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COMPREHENSIVE INDUSTRY DOCUMENT ON IRON ORE MINING

CENTRL POLLUTION CONTROL BOARD
(Ministry of Environment and Forests, Govt. of India)
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The Cover Photographs used are Controlled Blasting in Bailadila, NMDC, Sluury disposal of KIOCL, Excavation & Loading in KIOCL, Dump stabilization & Dust suppression at Bailadila, NMDC (clockwise from top left)

FOREWORD

The series of publication entitled under "Comprehensive Industry Document Series" (COINDS) is designed to cover the status of each specific type of industry in the country in detail, covering all environmental issues. These documents facilitate the concerned units in the sector to improve environmental performance and compliance with the National Environmental Standards.

The Comprehensive Industry Document on Iron Ore Mining Industry is one in the series that the Central Pollution Control Board has taken up for publication. The main objective of this document, apart from giving an overall view of iron ore mining industry, is to develop the National Environmental Standards, to provide cleaner technologies and to specify Guidelines / Code of Practice for Pollution Prevention & Control. The report has been finalized after a series of discussions with the industry representatives, industry associations, State Pollution Control Boards and other statutory bodies associated with the mining industry.

This study was taken up by the Central Pollution Control Board through the Steel Authority of India Limited (SAIL), Environment Management Division (EMD), Kolkata. The help and assistance extended by the State Pollution Control Boards, Indian Bureau of Mines, Iron ore mining Industries, iron ore mining Industry Associations etc. during the study is gratefully acknowledged.

I would like to express my sincere appreciation for the work done by the SAIL, EMD's team headed by Dr. R. K. Agrawal, Executive Director, EMD and comprising Er. T. K. Bhowmick, Assistant General Manager, Er. Malla Srinivasu, Manager.

I commend the efforts made by my colleagues Er. R. C. Kataria, Senior Environmental Engineer for co-ordinating the study and finalizing the report under guidance of Dr. B. Sengupta, Member Secretary, CPCB. The contribution of Shri Mahendra Kumar Gupta, Data Entry Operator, in preparing the typed manuscript deserves due acknowledgement.

We, in CPCB, hope, that the document will be useful to the Industry, Regulatory Agencies, the Consultants and others interested in pollution control in Iron Ore Mining.

(J. M. Mauskar)

August 29, 2007

R E P O R T

Development of Clean Technology for Iron Ore Mines and Development of Environmental Standards

Prepared for

Central Pollution Control Board
(Ministry of Environment and Forests, Govt. of India)
Parivesh Bhawan, East Arjun Nagar, New Delhi – 110032

September 7, 2007

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A

AAQ	-	Ambient Air Quality
AMD	-	Acid Mine Drainage
ANFO	-	Ammonium Nitrate & Fuel Oil
ARD	-	Acid Rock Drainage

B

BADT	-	Best Available Demonstrated Technology
BAT	-	Best Available Technology (Economically Achievable)
BF	-	Blast Furnace
BHP	-	Broken Hill Properties
BHQ	-	Banded Hematite Quartzite
BIF	-	Banded Iron Formations
BMQ	-	Banded Magnetite Quartzite
BOF	-	Basic Oxygen Furnace
BPT	-	Best Practicable Control Technology
BDL	-	Below Detectable Limit
BOD	-	Biochemical Oxygen Demand

C

CCW	-	Cyclical and Continues Working
CERLA	-	Comprehensive Environmental Response, Compensation and Liberty Act
CIL	-	Coal India Limited
CLO	-	Calibrated Lump Ore
CMRI	-	Central Mining Research Institute
CO	-	Carbon Monoxide
COD	-	Chemical Oxygen Demand
CPCB	-	Central Pollution Control Board
CSN	-	Companhia Sideraurgica Nacional
CTP	-	Crushing & Transferring Points
CVRD	-	Compantia Vale do Rio Doce
CZ	-	Central Zone

D

dB (A)	-	decibel in A-Weighted Scale
DGMS	-	Director General of Mines Safety
DO	-	Dissolved Oxygen
DME	-	Department of Minerals and Energy
DMP	-	Disaster Management Plan
DPM	-	Diesel Particulate Matter
DR	-	Direct Reduction
D/s	-	Down Stream
DTH	-	Down the Hole

E

EAF	-	Electric Arc Furnace
EIA	-	Environment Impact Assessment
EMP	-	Environment Management Plan
EPA	-	Environment Protection Agency
EMPR	-	Environmental Management Programme Report
EMS	-	Environment Management System
ETP	-	Effluent Treatment Plant
EZ	-	Eastern Zone

F

FIMI	-	Federation of Indian Mineral Industries
FSI	-	Forest Survey of India
FWS	-	Ferrous Wheel Separator

G

GDP	-	Gross Domestic Product
GPS	-	Global Positioning System
GSI	-	Geological Survey of India

H

HANFO	-	Heavy Ammonium Nitrate Fuel Oil
HEDC	-	High Energy Detonating Cord
HEMM	-	Heavy Earth Moving Machinery

I

IBM	-	Indian Bureau of Mines
IISCO	-	Indian Iron & Steel Company
IPC	-	Inpit Crusher
ISM	-	Indian School of Mines

K

KIOCL	-	Kudremukh Iron Ore Company Limited
KMPH	-	Kilometre per Hour

L

LEDC	-	Low energy Detonating Cord
LHD	-	Load Haul Dump vehicles
LOI	-	Loss on Ignition

M

MBR	-	Mineracao Brasileiras Reunidas
MCDR	-	Mineral Conservation and Development Rules
MGS	-	Multi Gravity Separator
ML	-	Mining Lease
MML	-	Mysore Mineral Limited
MMER	-	Metal Mining Effluent Regulations
MMRD	-	Mines and Minerals Regulation & Development
Mn	-	Manganese
MoEF	-	Ministry of Environment and Forests
MSHA	-	Mine safety and Health Administration
MSL	-	Mean Sea Level
MT	-	Million Tonnes
MTPA	-	Million Tones per Annum
MWMP	-	Mine site water management Plan
Mt/MT	-	Million Tonnes

N

NAAQS	-	National Ambient Air Quality Standards
NE	-	North East
NEERI	-	National Environmental Engineering Research Institute
NEMA	-	National Environment Management Act
Ng	-	Nitro glycerine
NH_3	-	Ammonia
NMDC	-	National Mineral Development Corporation
NONEL	-	Non-electric
NOx	-	Oxides of Nitrogen
NRSA	-	National Remote Sensing Agency
NSPS	-	New Source Performance Standards

O

OAQPS	-	Office of Air Quality Planning and Standards
OB	-	Over burden
OCB	-	Oil Circuit Breaker
OCM	-	Open Cast Mines
O&G	-	Oil and Grease
OMC	-	Orissa Mineral Corporation
OMS	-	Output per man per shift
OSHA	-	Occupational Safety and health Administration

P

P	-	Provisional
Pb	-	Lead
PC	-	Pollution Control
PCB	-	Pollution Control Board
PL	-	Prospecting License
PLC	-	Permanent Logic Control
PM	-	Particulate Matter
PMS	-	Pump Managing System

R

RDCIS	-	Research and Development Center for Iron and Steel
R& D	-	Research and Development
ROM	-	Runoff Mine
RPM	-	Respirable Particulate Matter

S

SAIL	-	Steel Authority of India Limited
SMCRA	-	Surface Mining Control and Reclamation Act
SMS	-	Site Mixed Slurry
SO_2	-	Sulphur Dioxide
SPCB	-	State Pollution Control Board
SPM	-	Suspended Particulate Matter
SW	-	South West
SZ	-	South Zone

T

TDS	-	Total Dissolved Solids
TERI	-	Tata Energy Research Institute
TISCO	-	Tata Iron & Steel Company
TLD	-	Trunk Line Delay
TLV	-	Threshold Limit Value
TNT	-	Tri Nitro Toluene
TSP	-	Total Suspended Particulate
TSS	-	Total Suspended Solids
TWA	-	Time Weighed Average

U

USA	-	United States of America
U/s	-	Up Stream

W

WHIMS	-	Wet High Intensity Magnetic Separation
WHO	-	World Health organization
WZ	-	Western Zone

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The Central Pollution Control Board (CPCB), Ministry of Environment and Forests, Government of India, has initiated a study entitled "Description of Clean Technology for Iron Ore Mines and Development of Environmental Standards " for sustainable development and to prepare a comprehensive document. The study was entrusted to M/s Steel Authority of India Limited, Environment Management Division, Kolkata. The study has been carried out by the Environment Management Division, SAIL in association with the Central Pollution Control Board, New Delhi. The main objective of the study are as under;

- To develop environmental standards for iron ore mines operating in India, with a view to meeting techno-economic feasibility as well as to preserve the environmental quality and protect the human health.
- To develop clean technology with a view to achieve the proposed environmental standards.
- To provide guidelines/ code of practices for pollution prevention for iron ore mines.

The scope of the study includes baseline data generation on production, technology, environmental quality, assessment of environmental impacts due to iron ore mining and literature survey on mining technology, advancements and standards in other developed countries.

The study was conducted in two phases. In the first phase, operating iron ore mines were identified and basic operational and environmental related data were collected through appropriate questionnaire including environmental management practices. Statutory and regulatory bodies related to mines such as Indian Bureau of Mines (IBM), State Directorates of Mines and Geology, Regional IBM's and State Pollution Control Boards were contacted. Initially, a reconnaissance survey was conducted, which covered visits to the different iron ore mining areas.

Based on the information gathered during the visits, the entire iron ore mining network of India was divided into four zones and representative mines from each zone to represent the cross-section of iron ore mining across the country were selected for in-depth study based on geological condition, geographical locations, nature of the deposits, scale of operation, capacity, mode of operation and environment management practices. In-depth study in the identified mines of the four zones were conducted to study detailed aspects of mining techniques and existing environmental management practices, which includes monitoring of various environmental attributes.

Study of Phase –II basically consisted of four season environmental quality monitoring at two mechanised iron ore mines in the eastern region.

Additional data with respect to environmental monitoring were also collected from different agencies like IBM, CMRI, NEERI, etc. Data generated and collected from various agencies have been analysed in order to assess environmental impacts. The findings and baseline data generated were used to develop environmental standards and code of practices for pollution prevention for iron ore mines. Environmental standards of developed countries and cleaner technologies in practice have been studied and considered while developing the standards and guidelines. Opinions were also sought from the reputed experts in the field iron ore mining, particularly with regard to phasing out old mining techniques by cleaner and eco-friendly technologies.

The draft report has been discussed in detail, among industry representatives, industry associations, State Pollution Control Boards for finalising environmental standards, best environmental management practices and cleaner technologies for Indian iron ore mines. Summary of the final report is given below:

Iron Ore - Deposits, Reserve, Demand & Mining

(details given in Section Two & Three)

1. Haematite and magnetite are the most prominent of the iron ores found in India. Indian deposits of haematite belong to pre-Cambrian iron ore series and the ore is within banded iron ore formations occurring as massive, laminated, friable and also in powdery form. The major deposits of iron ore are located in Jharkhand, Orissa, Chattisgarh, Karnataka and Goa States.

   About 60% of haematite ore deposits are found in the Eastern sector and about 80% magnetite ore deposits occur in the Southern sector, specially in Karnataka. Of these, haematite is considered to be superior because of its high grade. Indian deposits of haematite belong to the pre-Cambrian iron ore series and the ore is within banded iron ore formations occurring as massive, laminated, friable and also in powder form. India possesses haematite resources of 14,630 million tonnes of which 7,004 million tonnes are reserves and 7,626 million tonnes are remaining resources. Major haematite resources are located mainly in Jharkhand-4036 million tonnes (28%), Orissa-4761 million tonnes (33%), Chattisgarh-2731 million tonnes (19%), Karnataka-1676 million tonnes (11%) and Goa-713 million tonnes (5%). The balance resources are spread over in the state of Maharashtra, Madhya Pradesh, Andhra Pradesh, Rajasthan, Uttar Pradesh and Assam together contain around 4% of haematite.

Magnetite is the other principal iron ore occurring in the form of oxide which is either of igneous or metamorphoses banded magnetite silica formation, possibly of sedimentary origin.

The magnetite resources are placed at 10,619 million tonnes of which only 207 million tonnes constitute reserves located mainly in Karnataka and Goa. The balance 10,413 million tonnes constitute remaining resources. A major share of magnetite resources is located in Karnataka-7812 million tonnes (74%), Andhra Pradesh-1464 million tonnes (14%), Rajasthan-527 million tonnes & Tamil Nadu-482 million tonnes (5% each), and Goa-214 million tonnes (2%). Assam, Jharkhand, Nagaland, Bihar, Madhya Pradesh and Maharashtra together account for a meager share of magnetite resources. The most important magnetite deposits are located in Babubadan, Kudremukh, Bellary, Anadurga and Bangarkal areas of Karnataka, Goa region, Ongole and Guntur districts of Andhra Pradesh etc. Other deposits are also located in Jharkhand, Bihar, Tamilnadu, Kerala and Assam etc. However, reserves of high grade ore may be a cause of concern. The total iron ore resources are estimated at 25.25 billion tonnes, of which Hematite ore resources stands to the order of 14.63 billion tonnes and the remaining 10.61 billion tonnes are magnetite as on 1.4.2005 (Source: IBM, Nagpur).

2. Production of iron ore in the country is through a combination of large mechanised mines in both public and private sectors and several smaller mines operated in manual or semi mechanised basis in the private sector. During 2001-02, 215 numbers of iron ore mines were operating in a total 638 leases with a lease area of 1,05,093 hectares and produced 86.22 million tones of iron ore (including lumps, fines and concentrate), out of which 37 iron ore mines were working under public sector and remaining 178 mines are under private sector. During 2005-06, 261 numbers of Iron Ore mines were operating in a total 505 leases (as on 31-03-06) with a lease area of 78,238.44 ha and produced 154.456 million tonnes of Iron Ore (including lump, fines & concentrate), out of which 41 iron ore mines were working under public sector and remaining 220 mines are under private sector. During 2006-07, India has produced 172.296 (P) million tonnes of iron ore including lump, fines & concentrate.

3. Normally, iron ore mining in India is done by opencast method and on the basis of mining methods, the mining can be broadly divided into two categories, i.e., manual and mechanized. Majority of the large mechanised mines are in the public sectors whereas manual mines are mainly in the private sector. The current production capacity of iron ore in India is around 160 Mt. The iron ore deposits of the Eastern, Central and Southern zone do not contain much overburden material except laterite and some low grade ferruginous shales and BHQ patches,

whereas in Western zone, (Goa region) about 30 Mt of iron ore is produced during 2006-07 and another 2.5 to 3.5 times of the waste is excavated as overburden. In general, iron ore mining in India being done by developing benches from the top of the hill and carried downwards as the ore at the top gets exhausted. The methodology being adopted for winning of iron ore is by shovel – dumper combination in case of major mechanised iron ore mines. The bench height generally adopted in iron ore mines in India is ranging from 6meters to 14meters and the slope of the benches ranging from 45^0 to 60^0 depending on the consistency / tensile strength of the rock. However, in Goa region where the ore is softer, hydraulic excavator and wheel loaders are the principal loading equipment used, height of benches is restricted between 4Mts. and 7Mts.

4. As per the tenth 5 year plan working group committee's projection, the expected requirements of various grades/ specifications of iron ore are estimated to be 122 million tonnes and 156 million tonnes during 2006-07 and 2011-12, respectively. However, as per National Steel Policy 2005, in order to support steel production of 110 million tonnes by 2019-20, the requirement of iron ore is placed at 190 million tonnes. Thus the projected domestic demand of iron ore will be 190 million tonnes; similarly, exports have been estimated to be around 100 million tonnes by 2019-20. The total demand of iron ore will be around 290 million tonnes by 2019-20. It is expected that the additional demand will be met through capacity augmentation from Bellary-Hospet sector, opening up of deposit no. 1, 4, 11B & 13 of Bailadila and capacity expansion of existing Bailadila group of mines, capacity enhancement of SAIL mines, new mines by M/s Rio Tinto in eastern sector, opening up of new deposits like Chiria, Thakurani, Taldih, Rowghat, Ramandurg, Kumarswamy etc.

5. World resources of Iron Ore are estimated to exceed 800 billion tonnes of crude ore containing more than 230 billion tonnes of iron. World iron ore production has touched 1690 million tonnes during 2006. Although iron ore is mined in more than 50 countries, the bulk of world production comes from just a few countries. The five largest producers, in decreasing order of production of gross weight of ore, were Brazil, China, Australia, India & Russia. Brazil was the largest producer in gross weight of ore produced. Open cast mines in China, CIS countries are now working at greater depths (sometimes more than 300m below ground level). This has necessitated adopting in-pit crushing with conveying system of ore transportation. Sweden is the only country where all its iron production (24Mt) comes from under ground iron ore mines. Under ground iron ore mining are also being practiced to an extent of 10 to 15% of total production in China and CIS countries.

Australia and Brazil are operating in fully open cast methods. The control of Acid Rock Drainage (ARD) or Acid Mine Drainage (AMD) is the single largest environmental problem in these countries.

Environmental Impact of Iron Ore Mining ***(details given in the Section Four)***

1. The exploration, exploitation and associated activities of iron ore mining directly infringe upon the environment and affect air, water, land, flora & fauna. These important natural resources need to be conserved and extracted optimally to ensure a sustainable development. The impacts of Indian iron ore mining on environment has been discussed in detail in the Section – Four of the report. Some of the findings are highlighted below:

2. The most significant environmental damages due to iron ore mining in India are the deterioration of forest ecology, alteration of land use pattern and change in local drainage system due to inadequate landscape management during mining operation and improper & inadequate rehabilitation strategy adopted. Management and rehabilitation of the wastes and overburden dumps are of particular concern. It was observed that the ecological principles were not taken into account while carrying out the rehabilitation of the mined out areas and the waste rock dumps in the reserved forest areas, which require a completely different approach. Current rehabilitation is principally directed at restoring visual amenity, stabilizing disturbed areas and growing trees that will prove useful to the future generations. Rehabilitation practices for Reserved Forests, while also meeting these objectives, should aim to restore the native forest in all its diversity. Restoration of the forest vegetation requires re-establishment of all forest components, not only trees.

