplorable condition. A cess on coal to meet the investment needs is suggested. If some amount is committed by the state government, then to that extent, the cess can be reduced. This cess works out to be Rs.18/t of coal, taking coal production in 2001-02 to be 43 Mt.

Management strategy evaluation

Three criteria are used to evaluate the management strategies. One is the net present value (NPV). The second is the reduction in mortality. The third is the cost-effectiveness of mortality reductions.

For Management Strategy I, some funds have already been provided for ESPs and closed circuit washeries. The NPV cost (circa 1991) after these sums have been taken into account, is Rs 2350. The NPV for this management strategy is negative as there are no offsetting financial gains.

There are environmental benefits of this strategy, as well as the other two strategies, that can be measured as reductions in total SPM-household exposure. For this strategy, total household exposure actually increases (as detailed in **Annexure 3.13**), though the severity of the exposure is less. This increased exposure is primarily due to growth in population which would happen anyway. The implementation of MS I mitigates the severity of this increased exposure from what it might have been had abatement not been implemented.

Some 270 lives would nonetheless be prolonged by implementing Management Strategy I because of the less severe overall levels of SPM.

For Management Strategy I, the NPV of the costs for SPM reductions is a negative Rs 55 million (circa 1991) and the PV of SPM-household reductions is Rs 1.72 million. This results in a negative cost per SPM-household of Rs 320. As will be seen below, it appears that the cost effectiveness of SPM-household reductions is considerably higher for Management Strategy I than for either one of the other two strategies.

For Management Strategy II, the strategy evaluation is more complex because there are both financial and environmental health benefits. The NPV calculations include the costs of new housing and relocation, the costs of mining and the coal revenues from the new mines in the vacated areas based on conservative estimates of coal production. The NPV (1991) is positive as the PV revenues are Rs 5,600 million and the PV costs are Rs 4,300 million giving a net NPV of Rs 1,300 million (**Table 3.11**). As can be seen in the table, in three of the sites the NPV is positive and therefore indicates a potential business venture which would generate resources, along with an improved habitat for some of the population. Relocation of people from cell 4c and additional mining has a negative NPV. This is due to higher costs incurred for rehabilitation for a large number of people, which is not offset by additional coal production.

Table 3.11 NPV for relocation costs and revenue from mining for the four sites

	Cell 1d	Cell 3d	Cell 4c	Cell 8a
PV (circa 1991) cost (Million Rs)	1,430	290	1,700	860
PV(circa 1991) revenue (Million Rs)	1,600	1,250	1,600	1,200
PV (circa 1991) SPM-Households (Million microg/m^3 households)	3.8	3.2	5.3	4.5
Rs/SPM-household	47	285	-21	76
Total cost analysis for relocation and mining for the study area				
PV (circa 1991) cost (Million Rs)				4,300
PV (circa 1991) revenue (Million Rs)				5,600
NPV (circa 1991 (Million Rs)				1,300
NPV (circa 1991) SPM households (Million microg/m^3 households				17
Rs/SPM-household				79

Note: NPV is positive for relocation - mining implies that along with additional resource generation, environment health for the 75,000 households will be improved.

The health-related environmental benefit of this strategy is approximately 320 lives prolonged.

Given the positive NPV for this management strategy, it is not surprising that the cost per SPM-household reduced is also positive as can be seen in **Table 3.11**. This means that the environmental benefits are costless overall as well as costless for three out of the four cells. Only in cell 4c is there a negative cost.

For Management Strategy III, the NPV is a negative Rs 3,663 million assuming that all measures are implemented (**Table 3.12**). Even though infrastructure measures such as road improvements lead to greater productivity, fuel savings and automotive life, they do not generate financial revenues such as those from increased coal production.

Table 3.12 Cost analysis: NPV and cost per SPM household reduction for the three roads

Type of roads	Length (km)	Capital cost (Million Rs/km)	O&M cost (Percentage of capital)	Life (Years)	Net present value (costs) (circa 1991)		Cost per unit SPM-household reduction [Rs/(μg/m³ - household)]
					Million Rs	Million SPM-households	
PWD roads	300	5.0	2.5	5	1882	195	10
Colliery roads	200	2.5	2.5	5	603	103	6
Haul roads	Annualized cost Rs.10/t of coal produced from opencast mines				1178	86	14
	Discount rate = 12 per cent						

The health related environmental benefit from this strategy is 1930 lives prolonged. There is a large reduction in fugitive dust levels resulting in approximately 60 per cent of the population living below the prescribed standard of 200 $\mu g/m^3$ and with those remaining marginally over the standard.