3. The most conspicuous positive impacts of iron ore mining in India are social and economic upliftment. Almost all iron ore mining areas support quite large local communities who are totally dependent on mining and associated operations. Better healthcare, education, living standards being some of the benefits, the local populace had got due to mining.

4. Dust is the major issue of concern in all the mining areas during non-monsoon periods. The study team however found that this aspect varies from deposit to deposit (nature of deposit) and season to season. Suspended solids in the drainage basins around the iron ore mining areas is also an issue of concern during monsoon. In the areas of high rainfall (more than 2500mm annual average in the Goa and Kudremukh region), the control of suspended solids in the surface runoff become an issue of major concern, and the situation further worsen because of the presence of scattered, unstabilised and improperly designed waste

dumps. Recently, the water scarcity has also been assumed a greater significance in the Bellary-Hospet sector, where the mines have reported that they are facing problem in finding sufficient water in the region to use in dust suppression through sprinkling and wet drilling.

5. A study conducted by a committee constituted by MoEF during March'1998 consisting of representative from Forest Survey of India (FSI), Botanical Survey of India (BSI), Indian Bureau of Mines (IBM), Geological Survey of India (GSI), National Remote Sensing Agency (NRSA), Indian School of Mines (ISM), Federation of Indian Mining Industries (FIMI) and SAIL found out that a total of 14,111 ha of forest cover exist over the iron ore mining lease area in the state of Chattisgarh covering Baster, Durg and Rajnandangaon districts; 20968ha of forest cover exists over the iron ore mining lease area in the Singhbhum districts of Jharkhand and Sundergarh & Keonjhar districts of Orissa. The study has used Corollary temporal study of satellite data. The study also showed that there is an increase in the forest cover in the Bailadila area due to the rehabilitation measures taken by M/s NMDC. The LANDSAT-TM data for October'1989 and IRS-IB LISS II data for June 1997 was analysed to detect the change in the forest cover. The study revealed about 10% gain in the forest cover (increase from 6744ha of forest area to 7435ha, i.e. a gain of 691ha) in the lease area during the period.

6. The Iron ore industry in Goa operates under certain difficult conditions specific to Goan iron ore mines. Mining activity in several places is being carried out below the water table, which requires dewatering of pits for operation to continue. This necessitates transport problem within the mine because of greater working depth. Drilling and blasting are restricted due to limited lateritic overburden, presence of villages and inhabited areas in the vicinity of the mines. Mining lease in the area is restricted to 100ha and resulted in improper mine infrastructure development and lateral mine development. Coupled with high overburden to ore ratio (of an average of about 2.5 to 3.0:1), it makes very difficult for having waste dump properly designed or even there is very limited space (or non at all) available within the lease area to dump the waste material. This leads to acquiring land outside the lease area for dumping rejects. Land being in short supply, dumps are typically steep with slopes greater than 30° and height of 30-50 Mts. Many waste dumps are situated in the upper part of the valley regions and during monsoon, run off from dumps is common, which blankets agricultural fields and settles in water courses. Again, because of small land holdings, large amount of ore is blocked in barriers of adjoining mines; operations could be carried out close to common boundaries of two lease holders with mutual understanding.

Proposed Environmental Standards ***(details given in the Section Six)***

It is recognised that minerals and metals are the mainstay of the economic development and welfare of the society. However, their exploration, excavation and mineral processing directly infringe upon and affect the other natural resources like land, air, water, flora and fauna, which are to be conserved and optimally utilised in a sustainable manner. To protect the environment, mining sector in general, is regulated by the Environment (Protection) Act, 1986, the Forest Conservation Act, 1980, the MMRD Act 1957, Wild life Act, 1972, Water (Prevention & Control of Pollution) Act, 1974 and Air (Prevention & Control of Pollution) Act, 1981, etc.

In order to protect the environment from iron ore mines, environmental standards specific for Indian Iron Ore Mines are being proposed under Environment (Protection) Act, 1986. The proposed standards are primarily based on the studies conducted, normal background information, (collected through actual site monitoring during the mines visit and collected from different mining authorities and regulatory bodies), comparison and evaluation of national and international standards as well as the presence of different harmful elements and their likely health effect. There is not much precedence of existing iron ore mine specific environmental standards, internationally. Only USEPA has specified the discharge standards for iron ore mining, whereas the same is covered by Canada through a blanket standard for all the metalliferous mines. World Bank has issued certain guidelines on pollution limits for air, water and noise. The details of proposed environmental standards for air, water & noise quality and guidelines for pollution prevention & control are discussed in Section – 6. Proposed environmental standards specific to Indian Iron Ore Mines for air, water & noise quality are as follows;

<u>Proposed Emission Standards</u>

In iron ore mining & other allied activities including processing of ore, dust is the single largest air pollutant and can be a significant nuisance to surrounding land users as well as a potential health risk in some circumstances. Dust is being produced from a number of sources and through number of mechanisms such as land clearing, removal of top soil, overburden removal, drilling, blasting, crushing & screening, processing of ore, loading & unloading of material on site & subsequent transport off the site etc. In addition to this, wind action affecting stockpiles, dry tailings and exposed mining areas also generate significant amount of dust. Various types of dust control measures i.e. dust extraction and / or dust suppression measures have been adopted by the Indian iron ore mines.

In order to maintain the air quality in and around the iron ore mines, all the high dust prone areas need to be equipped with dust extraction and / or dust suppression facilities. The dust levels in the mines mainly depend on the type of dust control measures adopted & its effectiveness. The dust levels also depend on the nature ore feed, method of mining & ore processing, topography & climatic conditions of the area etc. Keeping in view of all these factors, air quality standards specific to Indian Iron Ore Mines have been proposed for both point and area sources.

I Stack Emission Standard for De-dusting units

S. No	Parameter	Standard
1.	Particulate Matter (PM)	100 mg/Nm^3

Height of the stack attached to the de-dusting system should be calculated for proper dispersion of particulate matter using the formula $H = 74\ Q^{0.27}$ m (where H = Stack height in metres and Q = PM emission in tonnes/hr). Height of the stack should be at least 2.5 m above the nearest building height. But in any case, stack height should not be less than 15 m. Sampling portholes and platforms shall be provided as per the CPCB guidelines.

Stack height for various particulate matter emission rates (kg/hr) are given below for reference;

S. No.	PM Emission Q (kg/hr)	Stack Height H (m)
1.	2.71 kg/hr	15
2.	7.86 kg/hr	20
3.	17.96 kg/hr	25
4.	35.29 kg/hr	30

Stacks attached with power generating units / DG Sets shall follow the existing stack emission standards and guidelines for the Power Plants/ DG Sets.

II Fugitive Dust Emission Standards

Fugitive dust emission levels of Suspended Particulate Matter (SPM) and Respirable Particulate Matter (RPM) from the dust generation sources identified and mentioned below in table -1, should not exceed 1200 µg/m3 and 500 µg/m3 respectively at a distance of 25 m (± 5 m) from the source of generation in downwind direction considering the predominant wind direction.

Table - 1

Area	Sources of Dust Generation / Monitoring Location
Mine face / benches	Drilling, Excavation & Loading (Not required for benches operating below water tables. However applicable for operating benches above water table)
Haul Roads / Service Roads	Haul roads leading to Ore Processing Plant, Waste dumps & Loading areas and Service Roads.
Crushing Plant	Run-off-mine unloading at Hopper, Crushing Areas, Screens, Transfer Points
Screening Plant	Screens, Transfer Points
Ore Storage & Loading	Intermediate Stock Bin / Pile areas, Ore stock bin / pile areas, wagon / truck loading areas
Waste Dump Areas	Active waste / reject dumps

The measurement shall be done for a period of 8 hours in any working shift. However, depending upon the prevalent conditions at site, the period of measurement can be reduced.

Proposed Effluent Discharge Standards

Quality of effluents discharged from iron ore Mining, beneficiation and associated activities or any other discharges leaving the mining lease boundary, to natural river / stream / water bodies / sewer / land to conform to the following standards given in the Table - 2 below.

Table - 2

S. No	Parameter	Standards
1.	pH	6.0 – 9.0
2.	Suspended Solids	50 mg/l * 200 mg/l - during monsoon
3.	Oil & Grease	10 mg/l
4.	Dissolved Iron as Fe	2 mg/l
5.	Manganese as Mn	2 mg/l

* Existing iron ore mines are allowed up to 100 mg/l for one year from the date of notification to upgrade existing treatment facilities / installation of new facilities.

Proposed Noise & Airblast Standards

I Noise Level Standards

The noise levels in the mining and other associated activities shall not exceed the following limits:

S. No	Parameter	Noise Limits	
		Day time (6.00 AM to 10.00 PM)	Night time (10.00 PM to 6.00AM)
1.	Noise Level – Leq	75 dB(A)	70 dB(A)

Noise levels shall be monitored both during day and night times on the same day while in operation. The noise measurements shall be taken outside the broken area, boundary of ore processing & material handling areas, which include mine site & general offices, statutory buildings, workshops, stores etc.

In addition to this, occupational exposure limit of noise specified by the Director General of Mines Safety (DGMS) shall be complied with by the iron ore mines.

II. Airblast Standard

Airblast level resulting from blasting on any premises or public place must not exceed 120 dB Linear, peak.

Ground vibrations from the blasting operation shall be within the permissible Peak Particle Velocity (ppv) specified by DGMS at the foundation levels of various types of structures in mining areas depending on dominant excitation frequencies.

Note (i) For facilitating the compliance of the standards and pollution prevention at source the guidelines / code of practice issued by the Central Pollution Control Board should be followed.

The above standards will be applicable to new iron ore mines and expansion projects w.e.f the date of notification. However, the existing mines are allowed six month time from the date of notification to upgrade / install facilities to meet the standards.

Frequency of monitoring of the various parameters shall be specified by the State Pollution Control Boards/Pollution Control Committees.

Recommended Management Practices and Cleaner Technologies

(details given in the Section Seven)

1. As mechanised open cast iron ore mines becoming larger, deeper and more capital intensive, continuing efforts should be made to improve upon the open cast mining activities through advances in the equipment size / design and practices and also through introduction of innovative techniques. The application of high capacity continuous surface mining techniques to harder formations, new concept of high angle belt conveying system, in-pit crushing systems (mobile and semi-mobiles), high capacity dumpers, automatic truck dispatch system, non-electric blast initiation systems etc. and developments in the area of bulk explosive systems hold out almost unlimited opportunities for upgrading the performance of opencast iron ore mining in India, while minimising the environmental impacts. In addition, the following proved cleaner technologies are need to be implemented in Indian iron ore mines, considering the suitability to the particular site:
   - Adoption of Wet drilling
   - Use of ripper dozer as an alternative to drilling and blasting
   - Use of hydraulic hammer/rock breaker as an alternative to the secondary boulder blasting
   - Use of opti blast technology and split charge blasting techniques wit air decking by the gas bags
   - Use of non electric (NONEL) initiation devices (EXEL of ICI and RAYDET of IDL)
   - Application of in-pit crushing and conveyor transport system as an alternative to all dumper transport system in deep mines
   - Dry Fog dust control system at the crushing, screening & material handling/processing plant as an alternative to de-dusting system with bag-house
   - Use of Hydro-cyclones and Slow Speed Classifiers in the wet beneficiation circuits to maximise the recovery of iron ore fines.

2. The reserves of high grade iron ore are limited. Therefore, it would be necessary at this stage to ensure conservation of high grade ore by blending with low grade ores. As a matter of policy, only low and medium grade iron ore, fines and only temporary surplus high grade iron ore (+67 % Fe), particularly from Bailadila (Chattisgarh) should be exported in the coming years. R&D efforts are needed for developing necessary technologies for utilising more and more fines in the production of steel as a measure of conservation of iron ores. Further, in the iron ore mines where wet processing of the ore is done, around 10-20% of ROM is lost as slimes depending on nature of ore feed, and in this

context, coarser fines can be recovered up to 5 % by introducing hydro-cycloning and slow speed classifiers in wet circuit system.

3. Efforts are also necessary to utilise the tailings/ waste as well. It has been found feasible to make bricks using 8 % of binding material such as cement and lime in slimes and 12 % in shale. A mixture of slimes and shale in the ratio of 4:1 by weight with 8% binder cement has reported to show good results in brick making. In the Bellary-Hospet area of Karnataka, the production of iron ore fines from the private mines is substantial, but the fines are unwashed and contain high fine percentage (40% of -100mesh fraction). In various R&D studies carried out so far, it has been found feasible to consume – 100 mesh fraction up to 30% blue dust in concentrate feed. The fines from Bellary-Hospet region generally have 63-64 % Fe content and if 100 mesh fractions can be limited to 3%, these fines can be used for sintering feed.

   In this regard the possibilities of setting up "Mine site" pelletising units are recommended wherever technically feasible on the lines of LTV (USA) TACONITE mines pelletising plants in North Minnesota.

4. The use of consistently appropriate mine planning is the most effective way to harmonise mining with the environment. No single element of mining, by itself, minimise environmental impacts. The first step in planning is to recognise the environmental issues that need to be faced during designing a feasible mine layout. It may range from air quality, noise and vibration, water management, water quality, soil conservation, flora and fauna, transport, rehabilitation, visual impacts, hazard and risk assessment, waste management to socio-economic issues. All the environmental considerations to be firmly integrated into the planning of each stage of a mining project. It may further emphasized that there is a need for allocating adequate lease area for developing iron ore mining project and small scale mining should always be discouraged.

5. The underlying principle for effective pollution prevention and control is to contain contaminants on the site itself. This can include storing chemicals properly, avoiding unplanned equipment maintenance, etc. Air quality controls include the use of water tankers for dust suppression, water sprays on conveyors and ore stock piles, adopting controlled blasting techniques and limiting freefall distances while stockpiling the ores and overburdens. The design and maintenance of haul roads is also an important consideration in dust control. One of the critical factors in successful pollution prevention and control is through proper training of the workforce. It is no matter how sound the plant design or committed the mine management, ultimately environment protection can only be achieved with the understanding and commitment of the every person working in the mine.

6. Noise, vibration and air blast are unavoidable fallouts of mining operations, which involve using large mobile equipment, fixed plant and blasting. Noise, vibration and airblast are among the most significant issues for communities located near mining projects. The adverse impacts due to noise, vibration and air blast emissions should be contained by the following three stage approach:
   - Noise, vibration and air blast impact assessment.
   - Developing and implementing a noise, vibration and air blast management plan.
   - A monitoring and audit program.
7. Ore extraction and processing, workforce health and safety, and rehabilitation, all require water. Developing water management systems for a mine must account for site-specific physical, chemical and climatic characteristics as well as mine process factors. A minesite water management system consists of a number of physical elements to control the movement of clean and 'dirty' water onto, across and off the minesite, together with a number of process elements to control potential water problems at source, while maintaining and verifying the appropriate functioning of the water management system. It is essential that every effort should be made to avoid uncontrolled releases.
8. At present, approximately 14Mt of tailings are being generated per annum from the iron ore beneficiation. Management of such huge amount of tailings are important from control of pollution and resource conservation point of view. Normally tailings are being managed through impoundments in big settling ponds obstructed by big dams, more commonly known as tailings dam. The primary objective of the tailings dam is for the safe storage of tailings material and separation of water and solids. The detail guidelines for tailings dam construction and tailings management are discussed in section 5.2.6.
9. Climate, soils and the rehabilitation strategy are important considerations in minimising impacts on native flora and fauna. Soil erosion can be minimised by a proper understanding of soil structure, conservative landform design, utilising complex drainage networks, incorporating runoff silt traps and settling ponds in the rehabilitated landform. Careful use of topsoil can promote vegetation cover if the topsoil material is structurally appropriate and contains propagules of native vegetation. Selection of native floral species is desirable in promoting a stable and robust vegetation cover. Where possible, species endemic to the area should be used, preferably those from the site itself.

10. Ideally mine decommissioning should be planned at the commencement of operations. For the existing and long established iron ore mines in India, proper decommissioning to be integrated with the final year of mine operation. Final rehabilitation should be influenced by the long term post-mining land use and environmental condition of the site determined in consultation with the local community. Mine sites normally established transport links, heavy workshops and other infrastructure that can be put to a range of post-mining uses. Whether his is not the case or where restoration of pre-mining condition is required, hauls roads and buildings should be removed and the site rehabilitated and revegetated. One of the longer-term challenges is to ensure the safety and environmental appropriateness of final mining voids. It is, sometimes, possible to use these voids for disposal of surplus rejects and overburden from an adjoining mine, or to provide make up water and additional sedimentation capacity to other operations. A coordinated and planned approach to the issue of final voids for adjacent mines can significantly reduce environmental impacts.

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1.1 BACKGROUND

The Central Pollution Control Board (CPCB) (Ministry of Environment and Forests, Government of India) has taken up the task to develop *National Environmental Standards* for emissions, effluents and noise pollution from various sources which gets generated due to operation and process followed in the Iron Ore Mining. For the purpose, they have assigned the work of the project entitled **"Development of clean technology for iron ore mines and development of environmental standards and preparation of comprehensive document"** to M/s Steel Authority of India Limited, Environment Management Division, 6, Ganesh Chandra Avenue (5^{th} Floor), Kolkata – 700013. The study has been conducted by the Environment Management Division, SAIL in association with Central Pollution Control Board, New Delhi. The basic objectives of the project were:

- To develop environmental standards for iron ore mines operating in India, with a view to meeting techno-economic feasibility as well as to preserve the environmental quality and protect the human health.
- To develop clean technology with a view to achieving the proposed environmental standards.
- To provide guidelines for pollution reduction, recovery, reuse and recycle as well as to reduce the fugitive emissions.

The project for evolving industry specific standards envisages certain limits for the pollutants, necessary to protect the recipient environment and at the same time it should be techno-economically viable for the mining industry to achieve, regardless of variation in pollutants generated in the processes. The standards and pollution prevention guidelines, thus developed will be applicable to the iron ore mining industries throughout the country.

1.2 SCOPE OF THE PROJECT

The scope of the project as outlined in the work order is briefed below:

Baseline Data Generation:

- Identification of all the iron ore mines working in India and indicating their location on the map of India.
- Collection and collation of data on the iron ore reserves, status of exploitation at present and future forecast.
- Collection and collation of data on iron ore mining in India and plotting its trends and comparison with world scenario.
- Technology presently used in iron ore mining in pollution control in various parts of the country.
- Collection of data through questionnaire survey, field visits and field monitoring with respect to air quality, water quality, solid waste and other environmental problems posed by iron ore mining. The data should be of at least one year covering all the four seasons at one mining cluster.
- In-depth study of representative cross sections of iron ore mines after classification on the basis of technology and pollution levels. The data can be used in decision making for the clean technology.

Literature Survey:

Literature on the iron ore mining and pollution control technology used in developed countries like USA, Japan, Germany, CIS etc to be compiled. The feasibility of adopting the technology in India to be discussed while identifying the clean technology suitable for Indian conditions.

Environmental Impact of Iron Ore Mining:

The environmental impact of various iron ore mining clusters in the country, with respect to water bodies, ground water, air quality, flora and fauna, topography and socio-economic factors will be evaluated, collecting the data through secondary sources. Environmentally benign mining practices adopted in modern mines will be collected and collated to serve as an input to Environmental Management Plan for abating the adverse impacts. The applicability and suitability of these mining practices in Indian context are to be discussed.

Development of Clean Technology and Environmental Standards:

- Environmental standards to be developed with a view to meeting techno-economic feasibility by the iron ore mines as well as to preserve the Environmental quality and protect the human health.
- The clean technology should be developed with a view to achieving the proposed environmental standards.
- Guidelines for pollution reduction, recovery, reuse and recycle as well as to reduce the fugitive emissions should also be provided.

Laboratory Facilities and Monitoring Frequency:

- Details of the laboratory facilities required by the iron ore mines to conduct monitoring for the assessment of the environmental quality have to be provided.
- Monitoring programme including frequency of monitoring for air quality, water quality, ground water, solid wastes, noise levels etc. are to be provided.

1.3 STUDY METHODOLOGY

The project was basically carried out in two phases.

The phase-I of the study was mainly consisted of literature survey, field visits and field monitoring with an objective of collecting the baseline conditions of iron ore mining in India and the surrounding environment. The entire iron ore mining network of India was divided into four zones and representative mines from each zone were selected for in-depth study to represent all the cross-section of mining companies with respect to geological condition, geographical locations, nature of the deposits, scale of operation, capacity, product profile, mode of operation and Environment Management Practices (i.e. whether the company/mines has adopted EMS leading to ISO-14001 certification) and willingness of the mining authority for co-operation. The survey also covered visits to Indian Bureau of Mines (IBM), State Directorates of Mines and Geology, Regional IBMs and State Pollution Control Boards. In-depth study in the identified mines in each of the four zones has been undertaken for the detail study of both the mining technology being used and the environmental condition. Field monitoring was only restricted to the eastern group of SAIL mines, however detailed field monitoring was carried out at Meghahatuburu and Kiriburu iron ore mines of SAIL. Environmental quality monitoring data were collected from all the participating mines. The interim report was submitted to CPCB in December, 2001, containing the methodology followed and observations made during the in-depth study of the selected mining sectors in India, which also included the field monitoring results and the collected/reported data on environment quality monitoring by the mining companies covered during the in-depth study.

The phase-II of the study was basically consisted of the analysis of the collected literatures, environment monitoring data (both collected and generated) and development of environmental standards. A progress report was submitted to CPCB during September 2002, which contained the technological advancement in iron ore mining, the present environmental conditions of the iron ore mines in India and the results of the field monitoring. Additional data with respect to environmental monitoring were also collected from different agencies like IBM, CMRI, NEERI, etc. The environmental quality data are grouped in to three basic categories as:

- Data collected during the in-depth study
- Data generated through field monitoring
- Data compiled from other agencies

The draft report, containing the proposed environmental standards, environmental management practices and cleaner technologies, was discussed in detail with the industry representatives, industry associations, State Pollution Control Boards and other statutory bodies. As suggested, a detailed study on fugitive dust emissions from various mining operations has been carried out during November, 2005 at Meghahatuburu and Kiriburu Iron Ore Mines. All these data have been used as a baseline for recommending the proposed environmental standards. Various applicable national and international environmental standards are compiled. The details of the existing and the proposed environmental standards are placed in Section 6 of this report.

The environmental impacts of the iron ore mining in the four identified zones are discussed in Section 4 of this report based on the findings during the in-depth study, base line environmental conditions as compiled, findings of study conducted by different national and international organisations in different areas during different times, etc. Suggested cleaner technologies to be adopted in the iron ore mining in India along with environmental management practices are discussed in the Section 5 of this report.

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2.1 PRINCIPAL ORES OF IRON

Haematite and magnetite are the most prominent of the iron ores found in India. Of these, haematite is considered to be the most important Iron ore because of its high grade quality, which is consumed in a number of steel and sponge iron industries. Indian deposits of haematite belong to pre-Cambrian iron ore series and the ore is within banded iron ore formations occurring as massive, laminated, friable and also in powdery form. The major deposits of iron ore are located in Jharkhand, Orissa, Chattisgarh, Karnataka and Goa States.

2.1.1 Haematite

Haematite is the most abundant iron ore mineral and is the main constituent of the iron ore industry. It occurs in a variety of geological conditions throughout the world. It is the red oxide crystallizing in hexagonal system. The fine-grained haematite is deep red, bluish red, or brownish red and may be soft and earthy ocherous, compact or highly porous to friable, or granular, or may form dense hard lumps. Considerable siliceous or argillaceous impurities are common. Fine-grained red haematite may occur in smooth reinform masses (Kidney ores) in botryoidal or stalacitic shapes, or may be columnar, fibrous, radiating or platy etc. The coarse crystalline haematite is steel grey with bright metallic to dull grey lustre and occasionally, coarse crystals have a deep bluish to purplish iridescent surface. The coarse-grained haematite is known as specularite or specular haematite and may form blocky or platy crystals with a strong icaceous parting. The cherry red streak is difficult to observe on this variety. The composition of haematite is Fe_2O_3. Ideally, haematite contains 69.94% iron and 30.06% oxygen. The specific gravity varies from 4.9 to 5.3 (when it is pure, i.e. 69.9% Fe_2O_3) but the ores met in practice generally have less specific gravity. The hardness varies from 5.5 to 6.5 for hard ore and is much less for softer varieties. Haematite is feebly magnetic, but a variety termed magnetite is found in many ore bodies in small quantities having magnetic properties closely akin to those of magnetite.

The iron content of the ore and physical characteristics vary from place to place in different types of ores. Some idea about the change in iron content and in bulk densities / tonnage factors of different types of ores mined in some important regions of India is given in below.

Table No. 2.1.1.1 Characteristic of Important Haematite Deposits in India

Sl. No.	*Type of Ore*	*Iron Content*	*Bulk density/tonnage factor (ton/m^3)*
1.	***Singbhum-Keonjhar-Bonai Deposits***		
	a) Massive Ore	65 - 69.9 %	4.5 - 5
	b) Laminated Ore	55 – 65 %	3.5 – 4.8
	c) Blue Dust	65 %	3.3 – 3.4
	d) Laterite Ore	52 %	2.3
2.	***Goan Deposits***		
	a) Massive bedded Ore	59 – 62 %	3 – 3.4
	b) Platy Ore	58 – 62 %	3 – 3.2
	c) Brecciated Ore	56 – 62 %	2.8 – 3.2

Sl. No.	*Type of Ore*	*Iron Content*	*Bulk density/tonnage factor (ton/m^3)*
	d) Mixed Ore	45 – 59 %	2.5 – 3.0
	e) Biscuity Ore	59 – 65 %	2.9 – 3.1
	f) Concretionary Ore	57 – 62 %	3.1 – 3.4
	g) Laterite	40 – 50 %	2.3 – 3.3
	h) Blue Dust or Powdery Ore	58 – 66 %	2.8 – 3.0
3.	***Bellary – Hospet Deposits***		
	a) Lumpy Ore (Massive & Laminated)	67 – 69 %	3 – 3.5
	b) Blue Dust	Average 65 %	3.8
4.	***Bailadila Deposits***		
	a) Massive Ore and Massive & Laminated	67 – 68.26 %	4.69 – 5.11
	b) Laminated Ore	63.47 %	3.4 – 4.19
	c) Laterite Ore	47.46 %	3.46 – 3.65

2.1.2 Magnetite

It is the most common species in the magnetite series of spinel mineral group and is the second most important iron bearing mineral of economic importance. It is black magnetic oxide of iron crystallizing in the isometric system and has hardness of 5.5 to 6.5. Its specific gravity is 5.17 and magnetic attractability 40.18 compared to 100 for pure iron. It occurs as fine or coarse-grained masses or in octahedral or less commonly decahedral crystals. It occurs as veins and stringers in igneous rocks and as lenses in crystalline schists. Large deposits are considered to be the results of magnetic segregation and its low grade deposits occur
as disseminations in metamorphic and igneous rocks. It also occurs as a replacement product in sedimentary or metamorphic rocks. It is found as placer deposits as "black sand" in beach deposits and as banded layers in metamorphic and igneous rocks.

2.1.3 Goethite and Limonite

These minerals are hydrated oxide of iron, forming a part of the complex group in which proportion of the various radicals can undergo considerable variations. Their colour is brown to ocherous yellow but may be black or dark brown to reddish brown and they are often called "brown iron ores". Their specific gravity varies from 3.3 to 4.3 and hardness is 5.5. They may contain 10 to 14.5 percent combined water and are converted into haematite or magnetite on calcinations. These are secondary minerals, being the product of alteration. They occur as thick cappings formed by weathering and hydration of the underlying ore body. When silica is leached out, iron content improves by 10 to 15 percent. These minerals form flakes and needles generally of small dimensions occurring as inter growths with the original constituents.

2.1.4 Siderites

Siderite, also called "spathic ore", is a carbonate of iron. Its colour is ash grey to brown with yellow and red stains resulting from oxidation and hydration. Its specific gravity is 3.8 and hardness varies from 3.5 to 4. It crystallizes under rhombohedral division of the hexagonal system. It occurs as sedimentary or replacement deposits.

2.2 DESCRIPTION OF IMPORTANT IRON ORE FORMATIONS IN INDIA

Indian reserves are predominantly distributed in pre-Cambrian formation.

2.2.1 Pre-Cambrian

The most important iron ore deposits of India are those associated with the banded haematite jasper / quartzite of the Dharawarian formations of South India and their equivalents of the iron ore series found in Northern India. The ores are derived from the enrichment of banded ferruginous rocks by the removal of silica. The ore body generally forms the tops of the ridges and hillocks, which are often of great magnitude. Most of them contain high grade ores near the surface, with an iron content of over 60% and are associated with even larger quantities of low grade ores. Where metamorphosed, regionally or by igneous intrusives, these banded haematite jaspers have been converted into banded quartzite magnetite rocks, which also attain considerable importance in certain areas in Tamil Nadu and in Southern Karanataka. These ores are of low grade, as they occur, containing only about 35 to 40% iron, but are amicable to concentration after crushing to a suitable size. At some places in Singhbhum and Mayurbhanj districts, titaniferous magnetite bodies are associated with basic and ultrabasic intrusives. These deposits are considered to be of ortho-magnetic origin.

2.2.2 Gondwanas

The Barakar formations in rare instances contain concretionary masses of limonite. In the Auranga Coalfield in Bihar, clay-iron stones are found in these formations. Some of these deposits appear to have been derived from the original carbonate ore by oxidation and hydration. The ironstone shale stage, particularly of Raniganj Coalfield, contains considerable amount of clay. Ironstone derived from siderite is irregularly distributed as thin lenses in the formation. At some places, iron ore lenses and concretions are reported to form 5 to 7% volume of strata. In the succeeding Raniganj-Kamthi group, there is much disseminated iron to produce the prevailing red tints in the sandstones, but nowhere sufficient concentration of the material to constitute workable ore is found.

2.2.3 Deccan Traps

The tropical weathering of Deccan traps at and near the surface has given rise to massive beds of laterite which at many places is fairly rich in iron, averaging 25 to 30% of the metal. The laterite also contains deposits of titaniferous bauxite. They are likely to assume importance in future when attention is focused on lower grade ores. It is known that the Late Sir Cyril Fox conducted some experiments to smelt laterite to obtain pig iron. Laterite also occurs over gneissic rocks in Malabar and Travancore and over the Rajmahal Traps in Bihar. The limonitic material from laterite, often forming rich concretions, has been won and smelted by the indigenous artisans for many centuries. At present, however, they are of little values as ores, because the rich haematite ores of the pre-Cambrian formations are available in abundance.

2.3 IRON ORE DEPOSITS AND RESOURCES / RESERVES IN INDIA

2.3.1 Iron Ore Deposits

The iron ore deposits of India can be broadly divided in to the following six groups on the basis of mode of occurrence and origin:

1. Banded Iron Formations(BIF) of Pre-Cambrian Age

2. Sedimentary Iron Ore Deposits of Siderite and Limonitic Composition
3. Lateritic Ores derived from the Sub-Aerial Alternations
4. Apatite-Magnetite Rocks of Singhbhum Copper belt
5. Titanifereous and Vanadiferous Magnetites
6. Fault and Fissure Filling Deposits

Indian deposits of haematite belong to Pre-Cambrian Iron ore series and the ore is within Banded Iron Ore Formations (BIF) occurring as massive, laminated, friable and also in powdery form. Extensive outcrops of BIF are found in the States of Jharkhand, Bihar, Orissa, Madhya Pradesh, Chattisgarh, Maharastra, Karnataka, Goa and Tamil Nadu. The most common names used in India to designate BIF are Banded Haematite Quartzite (BHQ) and Banded Magnetite Quartzite (BMQ). In Jharkhand and Orissa, the names like Iron-Ore series and Iron-Ore group are used as stratigraphic names. Elsewhere in the world, names like taconite (Lake Superior), itabirite (Barzil), jaspilite (Western Australia) and Calico rock (South Africa) have been in use. In recent years, however, BIF has come to be generally acceptable both as a field term as well as stratigraphic term to designate iron-rich sedimentary rocks.

The BIF has given rise to vast accumulations of commercial grade iron ore deposits in India; more than 90% of the iron ore supplied to the industry comes from the BIF. The major ore minerals are haematite and magnetite. Important accumulations are in Singhbhum district (Jharkhand), Keonjhar (Orissa), Bellary (Karnataka), Bastar district (Chattisgarh) and Goa. Magnetite ore deposits are mainly confined to the Chikmagalur district in Karnataka and Salem and North Arcot districts in Tamil Nadu.

Different types of iron ore derived from banded haematite rocks met within the deposits of this group are (a) massive ore, (b) laminated ore and (c) blue dust. The massive ores occur as massive bodies in which no planar structures are seen. The laminated ores, though mineralogically and chemically similar to massive ores, have planar structures, which may be very closely spaced giving rise to biscuity ores. The blue dust is a form of very fine-grained powdery ore consisting of loose haematite and magnetite crystals. It often occurs as pockets in harder ores and forms the major constituent at depth. Major part of blue dusts is minus 10 mesh in size and generally these are from 10 to 50% of 100 mesh size, the proportion of minus 325 mesh to 100 mesh fraction being 80%. In addition, float ore accumulations on the slopes and foot of the hills as a result of disintegration of in situ ore bodies are commonly met with. The float ores are of different sizes and of different degrees of purity. In certain places, like deposits in the vicinity of Banspani in Keonjhar district, Bailadila range and Bellary-Hospet area, the float ore concentration is mostly free from any major impurities. The percentage recovery of ore from such horizons varies within very wide limits and is cent percent in some cases. Wherever such float ores are derived from massive or hard laminated ore bodies, the grade of the float ore is fairly rich. Thus, in the float ore workings in the vicinity of Banspani and in Bellary-Hospet sector, grade of the ore is about 64% or even more. The gangue minerals in case of float ore s are usually shale, BHQ, dolerite and clay. Sometimes reconsolidated ores occurring as angular and sub-angular fragments cemented in the matrix of laterite is also noticed in float ore zones. For example, in Jharkhand and Orissa area, this type of re-cemented ore is found, where it is locally called as “Canga”. The embedded high grade iron ore pieces cannot be easily dislodged from adhering material. Though angular pieces can alone give 63 to 66% Fe, the overall material analyses only 55 to 60% Fe.

2.3.2 Iron Ore Resources/Reserves and Distribution in India

Iron ore is abundantly available in the Earth's crust. It forms basic raw material for Iron & Steel industry. India has large reserves of good quality of iron ore which can meet the growing demand of domestic iron & steel industry and can also sustain considerable external trade. With the total resources of over 25.25 billion tonnes (both haematite & magnetite), India is one of the leading producers as well as exporters of iron ore in the world.

Haematite and magnetite are the most prominent of the iron ores found in India. Indian deposits of haematite belong to pre-Cambrian iron ore series and the ore is within banded iron ore formations occurring as massive, laminated, friable and also in powdery form. The major deposits of iron ore are located in Jharkhand, Orissa, Chattisgarh, Karnataka and Goa States.

About 60% of haematite ore deposits are found in the Eastern sector and about 80% magnetite ore deposits occur in the Southern sector, especially in Karnataka. Of these, haematite is considered to be superior because of its high grade. Indian deposits of haematite belong to the pre-Cambrian iron ore series and the ore is within banded iron ore formations occurring as massive, laminated, friable and also in powder form. India possesses haematite resources of 14,630 million tonnes of which 7,004 million tonnes are reserves and 7,626 million tonnes are remaining resources. Major haematite resources are located mainly in Jharkhand-4036 million tonnes (28%), Orissa-4761 million tonnes (33%), Chattisgarh-2731 million tonnes (19%), Karnataka-1676 million tonnes (11%) and Goa-713 million tonnes (5%). The balance resources are spread over in the state of Maharashtra, Madhya Pradesh, Andhra Pradesh, Rajasthan, Uttar Pradesh and Assam together contain around 4% of haematite.

Magnetite is the other principal iron ore occurring in the form of oxide which is either of igneous or metamorphoses banded magnetite silica formation, possibly of sedimentary origin.