Given the negative NPV for this strategy, it is not surprising that the cost per SPM-household is negative. In a relative sense, however, the colliery road measures are more cost effective that either PWD or haul roads, which suggests that they should be implemented first. Also, these measures would appear to be more cost effective than the measures in Management Strategy I or for one of the four relocations associated with Management Strategy II.

Institutional requirements

To meet the challenge of abating environmental degradation and energizing improvement of the environment beyond the traditional regulatory measures that constitute Management Strategy I, the state government should re-invent the Mineral Area Development Authority (MADA). This authority is empowered with the development of the area. In view of the environmental degradation and haphazard development of the area, however, it is clear that it has been unable to plan or implement suitable measures for improvement. One reason for this failure could be lack of sufficient resources to implement plans; another could be lack of sufficient authority to implement/oversee developmental activities. In spite of its indifferent performance, MADA should be strengthened and made accountable to implement the AEQM plan so as to avoid creating a parallel agency. MADA should have equal status with other ministries in the state government and should be headed by a dynamic person of senior rank to enable it to function effectively

The non-traditional pollution abatement measures that constitute Management Strategies II and III are currently within the jurisdiction of agencies in the area, e.g. coal companies, state highway organizations, state PWD, and district administration, etc. There is a need for a strong authority, not only to coordinate these different agencies, but with the power to implement plans (See **Table 3.13** for agencies responsible) . This agency should be MADA, suitably strengthened with administrative and legal powers. The MADA Board should include representatives from agencies in the area and should be assigned primary responsibility for implementation of the AEQM plan.

The cess levied to implement any of the on-going or future measures should be implemented by the MADA.

Table 3.13 Agencies responsible for implementation of the AEQM plan measures

Abatement measures	**Responsible agency(ies)**
Land reclamation Chemical spraying on haul roads Close circuit washery	Mining companies
ESP & Ash Ponds	Power generating companies
Roads	
Public roads	NH Organization, PWD
Mine roads	Coal companies
Urban waste water and solid waste Sanitary land fill Stabilization/Sedimentation Ponds	Municipality/District administration
Shifting of population	Coal companies through private organizations
Smokeless fuel	Coal companies
FBC power plant	Coal companies through private organizations
Enforcement of emission standards	State PCB

CHAPTER 4

Conclusions and recommendations

The AEQM approach is a powerful problem solving technique for application to a wide range of situations and locations throughout the world. The core of the approach is to integrate economics, ecology, technology and institutions to identify and evaluate alternative solutions to pressing environmental problems. The application of such an interdisciplinary approach, however, is demanding, particularly when data are limited, which is often the case in developing countries.

The objective of the present study is to devise a framework that guides the improvement of environmental quality of the area. To accomplish this, information for decision-making is necessary; the AEQM plan is intended to supply this information in a systematic, orderly fashion in order to open, not foreclose, options. The focus is on the generation of non-traditional approaches to environmental management, such as housing relocation and road improvements, to bring about environmental improvements.

Present conditions

Present conditions in the study area can be summarized as follows:

- It is economically important due to large reserves of prime and medium coking coals;

- Coal mining has been going on since the early 1890s and has led to environmental degradation;

- There have been no effective measures to land, air and water pollution abatement;

- The population is almost 2.4 million and over 90 per cent of them are exposed to very high levels of SPM in the ambient air and the generation of air residuals is causing serious human health problem;

- Two power plants and a few washeries account for more than 50 per cent of the TSS load flowing into the river. The sub-area (cells 1c, 1d and 2c), which is less than 10 per cent of the total AEQM area, is the dominant source of liquid residual discharge;

- The generation of industrial solids associated with mining is several orders of magnitude larger than from the households. Wastes are concentrated in a small fraction of the total study area; sub-area 5 (cells 4c, 8a and 8 b) contains the highest concentrations of both household and mining-related wastes. The inclusion of other industrial solids, e.g., power plant ash, would change the inventory slightly but the general results would remain the same. There are no regulations for disposal of solid residuals at this time;

- The total area under mining is about 130 sq km of which about 70 sq km of land is damaged or degraded due to fire, subsidence, overburden dumps or abandoned mines.