The magnetite resources are placed at 10,619 million tonnes of which only 207 million tonnes constitute reserves located mainly in Karnataka and Goa. The balance 10,413 million tonnes constitute remaining resources. A major share of magnetite resources is located in Karnataka-7812 million tonnes (74%), Andhra Pradesh-1464 million tonnes (14%), Rajasthan-527 million tonnes & Tamil Nadu-482 million tonnes (5% each), and Goa-214 million tonnes (2%). Assam, Jharkhand, Nagaland, Bihar, Madhya Pradesh and Maharashtra together account for a meager share of magnetite resoures. The most important magnetite deposits are located in Babubadan, Kudremukh, Bellary, Anadurga and Bangarkal areas of Karnataka, Goa region, Ongole and Guntur districts of Andhra Pradesh etc. Other deposits are also located in Jharkhand, Bihar, Tamilnadu, Kerala and Assam etc. However, reserves of high grade ore may be a cause of concern. The total iron ore resources are estimated at 25.25 billion tonnes, of which Heamatite ore resources stands to the order of 14.63 billion tonnes and the remaining 10.61 billion tonnes are magnetite as on 1.4.2005 (Source: IBM, Nagpur).

The details of iron ore resources/reserves as per UNFC system for haematite & magnetite ores and its distribution in the different states of India are given in the Table No. 2.3.2.1 to 2.3.2.4. The Indian resources of iron ore have been made compatible with United Nations Framework Classification (UNFC) which is more scientific and adopted in most countries of the world. The resource positions since 1-1-1980 till 1-4-2005 have been given in table below.

Table No.2.3.2.1 Iron Ore Resources & Production in India between 1980, 1990, 2000 & 2005

(Unit: million tonnes)

Grade	*Resources as on 1.1.1980*	*Production between 1980-90*	*Resources as on 1.4.1990*	*Production between 1990-2000*	*Resource as on 1.4.2000*	*Production Between 2000-2005*	*Resources as on 1.4.2005*
Haematite	11469		12197 (+728)		11426 (-771)		14630 (+3204)
Magnetite	6095		10590 (+4495)		10682 (+92)		10619 (-63)
Total	**17564**	**470**	**22787 (+5223)**	**656**	**22108 (-679)**	**532**	**25249 (+3141)**

Figures in parenthesis indicate decrease(-)/increase(+) in resources

Note: (1) Annual average production: 1980-90 = 47 Mt; 1990-2000 = 66 Mt; 2000-05 = 106 Mt

(2) These resources do not include around 1000 Mt of haematite iron ore recently discovered by DMG, Chhatishgarh in Kabirdham district.

Source: Indian Bureau of Mines, Nagpur. ***The iron ore resources in India have been estimated at 25249 Mt (Haematite-14630 Mt & Magnetite-10619 Mt - as per UNFC as on 1-04-05).***

Table No. 2.3.2.2 State wise Reserves/Resources of Iron Ore (Haematite) as on 1.4.2005 (Revised)

(Unit:in '000tonnes)

Sl. No	**State**	**Reserves**	**Resources**	**Total**
1	Andhra Pradesh	39,596	123,443	163,039
2	Assam	-	12,600	12,600
3	Bihar	-	55	55
4	Chhatishgarh	760,512	1,970,275	2,730,787
5	Goa	458,704	254,244	712,948
6	Jharkhand	2,494,423	1,541,323	4,035,746
7	Karnataka	940,430	735,792	1,676,222
8	Madhya Pradesh	33,917	171,021	204,938
9	Maharashtra	13,997	251,359	265,356
10	Meghalaya	-	225	225
11	Orissa	2,251,771	2,508,848	4,760,625
12	Rajasthan	10,813	19,035	29,848
13	Uttar Pradesh	-	38,000	38,000
	All India	**7,004,167**	**7,626,220**	**14,630,387**

Source: Indian Bureau of Mines, Nagpur

Table No. 2.3.2.3 State wise Reserves/Resources of Iron Ore (Magnetite) as on 1.4.2005 (Revised)

(Unit:in '000tonnes)

Sl. No	State	Reserves	Resources	Total
1	Andhra Pradesh	-	1,463,541	1,463,541
2	Assam	-	15,380	15,380
3	Bihar	-	2,659	2,659
4	Goa	50,112	164,057	214,169
5	Jharkhand	3,391	6,879	10,269
6	Karnataka	148,437	7,663,347	7,811,784
7	Madhya Pradesh	-	83,435	83,435
8	Maharashtra	621	-	621
9	Meghalaya	-	3,380	3,380
10	Nagaland	-	5,280	5,280
11	Orissa	156	54	210
12	Rajasthan	4,225	522,652	526,877
13	Tamil Nadu	-	481,876	481,876
	All India	**206,941**	**10,412,540**	**10,619,481**

Source: Indian Bureau of Mines, Nagpur

Table No. 2.3.2.4 Grade wise iron ore resources as on 01.04.2005 (provisional)

(Unit: Million Tonnes)

Ore Type	Grade	Resources as on 01.04.2005 (Provisional)
Iron ore (Haematite)	(+) 65% Fe	2132
	(+) 62% to 65% Fe	6694
	Below 62% Fe (including all other grades)	5804
	Total	**14630**
Iron ore (Magnetite)	Metallurgical	2186
	Coal washery	8
	Foundry	1
	Others	25
	Unclassified	8113
	Not known	287
	Total	**10620**

Source: Indian Bureau of Mines, Nagpur

The iron ore mining is mainly being carried out in the following four zones of India. The detail distribution is shown in the map in the following pages.

Table No.2.3.2.5 Iron Ore Zones in India

Zone –A (Eastern Zone) Jharkhand & Orissa	**Haematite Ore** Singhbhum District in Jharkhand and Keonjhar and Sundergarh in Orissa. About 60% of the ore is concentrated in this sector.
Zone – B (Central Zone) Chattisgarh, M.P. and Maharastra	**Haematite Ore** Covers Dalli-Rajhara deposit of Durg district, Rowghat-Bailadila of Baster District and Surajgarh Deposit in Maharastra
Zone – C (Southern Zone)	**Haematite Ore** Bellary-Hospet Sector covering iron ore deposits in Sandur Range in Bellary district and includes Kumarswamy and Ramandurg Deposits, etc and **Magnetite Ore** Metamorphosed banded iron formation along West coast, Karnataka, Kerala, etc. About 80% of known reserves of Magnetite Ore are concentrated in Karnataka.
Zone –D (Western Zone)	**Haematite Ore** Goa-Redi covering iron ore deposits of Goa and Redi in Ratnagiri district of Maharastra.

2.4 STATUS OF EXPLOITATION

Production of iron ore in the country is through a combination of large mechanised mines in both public and private sectors and several smaller mines operated in manual or semi mechanised basis in the private sector. These can be broadly grouped as under:

- **Captive Mines:** Owned and operated by individual steel plants both in public and private sectors mainly for their own use (i.e. SAIL, TISCO etc.)
- **Non-captive mines:** These are mainly in public sector owned and operated by companies like National Mineral development Corporation Ltd. (NMDC), Kudremukh Iron Ore Co. Ltd. (KIOCL) and the state government undertakings like Orissa Mining Corporation (OMC), Mysore Minerals Ltd.(MML) etc.
- **Non captive mines owned and operated by private parties** for exports as well as for internal consumption. The companies include M/s Sesa Goa Ltd., M/s Chowgule & Co. Pvt. Ltd., M/s Mineral Sales Pvt. Ltd., Rungta Mines Private Ltd., Jindal Steel and Power Ltd. etc.

The domestic production of iron ore in 2005-06 was 154.436 million tonnes including lumps, fines & concentrates, which accounts about 10 % of the total world iron ore production of 1542 million tonnes during 2005-06. The public sector contribution for iron ore production during 2005-06 was about 40% and the remaining was private sectors contribution. During 2005-06, Orissa was the highest producer (32%) followed by Karnataka (22%), Chhatisgarh (16%), Goa (15%) and Jharkhand (11%). Andhra Pradesh, Madhya Pradesh, Maharashtra and Rajasthan accounted for remaining. The domestic production of iron ore during 2006-07 is about 172.296 (P) million tonnes, which is about 10.2 % of the total world iron ore production of 1690 million tonnes during calender year 2006.

During 2001-02, 215 numbers of iron ore mines were operating with a lease area of 1, 05,093 hectares and produced 86.22 million tonnes of iron ore (including lumps, fines and concentrate). During 2005-06, 261 numbers of Iron Ore mines were operating in a total 505 leases (as on 31-03-06) with a lease area of 78,238.44 ha and produced 154.436 million tonnes of Iron Ore (including lump, fines & concentrate), out of which 41 iron ore mines were working under public sector and remaining 220 mines are under private sector. During 2006-07, India has produced 172.296 (P) million tonnes of iron ore including lump, fines & concentrate.

Details of Indian iron ore statistics collected from IBM and other sources are given below (from A to J):

A) Iron Ore Resources/Reserves as per UNFC Classification

Grade	***Reserves & Resources as on 1-4-2005 (Unit.: Million tonnes)***	
Haematite	Reserves	7004
	Remaining resources	7626
	Total	**14630**
Magnetite	Reserves	207
	Remaining resources	10412
	Total	**10619**
Total	Reserves	7211
	Remaining resources	18038
	Total	**25249**

Source: IBM, Nagpur;

B) Status of Iron Ore Mining Leases in India

Leases as on	*No. of Leases*	*Lease Area (ha)*
Mining Leases as on 31-3-2001	638	1,05,093.46
Mining Leases as on 31-03-2006	505	78,238.44

Source: IBM, Nagpur

C) Iron ore mining leases in India as on 31-03-06

Sl. No	State	Total		Public		Private	
		Nos.	Area (Ha)	Nos.	Area (Ha)	Nos.	Area (Ha)
1	Andhra Pradesh	25	1511.15	01	266.33	24	1244.82
2	Chhatishgarh	15	6544.88	11	6402.97	04	141.91
3	Goa	187	14002.79	-	-	187	14002.79
4	Haryana	01	86.20	01	86.20	-	-
5	Jharkhand	48	12700.29	13	7091.79	35	5608.50
6	Karnataka	73	10501.58	02	6642.80	71	3858.78
7	Madhya Pradesh	09	124.67	-	-	09	124.67
8	Maharashtra	29	1060.86	01	43.82	28	1017.04
9	Orissa	103	30806.73	26	15887.29	77	14919.44
10	Rajasthan	15	899.29	-	-	15	899.29
	All India	505	78238.44	55	36421.20	450	41817.24

Source: IBM, Nagpur

D) Number of Reporting Iron Ore Mines in India

Year	*No. of reporting mines*
2000 – 01	208
2001 – 02	215
2002 – 03	242
2003 – 04	266
2004 – 05	270
2005 - 06	261

Source: IBM, Nagpur

E) Iron ore production by sectors: Captive vs. Non-captive

(Unit.: Million Tonnes)

Year	***2000-01***	***2001-02***	***2002-03***	***2003-04***	***2004-05***	***2005-06***
All India Total	80.76 (7.76)	86.22 (6.77)	99.07 (14.90)	122.83 (23.99)	142.711 (16.18)	154.436 (5.82)
Public Sector	43.49 (5.16)	45.09 (3.70)	49.69 (10.20)	57.54 (15.79)	57.17 (-0.64)	58.813 (3.13)
Private Sector	37.27 (10.96)	41.12 (10.35)	49.37 (20.05)	65.29 (32.24)	85.53 (31)	95.623 (7.55)
Captive	28.67 (6.78)	28.03 (-2.25)	29.97 (6.95)	33.48 (11.71)	35.202 (5.12)	35.079 (-0.35)
Non-Captive	52.08 (8.31)	58.19 (11.73)	69.09 (18.73)	89.34 (29.32)	110.74 (23.94)	119.357 (7.78)

Source: IBM, Nagpur

Figures in parenthesis indicate the % age rise or fall over previous year.

Note: Most of the increase in production of iron ore has been from non-captive mines in private sector and was export driven, especially for China.

F) State-wise Iron Ore Production (including lump, fines & concentrates) in India

(Unit: '000tonnes)

State	***2000 – 01***	***2001-2002***	***2002-2003***	***2003-2004***	***2004-2005***	***2005-06***
Chattisgarh	20,016	18,660	19,781	23,361	23,118	24,750
Jharkhand	12,403	13,068	13,702	14,682	16,087	17,435
Orissa	14,382	16,602	22,077	31,288	40,567	49,880
Karnataka	18,902	22,595	24,797	31,635	37,176	33,669
Goa	14,564	14,784	17,889	20,246	22,309	23,744
Others	495	517	826	1,626	3,454	4,958
All India Total	*80,762*	*86,226*	*99,072*	*122,838*	*142,711*	*154,436*

Source: IBM, Nagpur

G) Production and Consumption of Indian Iron Ore

Year	*Production (MT)*	*Export (MT)*	*Domestic Consumption (MT)*	*% of production exported*
2000-2001	80.76	37.49	36.02	46.42
2001-2002	86.22	41.64	37.71	48.29
2002-2003	99.07	48.02	40.94	48.47
2003-2004	122.84	62.57	44.97	50.9
2004-2005	142.711	78.14	48.15	54.75
2005-2006	154.436	89.27	52.23	57.8
2006-2007	172.296 (P)	93.26 (P)	56.28 (P)	54.1 (P)

Source: IBM, Nagpur; Joint Plant Committee, Kolkata; MMTC, New Delhi; GMOEA, DGCI&S, Kolkata, Panjim, Goa, P = Provisional.

H) Iron Ores and Concentrates: Indian Production (Product-wise)

(Unit.: '000 tonnes)

Grade	*2000 - 01*	*2001 - 02*	*2002 – 03*	*2003 - 04*	*2004 – 05*	*2005 – 06*
Lumps	33567(*41.56*)	34572(*40.09*)	39581(*39.95*)	48960(*39.85*)	57590(*40.35*)	62643(*40.56*)
Fines	41189(*51*)	45224(*52.45*)	52994(*53.49*)	67670(*55.1*)	79976(*56.04*)	87900(*56.92)*
Concentrates	6006(*7.44*)	6430(*7.46*)	6497(*6.56*)	6119(*5.05*)	5145(*3.61*)	3893(*2.52)*
Total	80762	86226	99072	122838	142711	154436

Source: Indian Bureau of Mines, Nagpur;

Figures in parenthesis indicate the %age contribution of lumps, fines & concentrates respectively in the total production

I) Destination wise Export of Indian Iron Ore (in MT)

(Unit.: Million Tonnes)

Country	*2000 - 01*	*2001 - 02*	*2002 – 03*	*2003 - 04*	*2004 – 05*	*2005 – 06*	*2006 – 07(P)*
China	14.10	19.22	26.27	42.06	60.46	74.13	79.78
Japan	16.77	15.62	15.75	13.10	10.91	10.33	8.69
S. Korea	2.31	3.00	2.41	2.14	2.17	1.32	1.90
Taiwan	0.90	0.43	0.58	0.88	0.57	0.14	-
Europe	1.48	1.81	2.04	2.47	2.82	2.10	1.97
Others	1.93	1.56	0.97	1.92	1.21	1.25	0.92
Total	37.49	41.64	48.02	62.57	78.14	89.27	93.26

Source: MMTC, New Delhi & Goa MOEA, Panjim; DGCI&S, Kolkata, IBM, Nagpur, *P = Provisional*

(J) Major Iron Ore Mines in India

Company	*Name & Address of Mine*
Central Zone/Chattisgarh	
M/s. National Mineral Development Corporation Ltd.	Bailadila Iron Ore Project,Deposit-5, Bacheli, Dantewada, Pin - 494553
	Bailadila Iron Ore Project, Deposit-14,Kirandul,Dantewada, Pin- 494556
	Bailadila Iron Ore Project,Deposit-11C,Kirandul,Dantewada, Pin- 494556
	Bailadila Iron Ore Project,Deposit-10,Bacheli, Dantewada, Pin- 494553
	Bailadila Iron Ore Project, Deposit-11A,Bacheli,Dantewada, Pin- 494553
M/s. Steel Authority of India Ltd.	Rajhara Iron Ore Mines, P.O. Rajhara, Dist. Durg, Pin - 491001
	Dalli Mechanised Mine, P.O.Dalli-Rajhara, Dist-Durg, Pin - 491228
	Dalli Manual Mine, P.O.Dalli-Rajhara, Dist-Durg, Pin - 491228
	Jharandalli Iron Ore Mine,P.O.Dalli-Rajhara, Dist-Durg, Pin - 491228
	Mahamaya-Dulki Iron Ore Mine, P.O.Balod/Durg, Dist-Rajnandgaon
Western Zone/Goa & Maharashtra	
M/s. Sesa Goa Ltd.	Codli Iron Ore Mines, Codli, P.O. Kirlapale, Taluk-Sanguem, Dist-South Goa, Pin - 403706
	Sonshi Gaval Iron Ore Mine, Sonshi, P.O. Honda, Taluk-Sattari, Dist-North Goa
M/s. Dempo Mining Corporation Ltd.	Bicholim Iron Ore Mines, P.O. Bicholim, Dist–North Goa, Pin – 403504
M/s. Chowgule & Co. Ltd.	Costi & Tundu Iron Ore Mines, P.O. Pale, Dist-South Goa, Pin – 403105
M/s. Bandekar Brothers Pvt.Ltd.	Jaquela ou Iron Ore Mines, P.O. Vasco da gama, Dist-North Goa, Pin - 493802
M/s. Sociedade De Fomento Industries Pvt. Ltd.	Shigao Iron Ore Mines, P.O. Collem, Dist-South Goa, Pin – 403410
M/s. V M Salgaoncar & Bros Ltd.	Velguem/Surla Iron Ore Mines, Vill-Velguem/Surla, Dist–North Goa,
M/s. Salgaonkar Mining India Ltd.	Smi Tatodi Iron Ore Mines, Dist-South Goa
M/s. Gogte Minerals Pvt. Ltd.	Redi Iron Ore Mines, P.O. Redi, Dist–Sindhudurg, Pin–416517
M/s. Sociedade Timblo Irmaos Pvt. Ltd.	Gautona Dusrifal Iron Ore Mines, Kirlapal, Dist South Goa, Pin-403727
M/s Gahra Minerals Pvt.Ltd.	Gunjewahi Iron Ore Mines, P.O./Dist-Chandrapur, Maharastra

Company	*Name & Address of Mine*
M/s. Maharastra State Mining Corporation Ltd.	Khuisipar Iron Ore Mines, Dist-Bhandara, Maharastra
M/s. D B Bandodkar & Sons Pvt. Ltd.	Matta & Dando Iron Ore Mines, Via Pale, PO Velgudi, Dist-North Goa, Pin-403105
M/s. M Talaulicar & Sons Pvt. Ltd.	Saniem Iron Ore Mines, Sancordem, Dist-South Goa, Pin-403406
Southern Zone/Karnataka	
M/s. Kudremukh Iron Ore Co. Ltd.	Kudremukh Iron Ore Mines, P.O. Kudremukh, Dist – Chikmagalur, Pin – 577142
M/s. National Mineral Development Corporation Ltd.	Donimalai Iron Ore Mines, Donimalai, Sandur, Dist-Bellary, Pin - 583118
	Kumarswamy Iron Ore Mines, Dist-Bellary
M/s. R Pampapathy Pvt. Ltd.	Aarpee Iron Ore Mines, 19/43, Bellary Road, P.B. No.64, Hospet, Dist-Bellary, Pin-583201
M/s. Tungabhadra Minerals Pvt. Ltd.	Bellary Iron Ore Mines, P.O. Taranagar, Dist-Bellary, Pin – 583119
M/s. Sandur Manganese & Iron Ore Ltd.	Deogiri Iron Ore Mines, Dist-Bellary, P.O. Deogiri, Pin – 583112
M/s. Bellary Mining Corporation	Halakundi Iron Ore Mines, P.O./Dist-Bellary, Pin – 583101
M/s. Mysore Minerals Ltd.	Jambunathanahalli Iron Ore Mines, Dist-Bellary
	Ubbalagundi Iron Ore Mines, Sandur,Dist Bellary, Pin – 583119
M/s. Mineral Sales Pvt. Ltd.	Vyasanakere Iron Ore Mines, P.O. Hospet, Dist-Bellary, Pin – 583203
M/s. Dalmia Cement (Bharath) Pvt. Ltd.	Bharatarayanaharu Iron Ore Mines, P.O. Hospet, Dist-Bellary, Pin – 583203
M/s. Visvesvaraya Iron & Steel Co. Ltd., Steel Authority of India Ltd.	Kemmangundi Iron Ore Mines, Tigada Village, Tarikere, Dist-Chikmagalur, e-mail ID – edvisl@blr.vsnl.net.in
M/s. S V Minerals Pvt. Ltd.	S V K Iron Ore Mines, K R Road, Hospet, Dist-Bellary, Pin – 583201
M/s. P Balasubba Setty & Sons Pvt. Ltd.	Karadikolla Sureeh Iron Ore Mines, Dist-Bellary, Pin – 583201
Eastern Zone/Jharkhand & Orissa	
M/s. TATA Iron & Steel Company Ltd.	Noamundi Iron Ore Mines, Noamundi, Dist-West Singhbhum, Jharkhand, Pin – 833217
	Joda East Iron Ore Mines, Joda, Dist-Keonjhar, Orissa, Pin - 758034
M/s. Steel Authority of India Ltd.	Barsua Iron Ore Mines, Tensa, Dist-Sundargarh, Orissa, Pin - 770041
	Bolani Ore Mines, Bolani, Dist-Keonjhar, Orissa, Pin – 758037

Company	***Name & Address of Mine***
	Kalta Iron Ore Mines, Kalta, Dist-Sundargarh, Orissa, Pin - 770052
	Kiriburu Iron Ore Mines, P. O. Kiriburu, Dist-West Singhbhum, Jharkhand, Pin – 833222
	Meghahatuburu Iron Ore Mines, P.O. Meghahatuburu Dist-West Singhbhum, Jharkhand, Pin – 833223
M/s. Indian Iron & Steel Co. Ltd.	Manoharpur(Chiria) Iron Ore Mines, Dist-West Singhbhum, Jharkhand, Pin – 833106
	Gua Iron Ore Mines, Gua, Dist-West Singhbhum, Jharkhand, Pin – 833213
M/s. Essel Mining & Industries Ltd.	Jilling Langolata Iron Ore & Manganese Mines, Jajang, Barbil, Dist- Keonjhar, Orissa, Pin – 758035
	Kasia Iron Ore Mines, Barbil, Dist-Keonjhar, Orissa, Pin – 758035
M/s. Orissa Mineral Development Co. Ltd.	Thakurani Iron Ore Mines, Thakurani, via-Barbil, Dist-Keonjhar, Orissa, Pin – 758035
	Belkundi Iron Ore Mines, Thakurani, Dist-Keonjhar, Orissa, Pin – 758035
	Bagaiburu Iron Ore Mines, Thakurani, Dist-Keonjhar, Orissa, Pin – 758035
M/s. Serajuddin & Co.	Balda Iron Ore Mines, Balda, Dist-Keonjhar, Orissa
M/s. Orissa Mining Corporation Ltd.	Balda Palsa Jajung Iron ore Mines, Dist-Keonjhar, Orissa
	Barpada Kasia Iron Ore Mines, Dist-Keonjhar, Orissa
	Daitari Iron Ore Mines, Talpada, Dist-Keonjhar, Orissa, Pin – 758026
	Gandhamardhan Iron Ore Mines, Shuakathi, Dist-Keonjhar, Orissa
	Roida Iron Ore Mines, Matkambeda, Orissa, Pin – 758036
M/s. Rungta Mines Pvt. Ltd.	Jojang Iron Ore Mines, Dist-Keonjhar, Orissa
M/s. Patnaik Minerals Pvt. Ltd.	Joribahal Iron Ore Mines, Boneikala (Joda), Dist-Keonjhar, Orissa, Pin – 758038
M/s. Jindal Steel & Power Ltd.	TRB Iron Ore Mines, Tensa, Dist-Sundergarh, Orissa, Pin – 770042
M/s. D R Patnaik Pvt. Ltd.	Murgabeda Iron ore Mines, P.O.- Boneikala (Joda), Dist-Keonjhar, Orissa, Pin – 758034
M/s. S L Sarda & M L Sarda	Thakurani Iron ore Mines, Thakurani, via-Barbil, Surabli, Dist-Keonjhar, Orissa
M/s. Kalinga Mining Corporation	Joruri Iron Ore & Manganese Mines, Joruri, PO-Jajang, Dist-Keonjhar, Orissa, Pin-758058

2.5 FUTURE DEMAND

2.5.1 Iron Ore requirement during 2006-07 and 2011-12

The expected production target of the Mild/Carbon Steel based on the Macro Economic model and the growth rate of the GDP as projected in the 10th Five year plan working group committee report (Working Group on Mineral Exploration & Development, other than Coal and Lignite) is projected as follows:

Table No.2.5.1.1 Future Iron Ore Requirement in India

(Figures in Million Tonnes)

Year	*Net Finished Steel Production*	*Crude Steel Equivalent*	*BF/BOF Share (60%)*	*EAF Share (40%)*
2006 – 2007	43.83	50.09	30.00	20.09
2011 - 2012	61.15	69.89	42.00	27.89

To meet the above projected tonnage of steel, the requirements of various grades/ specifications of iron ore are estimated to be ***122 million tonnes*** and ***156 million tonnes*** during 2006-07 and 2011-12, respectively. The detail estimation as per the Working Group on Mineral Exploration & Development (other than Coal and Lignite) committee report is given in the tables below:

Table No. 2.5.1.2 Iron Ore Requirement during 2006 – 07

S. No.	*Process*	*Quantity in million tonnes*	*Estimation of iron ore requirement (million tonnes)*
1.	BF/BOF (Crude Steel)	30.00	
	Hot Metal(30/0.85)	35.29	35.29 x 1.6 = 56.47
2.	Pig Iron	3.77	3.77 x 1.6 = 6.03
3.	DRI	7.30	
a)	Coal based	3.15	3.15 x 1.6 = 5.04
b)	Gas based	4.15	4.15x 0.5 x 1.5 = 3.11
	(50% requirement of lump)		
4.	Pellet Production		
	Essar	6.00	
	Kudremukh	3.00	
	Mandovi	1.80	
	JVSL	3.00	
	Total	13.80 x 1.0	13.80
Sub total for Domestic consumption			84.45
Expected Export including pellets & concentrates			45.00
Total requirement		**84.45 + 45 – 7.50***	**121.95**

Say 122.00 Million Tonnes

** 6.5 Million Tonnes pellets & 1 Million Tonne concentrate is expected to be exported out of 13.80 Million tonnes of total pellet production.*

Table No. 2.5.1.3 Iron Ore Requirement during 2011 - 12

S. No.	*Process*	*Quantity in million tonnes*	*Estimation of iron ore requirement (million tonnes)*
1	BF/BOP (Crude steel)	42.00	
	Hot Metal (42/0.85)	49.42	49.42x1.6=79.07
2	Pig Iron	4.37	1.37 x 1.6 = 6.99
3	DRI	20.65	
a)	Coal Based	6.50	6.50 x 1.6 = 10.40
b)	Gas Based (50% requirement of lump)	4.15	4.15 x 0.5 x 1.5 = 3.11
4	Pellet Production	13.80	13.8 x 1.0 = 13.80
Sub Total for domestic consumption			113.37
Expected Export (including pellets & concentrates)			50.00
Total requirement (113.37 + 50 – 7.5*)			**155.87**

Say 156.00 Million Tonnes

As per the National Steel Policy, 2005 the total demand of iron ore is placed at 290 million tonnes including 190 million tonnes for domestic consumption & 100 million tonnes for export by 2019-20. The current mining capacity of iron ore in the country is around 160 million tonnes. This capacity can be enhanced, through consolidation of leases, mechanised mining operations in Bellary-Hospet area and improvement in the operating capacity of existing mines in Bailadila and opening up of new deposits of Bailadila, new deposits in the eastern sector, Chhatisgarh area, and in Karnataka etc. Through better infrastructure handling, the existing capacity can be expanded in the eastern sector mines such as Kiriburu, Meghahatuburu, Bolani, Kalta etc. and by opening up of new mines in the eastern sector covering Chiria, Malangtoli, Gandhamardan and Dubna deposits and also at Rowghat of central zone.

2.5.2 Future Development Programme

The tenth five year plan has projected the iron ore demand of the country at about 122 million tonnes by 2006 – 07 and 156 million tonnes by 2011 – 12. Though, India has already achieved 172.296 million tonnes (Provisional) during 2006-07. With the total demand of iron ore likely to increase to 290 million tonnes by 2019-20 (as per National Steel Policy, 2005), both on account of domestic requirements (190 million tonnes) and export (100 million tonnes), capacity of around 305 million tonnes per annum (MTPA) is required at 95% capacity utilisation by 2019-20. The country has planned for capacity expansion on a large scale from its existing mines and development of new mines. Apart from expansion plans of present iron ore mines in all the sectors, development of following identified hematite and magnetite deposits/mines are envisaged for further exploration wherever required, and exploitation by interested parties from within or outside the country.

The additional capacity is expected to come from the following sectors:

1. From **Bellary – Hospet sector**, if consolidation of the leases is attempted and suitable size mechanised mine operations are started by developing new deposits, it is possible to increase the existing capacity.

2. From **Bailadila region**, opening up of Deposit No. 10 & 11A, 1, 4, 11B & 13 and improving the operating capacity & expansion of existing mines in Bailadila Sector may enhance the capacity.
3. **Eastern region** has the maximum share of the total iron ore resources in India. Capacity of this sector is proposed to be increased from the existing level. This can be achieved by improving the excavation arrangement through better infrastructure facilities and capacity expansion from the Eastern Sector mines including the mines of Bolani, Kiriburu, Meghahatuburu, Barsua, Kalta, Chiria, Thakurani, Taldih, TISCO, Jindal, Rungta, ESSEL Mining and other private mine owners.
4. In **Goa – Redi region,** the present capacity has already been enhanced. According to experts, consolidation in this area may help to produce an additional 3 to 5 MTPA.
5. In **Karnataka**, less than 800 MT of proven reserves of Magnetite deposit in Bababudan area can be tapped after overcoming the environmental hurdles.

In general, to meet the increased requirement, the existing production will have to be expanded in mines like Bolani and new mines will have to be opened up in Chiria in Jharkhand, Rowghat and other deposits of Bailadila in Chattisgarh, Malangtoli in Orissa, Ramandurg in Karnataka. Thus it would be possible to meet the increased requirement by the year 2019 – 2020 provided action is taken to improve the railway line infrastructure and the port infrastructure in Paradeep, Chennai and Goa, which will help in increasing export of the surplus medium and low grade materials. It may be noted that India has already achieved 172.296 MT (Provisional) iron ore production during 2006 – 07. However, during the next decade some of the large mines like Kudremukh already closed and iron ore reserve in some mines like Kiriburu, Meghahatuburu, Rajhara and Dalli will deplete.

2.6 PRESENT MINING PRACTICES IN INDIA

In India, iron ore deposits mostly occur in dense forest areas and on hill tops, which are water shed of important river valley and these deposits of iron ore are located in the states of Jharkhand, Orissa, Chattisgarh, Goa and Karnataka. The iron ore deposits of the Eastern, Central and Southern zone do not contain much overburden material except laterite and some low grade ferruginous shales and BHQ patches, whereas, in Western zone (Goa region) more than 30 MT of iron ore is produced during 2006-07 and another 2.5 to 3.5 times of the waste is excavated as overburden. Normally, iron ore mining in India is done by opencast method and on the basis of mining methods, the mining can be broadly divided into two categories, i.e. manual and mechanized. Majority of the large mechanised mines are in the public sectors whereas manual mines are mainly in the private sector. The present production capacity of iron ore in India is around 160 MT per year.

2.6.1 Manual Mines

This method of mining is generally confined to float ores. Mining of reef ore is also being done manually on a small scale. The float ore area is dug - up manually with picks, crowbars and spades, and the material is manually screened to separate plus 10 mm float ore, which is then stacked up. The waste is thrown back into the pits. Generally, the recovery of float ore ranges from 30 to 50% or at times even more. As regards to reef ore workings, holes of 0.6 m deep and 35 - 40 mm diameter are drilled with hand-held Jackhammers with a spacing of about 0.6m and each hole is charged with 150 - 200 g gunpowder or special gelatine cartridges. Usually Jackhammer drills are operated with the help of portable air - compressors. The tonnage broken per kg of gunpowder is around 2.5 - 3 tones. The blasted ore is manually loaded into trucks for transport either to the railway station or to the buyers' destination directly. Cost of mining and OMS (output per man per shift) varies from mine to mine. Presently, OMS in manual iron ore mines for producing 10 - 30 mm lump is about 1.5 - 2.0 tones and the –10 mm fraction is rejected at site. This method of mining is still prevalent in the two important zones of the Indian iron ore sector namely, Barajamda (Bihar & Orissa) and Bellary – Hospet (Karnataka). To increase the production from manual mines, setting up of centralised crushing & screening plants will be required, which also helps in optimal utilisation of resources.

2.6.2 Mechanised Mines

The history of mechanised mining operation starts with the establishment of iron ore mines in Gua in Singhbhum district, Jharkhand followed by TISCO's Gorumohisani mine in Mayurbhanj district, Orissa and Noamundi iron ore mine in Singhbhum district, Jharkhand. Mechanisation in Goan iron ore mines came into effect from the late 50s. With the establishments of integrated steel plants in India, setting up of captive mechanized iron ore mines was developed at Kiriburu, Rajhara, Bailadila, Barsua, Joda, Bolani, Daitari, Donimalai, Kudermukh, Meghahatuburu and Goa.

Apart from a few mines developed for iron ore export, most of the fully mechanised mines are captive to various steel plants and have been developed up to their requirements. In these mines, the methodology being adopted for mining of ore / overburden by shovel-dumper combination, mining is invariably done systematic formation of benches by drilling and blasting. The loading operations are also fully mechanised and transportation is facilitated by maintaining mine haul roads. Further, ore handling, washing and screening operations are mechanised. The degree of mechanisation and the size of the machinery vary with the material required to be handled by the mines.

In iron ore mines in India, generally, benching is started from the top of the hill and carried downwards as the ore at the top gets exhausted. Except in uniform deposits, if the direction of the bench is along the strike of the beds, it encounters different beds of ores as the working face advances, resulting in considerable fluctuations of the grade of ore produced, unless many benches are worked simultaneously at different depths. This, in turn, requires a large number of smaller machines which create their own problems of supervision, maintenance, etc. It is therefore, commonly preferred to open - up benches as far as possible across strike of the beds, so that more uniform grade of the ore is produced.

Mechanised mining operation by

4.6 m^3 Electric Rope Shovel with 50 T rear discharge Dumpers

The height of the benches is dependent on several factors, such as output requirement, shape, size and depth of occurrence of ore body, geological disturbances suffered by the ore body, hardness and compactness of ore body, type and size of the machinery proposed to be deployed, availability of finances, etc. All are interdependent factors. The bench height generally adopted in fully mechanised mines varies between 8 and 14 m. However, in Goa region, where the ore is softer, hydraulic excavators (backhoe) and wheel loaders is the principal loading equipment used; height of benches is restricted between 4 and 7 m. The length of the face is also dependent on various factors, such as contours of deposit, output required, variation in grade and blending requirements, capacity of loading machinery, etc. and varies between wide limits from as small as 60 m to as large as 400 m. The width of the bench is governed to a large extent by the size of the largest machinery deployed and varies, i.e. three times of the width of the dumper.

As an universal practice, iron ore is dislodged by drilling blast holes according to a particular pattern which depends on the bench height, the hole diameter, the drilling machinery deployed, nature of rock and the types of explosives used. These blast holes are vertical but can be inclined also for obtaining better blasting results.

The 310 mm dia rotary drill is the largest so far being deployed in India. Rotary drill is used normally in the size from 150 to 250 mm. Thus, the depth and diameter of the holes allow expanded drilling patterns in general and help in reducing generation of fines in softer ores. On the other hand, in hard ores or in strata where the hard bands are present, they can give poor fragmentation and toe formation. The poor fragmentation leads to lower rate of loading and increased wear and tear on the loading machinery. Investigations carried out by the Swedish State Power Board, by comparing the performance with 100 mm and 50 mm diameter blast holes, have shown that the digging rate of the shovels was 50 percent higher with small diameter blast holes. Drilling with 150 mm diameter blast holes has been the common practice in Indian iron ore mines. Probably, this is due to ready availability of indigenous drill machines of the size. But higher rate of production makes the incumbent to adopt greater bench heights and larger diameter holes. The greater bench heights permit the use of large shovels, which in turn can handle larger boulders and permit larger spacing and burdens. All the above drills are equipped with dry dust extraction system or wet drilling arrangements, sound proof cabin, dust hood at the collar of the hole to prevent air pollution due to drilling in the major iron ore mechanised mines in India. However, in Bellary – Hospet of Karnataka, where the rainfall is less than 750 mm per annum and there is a scarcity of water, the wet drilling practice is absent.