Management strategies

Economic activities with the potential for future growth are all coal related: coal mining, coal washing, coal transport and power generation. Because population is increasing, transportation and construction activities would increase. A time period of ten years has been chosen for the future plan (circa 2001) and three different management strategies have been selected. The results are summarized below for each strategy.

Management Strategy I

This strategy accepts as given the current regulatory regime that is currently being implemented by the BSPCB. Declines in TSS are predicted in sub-area 2 (cells 1c, 1d, and 2c) due to washery closed-circuits, a new ash pond for BTPS and an expansion of ash pond capacity in CTPS. Household solid wastes are expected to increase in direct proportion to the population. The ash discharge from power stations are also expected to increase due to expected improved performance. The solids associated with mining are not expected to change much, but net disturbed land is reduced from 6800 to 4500 ha due to reclamation. Air quality improves slightly in sub-area 5 (cells 4c, 8a and 8b (which is heavily populated) due to a reduction in open cast mining, but in other areas, air quality deteriorates marginally. For the most part, the number of households exposed to high and very high levels of SPM would still be significant.

Management Strategy II

This strategy includes the planned improvements of Strategy I plus household relocation; over a period of ten years, 75,000 households (employees of BCCL and CCL) would be shifted from the most affected areas to colonies on the periphery of the coalfield. Relocated families would be exposed to lower SPM from the present high levels and would therefore experience an improvement in environmental health. In addition, reserves of prime and medium coking coals would be released for mining and the relocation would assist in better fire abatement. The additional revenue from increased coal production would pay for the cost of relocation. No significant difference in water quality and solid waste would occur.

Management Strategy III

This strategy includes planned improvements, household relocation and mining from Strategy II plus fugitive dust reduction on roads. There would be a drastic reduction in air environmental pollution with SPM levels falling by more than 300 $\mu g/m^3$ SPM in the most affected areas. As a result approximately 60 per cent of the population would be exposed to levels below 200 $\mu g/m^3$ of SPM (the recommended standard for residential areas) and the rest, 40 per cent, exposed to only marginally higher levels.

Cost Analysis

Total investment spread over ten years is estimated at Rs.8,000 million for abatement measures in Management Strategy I, Rs.15,000 million for relocation in Management Strategy II and Rs.7,000 million for improved roads in Strategy III. Three measures, land reclamation, relocation and road improvement, constitute the bulk of the investments. Although costs should be reflected in the price of coal, coal prices are currently administered by the government and do not reflect social costs. Land reclamation and road improvements could be funded through a cess on coal of Rs.14/t and Rs.18/t of coal respectively. Population relocation (including new housing) could be funded by surplus revenues from the additional coal sales.

A NPV analysis for these measures shows that relocation (Management Strategy II) generates net positive resources and at the same time improves the environmental health of 75,000 households. Continuation of planned improvements (Management Strategy I) and fugitive dust abatement for roads (Management Strategy III), entail a cost, and their relative effectiveness, vis-a-vis reducing people-exposure to high levels of SPM, has been calculated in terms of cost per unit $\mu g/m^3$-household. The results show that merely continuing planned improvements, some of which are already underway, would result in a slight increase of overall people-exposure, but would reduce exposure to the highest levels of SPM. By contrast, reducing fugitive dust would significantly improve air quality. Colliery roads improvement strategy would be most effective in reducing people-exposure, followed by PWD roads improvement and haul roads improvement.

Recommendations

One of the main objectives of the study was to test the AEQM approach as one way to prepare an integrated plan for a "critically polluted area." As this approach generated scientifically based management strategies for the Dhanbad-Bokaro area, it would appear to have the potential to generate management strategies for other critically polluted areas.

For a successful AEQM study and its implementation, it is of utmost importance that major players actively participate in providing data and helping formulate realistic abatement measures in terms of costs and feasibility. Formulation of management strategies is fundamental to the AEQM method and this cannot be independently developed by the AEQM study team.

One major problem has been the lack of data on emissions generation and discharge. A handbook of gross residuals generation by type of activity would have been useful. Cost data used in the analysis are also estimates, especially for relocation and road improvement, and a handbook of generalized cost functions for certain types of residuals modification processes would have helped.

Major factors in implementing the plan are the political considerations. The following aspects need to be observed when presenting the plan to administrative authorities.

- Priorities of environmental problems in relation to other societal problems;
- Priorities of strategies within the AEQM plan;
- Inter-governmental relations (centre-state and state-district);
- Public acceptance; and
- Obtaining the legal authority for the institution entrusted with implementation.

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