To cope up with the need of higher production of iron ore, blasting materials are also being developed / manufactured at the same pace. From the conventional explosives, development has taken place in stages from NG based explosives, ANFO, Slurry, Emulsions are in use in the country today. Development of most advanced ICI's computer aided blast model SABREX, VIBREX etc. are already in use in the iron ore mines in India with significant improvement in productivity and blast induced environmental hazards. In the field of blasting accessories significant improvement has been made due to introduction and adoption of "non-electric delay initiation system" for reducing blast induced ground vibration and air blast noise. Introduction of "Bulk Explosive Systems" in India like global experience, use of slurry, emulsions, ANFO and HANFO in bulk explosive systems have been well established with considerable benefit to Indian Iron ore Mining Industries. Introduction of "Opti Blast" and "Air decking" techniques are already in use at Kudremukh Iron Ore Mines for reducing consumption of explosives, ground vibration and Air Blast Noise etc. Controlled blasting techniques are also in use in the major iron ore mechanised mines in India. Secondary drilling and boulder blasting in mines is usually done by jackhammer drills powered by compressed air and with slurry / gelatine cartridges. However, in order to avoid secondary blasting and to reduce noise due to blasting, the major iron ore mines are using hydraulic rock breaker instead of boulder blasting. Due to availability of high capacity ripper dozers (700 hp), in some cases, drilling/blasting, especially in case of overburden removal, is eliminated. High capacity dozer can rip and doze more effectively where contact plane of overburden/ore and that of different grade ores is uneven. This ripping/dozing operation is eco-friendly; noise/vibration is practically nil and generation of dust is very less.

For loading of blasted ore, generally electric rope shovels of capacity 3.5 m^3 to $6m^3$ bucket capacity are in use in the mechanised haematite iron ore mines but large capacity shovels of 10 m^3 are in use in magnetite iron ore mine at Kudremukh in Karnataka. For haulage of the blasted ore larger dumpers have been deployed indigenously of 35 to 120tonnes capacity. However, imported dumpers of 120 t and 170 t capacity are also being used in India. Because of the large sized equipment deployed in the mining front, the processing plant has also made significant developments matching with mining machineries. The size of crushers, conveyors etc., have gone up and processing plant equipments of capacity 2000 – 3000 tonnes per hour have been installed for iron ore mines to match the size of mining equipments. Further innovations have been made in loading plant equipments such as bucket wheel reclaimers, wagon loaders etc., of matching capacity. However, the reclaimers and wagon loaders needed larger layout of railway tracks and while the loading track itself required a length of 1 Km, the length of railway yard is about 2 to 3 times of the loading tracks. Of late, flood loading system has come into prominence which is out dating the reclaimer-wagon loader combination of loading equipments. In India, the system of bunker loading exists at many mines and for shunting purpose, some locos have been maintained by the mining companies where the operation level is high.

As mechanised open cast iron ore mines becoming larger, deeper and more capital intensive, continuing efforts are being made to improve upon the open cast mining activities through advances in the equipment size / design and practices and also through introduction of innovative techniques. Significant results have been achieved through increasing size of stripping and hauling units, which apparently has reached a plateau, efforts on further improvements are being spear headed through new concepts in equipment utilization by restoring to automation and control. The application of high capacity continuous surface mining techniques to harder formations, new concept of high angle belt conveying system, in-pit crushing systems (mobile and semi-mobiles), high capacity dumpers, automatic truck dispatch system, non-electric blast initiation systems etc. and developments in the area of bulk explosive systems hold out almost unlimited opportunities for upgrading the performance of opencast iron ore mining in India.

The reserves of high grade iron ore are limited. Therefore, it would be necessary at this stage to ensure conservation of high grade ore by blending with low grade ores. As a matter of policy, only low and medium grade iron ore, fines and temporary surplus high grade iron ore (+67 % Fe), particularly from Bailadila (Chattisgarh) need to be exported in the coming years. R&D efforts are needed for developing necessary technologies for utilising more and more fines in the production of steel as a measure of conservation of iron ores. With the present high capacity of iron ore mines, total utilisation of iron ore has become the need of the hour so as to obtain maximum returns. In most of the mechanised mines more than 50 to 60 % fines (except for Bailadila and some mines in the eastern zone where the ore is very hard) are generated. Blue dusts in these mines are to be fully utilised to make various value added products. Blue dust can also be used as additive in concentration of iron ore fines to the extent of 20-40 % for use in steel plants. Further, in the iron ore mines where wet processing of the ore is done, around 10-

20 % of ROM is lost as slime, depending on the nature of ore feeds and in this context, coarse fines can be recovered up to 5 % by introducing hydro-cycloning and slow speed classifiers in wet circuit system, even though, the Fe content of such fines will be slightly low which can be blended.

Efforts are also necessary to utilise the tailings/waste as well. It has been found feasible to make bricks using 8 % of binding material such as cement and lime in slimes and 12 % in shale. As reported by IBM, a mixture of slimes and shale in the ratio of 4:1 by weight with 8% binder cement has shown good results in brick making. In the Bellary-Hospet area of Karnataka, the production of iron ore fines from the private mines is substantial, but the fines are unwashed and contain high percentage (40% of -100mesh fraction). In various R&D studies carried out so far, it has been found feasible to consume –100 mesh fraction up to 30% blue dust in concentrate feed. The fines from Bellary-Hospet region generally have 63-64 % Fe content and if 100 mesh fractions can be limited to 3%, these fines can be used as sintering feed.

In case of magnetite deposits of Kudremukh, it is estimated that the weathered ore in the leasehold of KIOCL is underlain by 400 million tonnes of primary BMQ in the area. Whereas with the prevailing production rate, the weathered ore reserves would last for another five to six years, the hard / compact, fine grained and silicious nature of the primary ore does not make it amendable for mining. Hence, the techno-economic aspects of mining and beneficiation of primary magnetic ore in Karnataka for production of concentrates need to be examined at this stage.

In general, iron ore mining in India being done by developing benches from the top of the hill and carried downwards as the ore at the top gets exhausted. The methodology being adopted for winning of iron ore is by shovel – dumper combination in case of major mechanised iron ore mines. The bench height generally adopted in iron ore mines in India is ranging from 6 Mts. to 14 Mts. and the slope of the benches ranging from 45^0 to 60^0 depending on the consistency / tensile strength of the rock. However in Goa region where the ore is softer, hydraulic excavator and wheel loaders are the principal loading equipment used, height of benches is restricted between 4 Mts. and 7 Mts.

The Iron ore industry in Goa operates under certain difficult conditions specific to Goan iron ore mines. Some of these are listed below:

- Mining activity in several places is being carried out below the water table, which required dewatering of pits for operation to continue.
- Restricted drilling and blasting due to limited lateritic overburden, presence of villages and inhabited areas in the vicinity of the mines.
- Restricted lateral mine development due to smaller areal extension since the lease area of individual mines is less than 100 ha.
- Transport is a problem within the mine, due to greater working depth.
- High overburden to ore ratio (of an average of about 2.5 to 3.0:1) implies that a large amount of overburden is generated when ore is extracted. Since the mining leases are less than 100 ha, there is very limited space (or non at all) available within the lease area to dump the waste material. This leads to requiring land outside the lease area for dumping rejects.
- Land being in short supply, dumps are typically steep with slopes greater than 30^o and height of 30-50 Mts. Many waste dumps are situated in the upper part of the valley

regions and during monsoon, run off from dumps is common, which blankets agricultural fields and settles in water courses.

- Because of small holdings, large amount of ore is blocked in barriers of adjoining mines; operations could be carried out close to common boundaries of two lease holders with mutual understanding. Structurally, majority of ore deposits are in synclinal form. Consequently, almost 60% (by volume) of ore production comes from terrain below ground water table.

2.7 PRESENT IRON ORE PROCESSING TECHNOLOGY IN INDIA

The iron ore processing flow sheet depends on the type of ROM ore feed and the optimum product. For high quality flaky ore and blue dust, termed, “direct ore”, dry screening into lumps and fines are practised, because, if wet treated, good quality material is rejected in slime. Further, dry screened fines also retain ultra fines particles required for sintering. Beneficiable ore types are subjected to wet screening - classification or scrubbing - wet screening - classification for more tenacious gauge. Iron values are recovered from classifier for dewatering of hydrocyclone underflow. Ore processing plants at Barsua, Bolani, Bailadila, Donamalai, Dalli, Gua, Kiriburu, Meghahatuburu, Noamundi and Rajhara use dry screening for direct ore.

In addition, except for Rajhara and Gua all these plants use wet screening - classification for beneficiable ores. Scrubbers are additionally used at Barsua, Bolani, Dalli and Noamundi. Jigs to treat classifiers sand have been provided at Barsua. In Sesa Goa, washing in log washers produces stable and better quality lumps. The beneficiation equipments used in the major iron ore processing plants in India are given below.

Table No. 2.7.1 Crushing Equipment used in Major Iron Ore Processing Plants in India

Sl. No.	Mine	Ore sizes (mm)		Crushing Equipment size (mm)				Crushing Scheme
		ROM Ore	Crushed Ore	Primary Crusher	Secondary Crusher	Tertiary Crusher	Quarternary Crusher	
1.	Barsua	-1200	-80	Jaw 1500 X 2100	Reduction gyratory 610	--	--	Two stages each in open circuit
2.	Bolani	-1200	-50	Gyratory 1372	Standard cone 2134	--	--	-do-
3.	Bailadila 14	-1200	-150	Gyratory 1372	Reduction gyratory 610	--	--	-do-
4.	Bailadila 11C	-1200	-150	Gyratory 1372	Reduction gyratory 610	--	--	-do-
5.	Bailadila 5	-1200	-30	Gyratory 1500	Standard cone 2134	Short head cone	--	Three stages, first two stages each in open circuit & third stage in closed circuit
6.	Donamalai	-1200	-30	Gyratory 1372	Standard cone 2134	Short head cone 2134	--	-do-
7.	Dalli	-1200	-40	Jaw 1500 X 2100	Standard cone 2200	--	--	Two stages each in open circuit
8.	Gua	-1200	-75	Jaw 1500 X 2100	Standard cone 2134	--	--	-do-

Sl. No.	Mine	Ore sizes (mm)		Crushing Equipment size (mm)				Crushing Scheme
		ROM Ore	Crushed Ore	Primary Crusher	Secondary Crusher	Tertiary Crusher	Quarternary Crusher	
9.	Kiriburu	-1200	-40	Jaw 1500 X 2100	Reduction gyratory 610	Standard Cone 2200	Short head cone 2200	Four stages, first three stage each in open circuit and fourth stage in closed circuit
10.	Meghahatuburu	-1200	-40	Gyratory 1372	Standard cone 2200	--	--	Two stages each in open circuit
11.	Noamundi	-1200	-50	Gyratory 1372	Standard cone 2134	--	--	Two stages second stage in closed circuit
12.	Rajhara	-1200	-40	Jaw 1500 X 2100	Standard cone 2200	Short head cone	--	Three stages each in open circuit

Table No. 2.7.2 Beneficiation Plant Equipment used in Major Iron Ore Mines in India

All dimensions are in mm

Sl. No.	Mine	Screen		Scrubber	Classifier		Cyclone Dia.	Jig Width x length
		Dry width x length	Wet width x length	Dia. x length	Rake width x length	Spiral Dia.x Length		
1.	Barsua	1524 x 3658	1830 x 4280	2400 x 4500	--	1500 x 8460	--	1500 x 4800
2.	Bolani	3000 x 7000	2400 x 6000	3000 x 11500	4800 x 11500	--	--	--
3.	Bailadila 14		2130 x 6100	--	--	1830 x 9800	610	--
4.	Bailadila 11 C (new)	2400 x 6100	2400 x 6100	--	--	1830 x 9800	--	--
5.	Bailadila 5	--	2400 x 6100	--	--	1800 x 11580	--	--
6.	Donamalai	2135 x 4880	2450 x 5470		--	1830 x 11000	600	--
7.	Dalli	1750 x 3500	1750 x 3500	2400 x 6100	--	2400 x 9200 (Duplex)	--	--
8.	Gua	1830 x 3658	--	--	--	--	--	--
9.	Kiriburu	2100 x 6000	2100 x 6000	--		1500 x 10000	--	--
10.	Meghahatuburu	1830 x 6000	1830 x 6000	--	3657 x 10972	--	610	--
11.	Noamundi	1830 x 4877	1830 x 4877	2400 x 8800	2438 x 11582	--	--	--
12.	Rajhara	1500 x 3000	--	--	--	--	--	--

Various test work have carried out in India to improve the quality of lumps and fines and recover iron values from slime. Air - pulsated Jigs have been tested and it is reported that Al_2O_3 has reduced to 1.5 - 2% from 3.14 - 4% for Noamundi fines at a yield of 72 - 83%. Testing of slime from Noamundi plant in multigravity separator (MGS) showed that a concentrate of 2.78% Al_2O_3 could be produced from a feed of 5.59 % $Al_2 O_3$ at a yield 65% No commercial model of MGS has yet been developed in India. One stage wet high intensity magnetic separation at 1.8 mm gap and field intensity of 1.2 Tesla could produce Iron Ore of 63.1% Fe, 2.56 % $Al_2 O_3$ and 1.47 % SiO_2. This equipment produces good results for worse quality slime also. High gradient magnetic separators also produced good results in beneficiating iron ore slime from Bailadila 14 and Goan Ores. Gravity separation of slime by hydrocycloning and WHIMS are also carried out by prime research organisations in the country. Various techniques and methods generally being used in the Indians iron ore processing are schematically shown in the figures below.

Fig. No. 7.2.1 Dry Screening Process

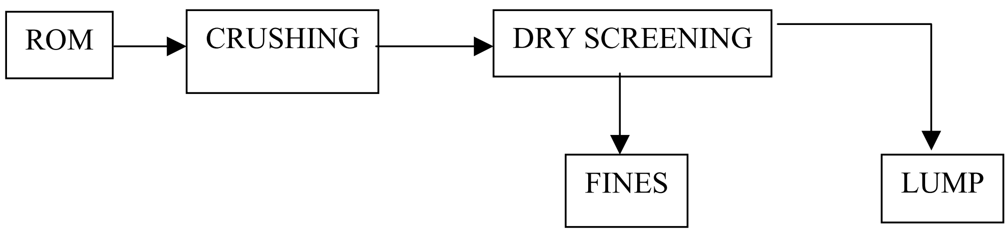


Fig. No. 2.7.2 Wet Screening - Classification

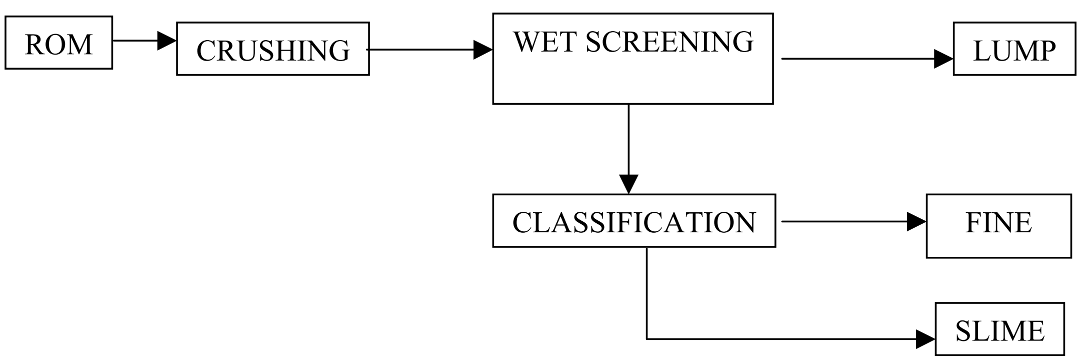


Fig. No. 2.7.3 Scrubbing – Wet screening - Classification

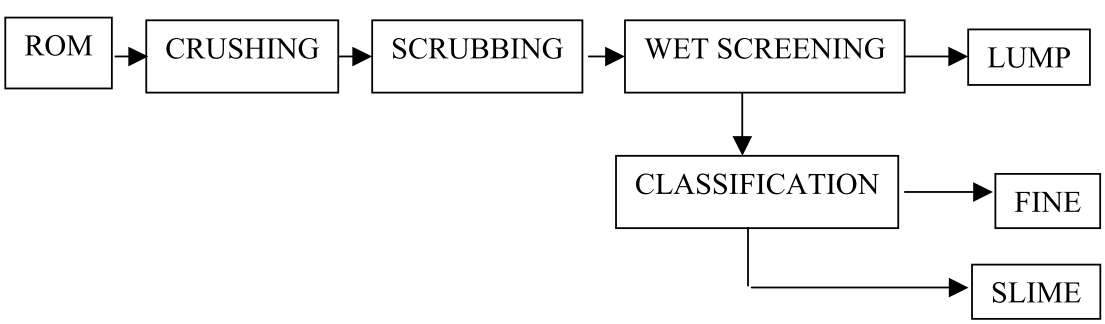
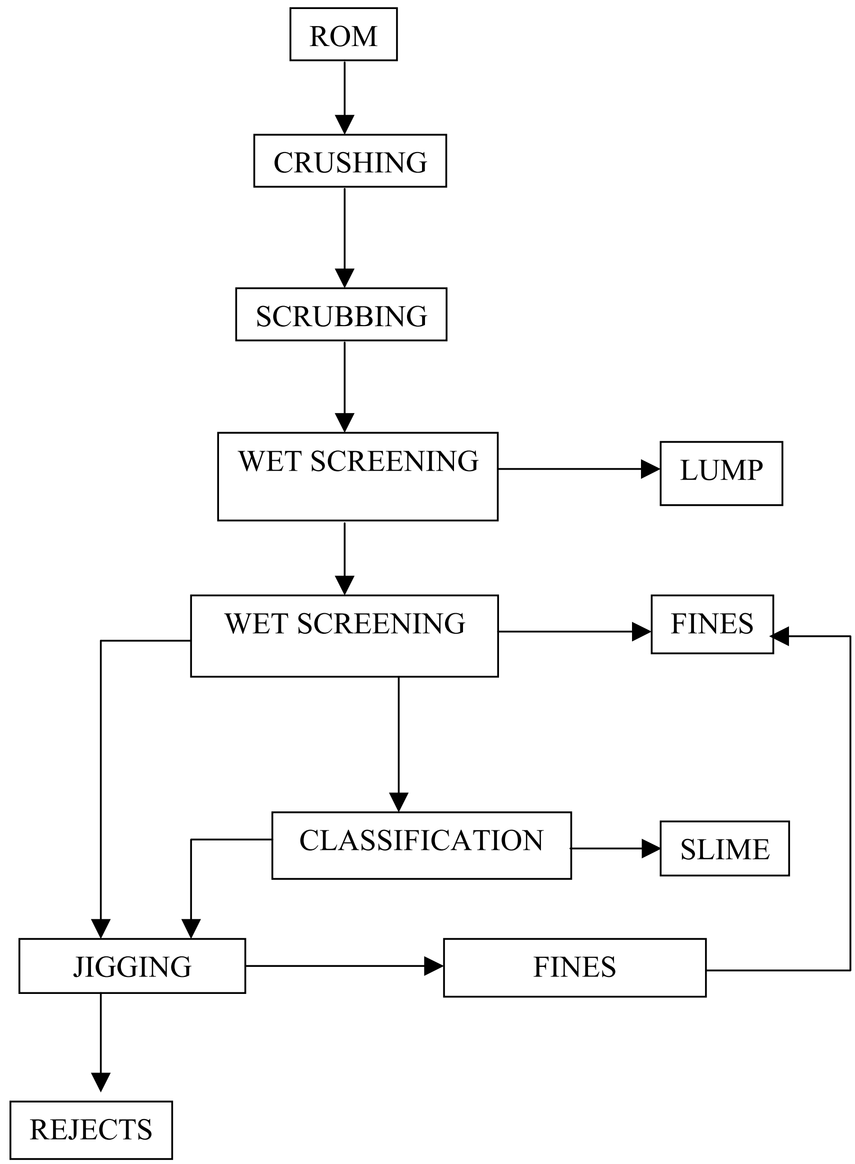


Fig. No. 2.7.4 Washing and Gravity Separation Process (Jigging)



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3.1 WORLD STATISTICS ON IRON ORE MINING

Iron is the fourth most abundant rock-forming element and composes about 5% of the Earth's crust. Astrophysical and seismic evidence indicate that iron is even more abundant in the interior of the Earth and has apparently combined with nickel to make up the bulk of the planet's core. Geologic processes have concentrated a small fraction of the crustal iron into deposits that contain as much as 70% of the element. The principal ore minerals of iron are hematite, magnetite, siderite, and goethite. An estimated 98% of the ore shipped in the world is consumed in the manufacture of iron and steel. The remaining 2% is used in the manufacture of cement, heavy-medium materials, pigments, ballast, agricultural products, or specialty chemicals. As a result, demand for iron ore is tied directly to the production of raw steel and the availability of high-quality ferrous scrap.

3.1.1 World Resource

World resources of Iron Ore are estimated to exceed 800 billion tons of crude ore containing more than 230 billion tonnes of iron. The world mine production, crude ore reserve base and its iron contents are given below:

Table No. 3.1.1.1 World Mine Production, Reserves and Reserve Base

Figures are in Million Tonnes

Country	*Mine Production*					*Crude Ore*		*Iron Content*	
	2002	*2003*	*2004*	*2005*	*2006*	*Reserves*	*Reserve Base*	*Reserves*	*Reserve Base*
China *	231	261	280	420	520	21000	46000	7000	15000
Brazil	225	212	220	292.4	300	23000	61000	16000	41000
Australia	187	187.2	220	261.7	270	15000	40000	8900	25000
India	94	105.5	110	145.5	150	6600	9800	4200	6200
Russia	84	91.7	95	96.8	105	25000	56000	14000	31000
United States	51	46.4	54	54.5	54	6900	15000	2100	4500
Ukraine	59	62.5	66	68.6	73	30000	68000	9000	20000
Canada	31	31	31	28.3	33	1700	3900	1100	2500
South Africa	36	38.1	40	39.5	40	1000	2300	650	1500
Sweden	20	21.5	22	23.3	24	3500	7000	2200	5000
Kazakhstan	15	17	20	16.5	15	8300	19000	3300	7400
Mauritania	10	10	11	10.7	11	700	1500	400	1000
Other countries	75	79.9	31	84.6	95	11000	30000	6200	17000
World Total (rounded)	1,118	1,163.8	1,250	1,542.4	1,690	160000	370000	79000	180000

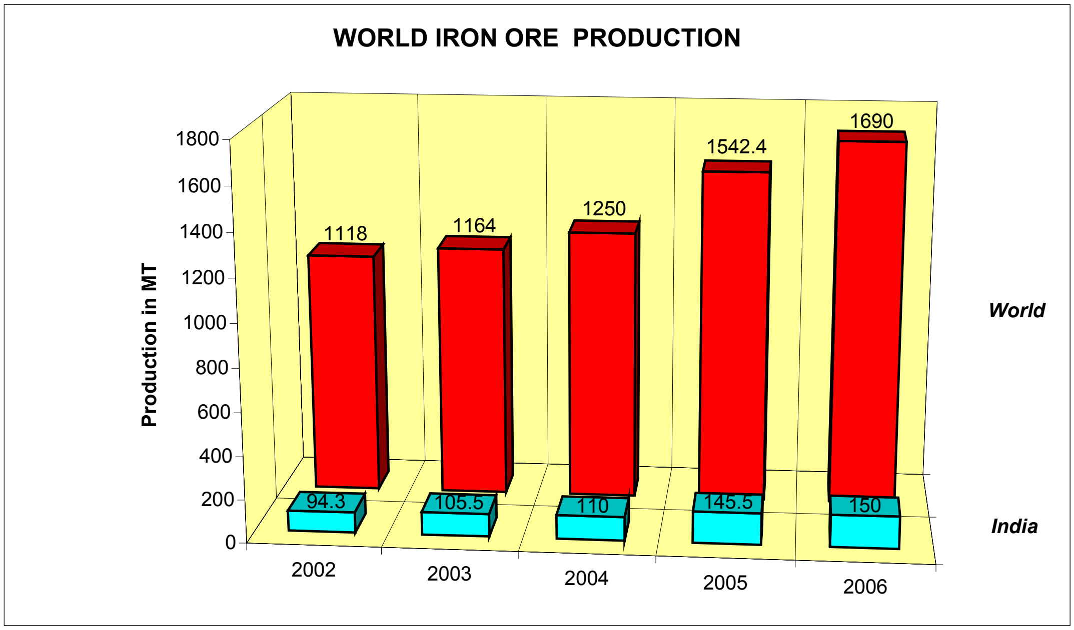
Source: Steel Statistical Yearbook, 2004 & 2005; IISI and U.S. Geological Survey, Mineral Commodity Summaries, January, 2004, 2005, 2006 & 2007, the iron ore market, 2005-07, UNCTAD

N.B.: World iron ore production during the calender year 2006 is 1,690 MT (Source: USGS Jan, 2007).

* China's iron ore production are significantly higher than that of the other countries, because China reports crude ore production only with an average iron content of 33%, where as other countries report production of usable ore.

3.1.2 Production

World iron ore production was 1,690 MT, during 2006, the details of production figures (calender year) of major iron ore producing countries up to 2006 is given in the tables below. The comparative production trends of iron ore in India versus that of the world for last 5 years up to 2006 are shown in the graphs below.



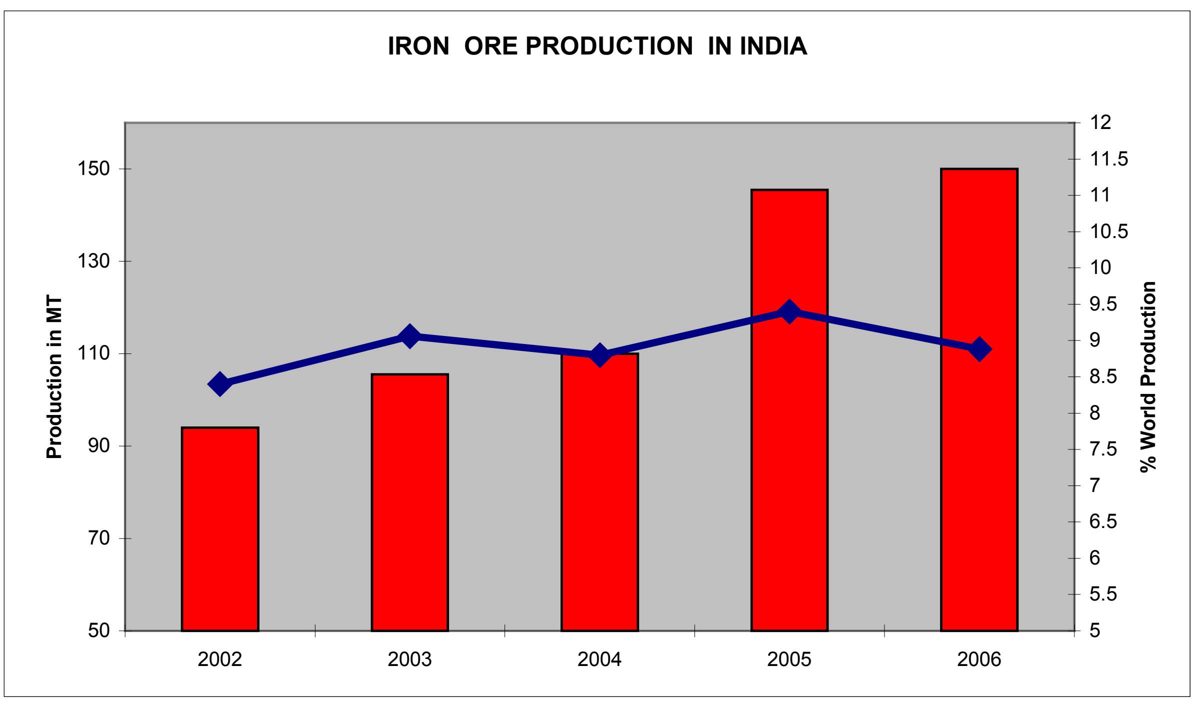


Table No. 3.1.2.1 Major Iron Ore producing Countries of the World

Figures are in Million Tonnes

Country	*Mine Production (calender year)*				
	2002	***2003***	***2004***	***2005***	***2006***
China *	231	261	280	420	520
Brazil	225	212	220	292.4	300
Australia	187	187.2	220	261.7	270
India	94	105.5	110	145.5	150
Russia	84	91.7	95	96.8	105
United States	51	46.4	54	54.5	54
Ukraine	59	62.5	66	68.6	73
Canada	31	31	31	28.3	33
South Africa	36	38.1	40	39.5	40
Sweden	20	21.5	22	23.3	24
Kazakhstan	15	17	20	16.5	15
Mauritania	10	10	11	10.7	11
Other countries	75	79.9	31	84.6	95
World Total (rounded)	1,118	1,163.8	1,250	1542. 4	1,690

Source: Steel Statistical Yearbook, 2004 & 2005 IISI and U.S. Geological Survey, Mineral Commodity Summaries, January, 2004, 2005, 2006 & 2007, the iron ore market, 2005-07, UNCTAD.

N.B.: World iron ore production during the calender year 2006 is 1,690 MT (Source: USGS Jan, 2007).

* China's iron ore production are significantly higher than that of the other countries, because China rports crude ore production only with an average iron content of 33%, where as other countries report production of usable ore.

Although iron ore is being produced from more than 50 countries, the bulk of world production came from just a few countries. The five largest producers, in decreasing order of production of gross weight of ore, were Brazil, China, Australia, India and Russia. These top five countries accounted for about 80% of world production. Brazil was the largest producer of iron ore.

3.1.3 Consumption

The China driven high demand for iron ore continued in the year 2006-07 also. The world production of iron ore during the year 2006 went up to 1690 Mt, and India's contribution therein was 172.296 Mt (P), which accounted for 10.2%. The world-wide trade of iron ore was 759 Mt in 2006, in which India's share in export was 97 Mt (P), about 12.8 %. China has remained the largest iron ore consuming nation since 1992. About 98% of iron ore is used in producing pig iron, which is, therefore, the best indicator of iron ore consumption world-wide. During 2006, Australia was the leading exporter at 248.4 Mt followed by Brazil at 246.6 Mt and India at 97 Mt (Provisional).

China's astonishing growth affected the large global iron ore producers long before it had an impact on U.S. production. The three leading iron ore producing companies i.e. CVRD, Rio Tinto and BHP Billiton, located in Brazil and Australia, continued to invest large sums of money to increase production to satisfy Chinese demand.

In 2006, around 1.5 billion tonnes of iron ore was consumed by the world steel makers of which around 759 Mt of iron ore was shipped around the world. In China alone, consumption of imported iron ore had grown meteorically from 70 Mt in 2000 to 300 Mt in 2006.

3.1.4 Trade & Transportation

Global trade in iron ore was 759 Mt in 2006 as against 719 Mt in 2005, of which a vast majority was seaborne trade (711 Mt). The two major exporters, Australia and Brazil both notched up record exports. Australia exported 248.4 Mt and Brazil exported 246.6 Mt in 2006. The largest importing countries during 2005 were China 275 Mt followed by the EU15 164Mt and Japan 132 Mt. Four company's viz. CVRD, Rio-Tinto, BHP-Billiton and Mitsui accounts for 70 per cent of seaborne iron ore trade globally.

Australian iron ore exports volume is reached 248.4 Mt during 2006 and expected to rise further over the next five years to reach 375 million tonnes in 2011. Brazilian iron ore exports are also expected to continue to grow strongly over the next few years, while Indian iron ore export growth is likely to be contained as strong domestic demand of iron ore.

Consequently, Chinese demand is expected to remain the main driver of increased global demand for iron ore. It is expected that China's imports of iron ore to rise to 448 million tonnes by 2011. Demand for iron ore by China is expected to account for 77 per cent of growth in world imports for iron ore in the period of 2011. China's share of total world imports of iron ore is 300 Mt (39% of Global trade) in 2006 and expected to reach 52 per cent by 2011.

With strong growth in global demand, close proximity to growth markets, and investment in new production and export capacity, Australia is well placed to continue to benefit from strong growth in iron ore exports.

3.1.5 Mergers and Acquisitions

The consolidation of the iron ore industry that began in 2000. The major acquisitions in 2000 were the Rio Tinto hostile takeover of North Ltd. and the CVRD purchases of Mineração Socoimex S.A. (Socoimex), S.A. Mineração Trinidade-Samitri (Samitri), and one-half of the 4 Mt/yr pellet plant in Bahrain.

Due to increased demand of iron ore and the lucrative market has led to expand production capacity of iron ore mines around the world. It is implied that around 240 Mt rise in demand between 2004 and 2010. Rio Tinto is adding 90 Mt by 2010. BHP-Billiton is adding 65-70 Mt by 2010. CVRD is adding 1850 Mt in 2007 from its northern system and 140Mt by 2008 from its southern system and about 15 Mt will be added by South Africa.

The purchase of North gained Rio Tinto 53% of the Robe River iron ore venture, a share of the West Angelas iron ore deposit, both in Western Australia, plus 56% of Iron Ore Company of Canada (IOC), Canada's largest iron ore producer. The CVRD purchase of Socoimex brought CVRD an iron ore mine on the CVRD-owned Victoria Minas railroad. CVRD then purchased Samitri, which owned 51% of Samarco Mineração S.A. (Samarco) with BHP holding the remaining 49%. BHP and CVRD agreed to enter a joint venture to rationalize the Alegria Iron Ore Complex in Brazil. The companies agreed that BHP would acquire a further 1% holding in Samarco to equalize its ownership with CVRD at 50-50. Samitri and Samarco both have iron ore mining and processing facilities in the Alegria Complex in Minas Gerais State.

In April 2001, CVRD purchased Ferteco Mineração (Ferteco) SA, a Brazilian iron ore producer and palletiser, from Thyssen Krupp Stahl AG (TKS), a German steel maker. CVRD, based in Brazil, is the world's largest iron ore producer. CVRD paid TKS $556 million and assumed $131 million in debt for Ferteco, Brazil's third largest iron ore producer. As part of the transaction, CVRD negotiated a long-term iron ore supply contract with TKS, traditionally Ferteco's largest customer, taking 6 Mt of iron ore in 2000. Ferteco, which produced 25 Mt of ore in 2000, owns two iron ore mines, Fábrica and Feijão, and a 4-Mt/yr pellet plant in Minas Gerais State, where CVRD's southern system iron ore mines are also located. Plans for a second pellet plant and a capacity expansion to 30 Mt/yr were well advanced. Ferteco also owns 10.5% of MRS Logistica System, which until the purchase had been the only iron ore carrying railway in Brazil in which CVRD did not have a stake. Ferteco also owns 100% of the iron ore export terminal Guaíba, whose capacity was being expanded to 20 Mt/yr. The company reportedly had 263 Mt of reserves. The acquisition of Ferteco gave CVRD shares in all of Brazil's pellet plants.
Early in the year, BHP and CVRD made offers for a 20% shareholding of Caemi Mineração e Metalurgica SA (Caemi), which was equivalent to 60% of Caemi's voting shares. Caemi was a Brazilian nonoperational holding company based in Rio de Janeiro that owned 84.80% of Mineração Brasileiras Reunidas SA (MBR) and 50% of Quebec Cartier Mining Co. Caemi owned 49% of MBR directly and 35.8% through Empreendimentos Brasileiros de Mineracao SA. BHP made the larger offer ($332 million) but could obtain Caemi only if Mitsui & Co. Ltd. chose not to exercise its right of first refusal.

Mitsui & Co., a Japanese iron ore trader, owned 40% of Caemi and had first-refusal rights to buy Caemi at the price offered by the winning bidder (TEX Report, 2001e). In April, Mitsui announced that the company had decided to purchase the 60% of Caemi that it did not own and sell 50% of Caemi to CVRD (TEX Report, 2001j). The European Commission (EC) antimonopoly regulators then began an investigation to determine whether competition issues existed that could have an adverse effect on European steel producers. A major portion of the iron ore imported into Europe each year comes from Brazil and Canada, and the EC was concerned that, without the divestiture of QCM, the transaction would create or strengthen a dominant position by Caemi in the iron ore market. Brazil's share of Western Europe iron ore imports rose to 45% in 2000 from 35% in 1990, while Canada's share remained steady at slightly more than 10%. To gain acceptance by the EC, Mitsui agreed to sell its 50% stake in QCM that it owned through Caemi. The other 50% of QCM was owned by Dofasco Inc., a Canadian steel maker that decided to sell its stake as well. As agreed, Mitsui bought Caemi and sold 50% of it to CVRD. Although Caemi will be run as a distinct joint venture, its acquisition completes the consolidation of Brazil's iron ore industry.

CVRD also bought the 5% of MBR owned by Bethlehem Steel for $25 million. CVRD paid $4.4 million in cash, and the remainder will be paid in the form of iron ore shipments to Bethlehem over a 9 month period. Caemi held 85% of MBR, and a group of Japanese steel makers and traders owned the remaining 10%.

BHP Limited (BHP), the world's third largest iron ore producer, merged with Billiton PLC on June 29. Billiton, with major holdings in other metals, had not previously produced iron ore. BHP Billiton will be run by a unified board and management team, with headquarters in Melbourne, Australia, and a significant corporate management center in London, United Kingdom (BHP Billiton, 2001§). When Rio Tinto purchased North Ltd., in 2000, it gained a 56.1% interest in IOC. In late 2000, Rio Tinto began an effort to acquire the 18.9% of IOC owned by the Labrador Iron Ore Royalty Income Fund through its Labrador Mining Co. subsidiary. This would bring Rio Tinto's ownership in IOC to 75%. The other 25% is owned by

Mitsubishi Corp. of Japan (Skillings Mining Review, 2001y; Dow Jones Newswires, 2001§). As of April 2001, Rio Tinto had acquired 20.26% of the fund. There had been no change in their holding since then (Rio Tinto, written common, February 5, 2002). There also was acquisition activity in the United States, but in this case it was because financially troubled steel companies wanted to sell their shares in iron-ore-producing companies. Between 1997 and mid-2001, 18 domestic steel mills had filed for bankruptcy (Webb, 2001§). Cliffs, the leading iron ore company in North America, announced that consolidation of the North American iron ore industry would lead to a more cost-efficient industry and that the company intended to lead that consolidation (Metal Bulletin, 2001a).

Just as Bethlehem sold its share of MBR, the financially troubled company intended to sell its 70% share of Hibtac (Bloomquist and Passi, 2001§). Cliffs announced that it would like to buy Hibtac, raising its ownership share to 85% (Bloomquist, 2001a§). Cliffs also announced the planned acquisition of Algoma Steel, Inc.'s 45% interest in the Tilden Mine. The deal would raise Cliffs' ownership in the mine to 85% from 40% (Cleveland-Cliffs, Inc., 2001d§). In the fall 2000, Cliffs purchased the 12.5% share of the Empire Mine that was owned by Wheeling-Pittsburgh Steel Corp., another steel maker that had filed for bankruptcy protection (Singer, 2001§; Cleveland-Cliffs, Inc., oral commun., February 14, 2002). National Steel Pellet was being marketed by National Steel Corp., 100% owner of the facility (Bloomquist, 2001b§).

Minnesota Iron & Steel Co. (MIS) were seeking a $25 million loan guarantee from the State of Minnesota so that the company could acquire additional financing needed to purchase National Steel Pellet (Webster, 2001). MIS, a Minnesota based company, was formed with the idea that it would build & operate the first fully integrated sheet steel minimill in the United States at the former Butler taconite mine near Nashwauk, MN, on the western end of the Mesabi iron range. Acme Steel Inc., Riverdale, IL, operating under bankruptcy protection, announced its intention to sell its 15.1% share of the Wabush Mine in Canada. Acme stopped providing its share of the mine's cash requirements in August, forcing a cutback in production (Sacco, 2001b).

The iron ore industry is consolidating more or less continuously since the 1970s. The three largest companies, CVRD, Rio Tinto and BHP Billiton, together control 35 % of the global market. After a period of limited merger & acquisition activity during 2004-05, possibility of an extended period of high prices together with both mining & steel companies having coffers fully loaded with cash triggered another merger and acquisition wave in 2006, which has continued into 2007. The trend towards creating a network of captive mines, which started in CIS, has strengthened and over a few years Mittal Steel has built a strong holding in the iron ore sector.

3.2 MAJOR IRON ORE PRODUCING COUNTRIES

Among the top producers of iron ores in the world, Brazil, Australia, China, India and CIS (former USSR) are important for their levels of production and Sweden is equally important for underground mining and its automation. In case of former four countries, 80 to 90 percent ores comes from opencast mines whereas in case of latter, actually entire production comes from underground mining. Mass production of iron ore in these countries has resulted in technological development especially in opencast mines, but every country has retained her technology culture in a particular form.

3.2.1 China

Since the formation of People's Republic of China, iron ore mining has been developing from 0.6 million tonnes in 1948 to 520 million tonnes of crude ore (usable ore : 276.4 million tonnes) in the year during 2006. Iron ore production from underground mines has only 10 – 12 percent share. Considerable progress has been made in the field of mining technology and mining machinery. China is presently producing crude steel 420 Mt in the year 2006. This level of crude steel production will demand around 660 Mt of iron ore annually and to cope up with this situation, the country has taken sound steps.

3.2.1.1 Present Status

The methodology of extraction of iron ore being adopted in China is through open cast mining methods by shovel-dumper combination, shovel-dumper conveyor transport / Railway haulage transport. There are also few underground iron ore mines in China. Mining technology and major technical equipment for large opencast mines having production of 10 Mt and above have come up to the level of world's developed countries. The recovery of iron ores from underground mines has come to about 80 percent, but dilution of ore with waste has come down to 15-20 percent, and for the under ground mines, labour productivity has gone close to 2,000 tonnes per man-year.

3.2.1.2 Development of Heavy Duty and High Efficiency Mining Equipment

There are several iron ore mines having annual production over 5 Mt and up to 12 Mt where drilling rigs (rotary) of 310 mm dia bits, 7.6 - 12 m^3 shovels, 108 - 240 tonne electric wheel trucks and other supporting equipment are being used. But 250 mm dia rotary drills or 200 mm dia down the hole drills are common. Likewise 4 - 7.6 m^3 shovels, 20 - 27 tonne trucks and 100 - 150 tonne electric locomotives are also commonly deployed in other opencast mines producing below 5 Mt per year. Since 1980, mechanisations in iron ore mines has been started especially in opencast mines and at the same time foreign equipment imported from other countries are now being manufactured in that country and some 10 types of such equipment are now being manufactured by indigenous companies including a few joint ventures with foreign companies. Considerable improvement has been made in the transfer facilities for ore-waste transportation within the constraint of small floor area, especially in the area of railway - track haulage system. To improve the automation level of truck haulage, computerised despatch system has been introduced. Further, computer control rotary drills, excavators, crushers, and in-pit crushing conveying system are now in practice. Now the semi-mobile crusher-transfer units, high strength steel cord conveyor belts and overburden spreaders with 60 m long boom are being developed. Also in underground mines, computer control system for hydraulic jumbos, remote control LHD units and automatic hauling- hoisting system are being developed.

There are several underground iron ore mines, producing more than 1 Mt per year, of which Jingtieshan mine having annual capacity more than 3 Mt, has deployed two boom hydraulic jumbos, 2-3.8 m^3 electric and diesel LHDs and 20 tonne electric locomotives, and in other mines, single boom pneumatic jumbos, 1-2 m3 electric or diesel LHDs and 8 - 12 tonne electric locomotives are used.

3.2.1.3 Development of High Intensity and Low Loss Mining Technology

For the technology improvement, certain thrust areas have been identified, viz. increase in mining intensity, reduction of ore loss and mineral dilution including increase in extraction rate, especially from underground mines.

In China, earlier mining with gentle slope was in practice. Working slope was 8 - 15^o in general. Therefore, removal of waste was high in pre-production stage and construction period was also high. Thus, to have achieved full production, it used to take a long time. In 1980s, experiment on steep slope mining had been made successfully in certain mines and now slope angles of 20 - 30^o are achieved in working opencast iron ore mines. Stripping ratio during production period was decreased by 20 percent and also has the flexibility as to performing the exposure of final pit walls by 3 - 9 years. In Nanfen Iron Ore Mines, truck haulage has been introduced replacing the inflexible rail haulage which was predominant haulage system in China till the recent past. According to the feasibility report of this mine, which has been implemented now, stripping ratio during production has decreased from 3.4 to 4.8/t. Now, yearly development and stripping during the early period can be reduced by 15 Mt rock. Some 180 Mt rock stripping can be postponed during the full period. So the steep slope mining has brought in increased high wall and its steep angle of slope. There are a few mines having 13 to 15m bench height which are now being increased to 15 - 17 m. Stability of these benches is being maintained by multiple row millisecond delay blasting technique. Such mining intensity and positive effects on economy of opencast iron ore mining have been experienced in China in recent years.

3.2.1.4 In-Pit/Crushing/Conveying System

Contrary to Indian practice, in China, both rail haulage and truck transportation are employed and the former accounts for 53 percent of total iron ores handled. Some opencast mines have turned deep (more than 100m) and more than ten such mines are working at present. Under these circumstances, only rail haulage cannot handle such transportation of ores and this rail transportation necessitated increased traction force and raised climbable grade (4 percent). So, combined haulage system, such as truck-rail-road and truck-belt conveyor is now being deployed. This practice has given full advantage of both flexibility of truck haulage and large haulage capacity with steep grade negotiation of belt conveyors which relatively cost less. Till recently, truck railway and truck, and electric shovels were being used for reloading. But this mode was proved to be less effective and costly. For this purpose, a fixed transfer station having facility of apron feeder has now been used in some opencast mines and this practice is giving better results. As a whole, this combined system has brought in considerable cost reduction, improved labour productivity and decrease in truck haulage. Further, a rail road and conveyor system for disposal of waste was built in Donganshan open pit. This conveyor system is 3 km long with 1.2 m wide belt having disposal capacity of 6 Mt per year and height of disposed waste is 90 - 130 m. Another medium size mine has 2.5 km long conveyor having disposal capacity of 5 Mt per year. In Daugshan open-pit, two conveyor belt systems for ore haulage and waste disposal, respectively, are installed in inclined shaft having total belt length of 2.8 km. Although a few problems exist in belt conveyor haulage system in China, advantages outweigh those problems. The conveyor belt systems in opencast iron ore mines are becoming popular especially in large open pits of more than 100 m deep.

3.2.1.5 Blasting Technology

Since 1970, considerable progress has been made in blasting technique of metal mines in China. Along with the advent of big mining machinery, large area multiple row millisecond blasting technique has been developed. Site specific blasting practices like pre-splitting near the pit slope walls, buffer blasting and smooth blasting for underground are also developed. In big mines, 0.5 - 0.7 Mt of ore/waste are now being blasted in a single shot. Some 200 - 400 boreholes in 10 rows are now commonly blasted in a single fire involving 100 - 200 tonnes of explosives and good powder factors of 5-8 tonnes per kg. have also been achieved. Boulder yield and formation of toe were also remarkably reduced. Shovel efficiency was increased by 30 percent due to better fragmentation of rock/ore.

To cope with the need of higher production of iron ore, blasting materials are also being developed/manufactured at the same pace. Nonel electric priming tube, detonators of non-priming charge, high precision millisecond relays and electric delay detonators, granulated ANFO, new TNT, powder rock explosives, emulsion explosives heavy ANFO and high power liquid explosive have been developed and are being effectively used in iron ore mines. Detonators of non priming charges and emulsion explosive have come up to the level of world class. As the quantum of rock/minerals blasted in a single shot has increased considerably, controlled blasting technique has also come to play an important role in the iron mining for which enough research work is being carried out, especially in the area of optimum blasting principal for reducing boulders and formation of toe, reduction of shock waves, flying rocks, noise dust, etc. and for increasing the utilisation factor of explosive energy.

3.2.1.6 Pit slope stability

There are several opencast iron ore mines which are being mined at deeper horizons (200 - 300 m vertical depth) and some opencast mines have proposals for working below 500m depth. Therefore, slope stability studies have assumed greater significance both for technical and economic reasons. The pit slope angles of metal mines in China is 40^{o} in general whereas in advanced countries, it is 45^{o} which is being followed by this country now and for which continuous monitoring technique and pit slope maintenance and management are being practiced including effective drainage system.

To improve mining methods of underground mines and to reduce ore loss and mineral dilution, several steps have been taken. Though share of the iron ore production from underground mines is only 10 percent, due to convenient locational advantage and high grade ore compared to that of opencast mines, this segment of mines is also important.

In underground iron ore mines in China, predominantly non-pillar sub-level caving method is in practice and its share is about 70 percent of the total production from underground mines. This method results in high ore loss and mineral dilution. In large mines, percentage of dilution was as high as 20 percent but extraction rate was hardly 70 percent. Labour productivity was hardly 750 tonnes per man-year which is poor compared to that in advanced countries. Main reasons are complicated ore deposits and improper selection of mining methods. Due to these reasons, intensive researches are being carried out since 1986 as to how the method of mining can be improved, especially for existing mines having complicated, broken and soft ore. In the light of geological conditions of these mines, different mining methods have been tested, stope and blasting parameters have been improved, drive support reinforced, which finally resulted in reduction in mineral loss and its dilution but higher extraction. High efficiency mining methods are further experimented mainly on decreasing amount of shaft sinking and driving of headings, lowering development ratio, speeding up deepening and reconstruction as well as employing deep hole drilling and large capacity LHDs. All these concerted efforts are now going to give labour productivity close to 2,000 tonnes per man-year.

Further, in the field of ground control, significant achievements have been made including dust treatment, blasting safety, control of harmful gases and noise. All these research achievements are now in practice in underground iron ore mines in China.

3.2.2 The CIS (Former USSR)

3.2.2.1 General Information

The former USSR (now CIS) produced 193 Mt of Iron ore during 2006. Out of the total production of iron ores, about 85 % comes from surface mining and rest from underground mines. The Independent States like Ukraine and Kazakhstan are the main centres of iron ore production. Most of the iron ore deposits are inclined or steep-dipping ones. Some mines have reached the depth beyond 350m. Of the total production of iron ores from opencast mines, about 60 percent is from mines having 250 - 300 m depth.

The commonwealth of Independent States (CIS) is technologically one of the world leaders, especially on the face of deterioration of mining and geological conditions like.

- Increase of pit depth (maximum vertical depth at some large open-pits reaching up to 360 m.)
- Decrease of ore content with pit depth.
- Increase in stripping ratio
- Increase in lift height and transportation distance including rehandling and re-transportation.

Iron ore mines in the CIS are characterised by high concentration of production. The share of production from large mines of capacity over 10 Mt per year is 85 percent at present. In the last decade, average depth of opencast mines was 150 - 200 m, but in the current decade, it is about 300 m, and volume of hard rock mass removed has grown from 66 to 75 percent. The average rock hardness and its removal have also increased. But the raw iron ore mining decreased by 2 percent as the working condition of mining and transport equipment has been deteriorated along with increase in overburden removal and thus the mining cost. An increase in mining depth by 100m (from 200 to 300 m) has led to increment of 25 - 30 percent cost per tonne.

It is projected that most of the above mentioned trends and characteristics of opencast mining evolution in the CIS will be maintained. However, due to recent political and economic reasons, production of raw ores and removal of rock mass have somewhat fallen, but it is stable.

Though most of mining operations are confined to deep seated deposits, productivity and cost effectiveness have increase. Also, detrimental mining impact on the environment has decreased. To achieve these goals, certain actual scientific and technical problems associated with mining are being faced and these are:

- Development of progressive ecologically harmless waste-free and resource - saving mining methods for complicated mining conditions.
- Securing open-pit wall stability up to 500 - 700 m depth.
- Development and deployment of new fleet of high performance mining and transport equipment of higher capacities.
- Electrification of railway transport
- Development and use of new slurry explosives and other blasting agents.
- Maintenance of normal hygiene and sanitary conditions, especially at deep opencast mines.

To exploit iron ore effectively and to enhance the production capacity in deep deposits, a process of dividing the working horizons in stages and increasing high wall slope angle in stripping areas, using temporary rock pillars are now in practice. Another step has been taken up by the way of increasing heights of working benches up to 20 - 30 m. This technology has been implemented in some important deep pits and is found to be effective. Another major trend in increasing mining intensification and efficiency is the changing over to cyclical - and - continuous method (CCW) in case of deep open-pits, i.e. from rigid railway transportation to track railway and truck - conveyor systems. Due to introduction of these systems, some 15 mining complexes, with annual capacity from 10-22 Mt are now benefited and these mines are now handling up to 170 to 180 Mt of rock mass per year. Till now over 1,200 Mt of rock mass and 900 Mt of iron ores were extracted by using this method. In pit primary ore crushing and its transportation by off-highway trucks conveyors are now very common in many mines. Jaco crushers and cone crushers are used in pits and conveyor system feeds ore at a secondary crushing and preparation plant for further treatment while rock is transferred into railway transport units with the purpose of delivering it to outside dump sites. All these methods together have resulted in cutting 20 - 30 percent operating cost for rock mass transportation from deep pits, decrease in truck number, increase in labour productivity by a factor of 1.2 - 1.5 reduction in ore mining cost by 10 - 15 percent and improved ecological conditions.

In the CIS, portable crushing and transferring plants with up to 2,000 tonnes per hour capacity as well as high angle belt conveyors are now available. The uses of portable units have provided reduced construction activities and stone drivage. The share of these crushing and transferring points (CTP) in removal ores from mines is 50 - 60 percent. This has further helped reduction in truck haulage. For implementation of this system, the erection of the expensive stationary in pit CTPs has been eliminated in certain cases, resulting in more effective operation of CCW - based complexes at deep opencast mines.

The concept of in pit overburden dumping is also being introduced in certain cases, it has provided not only a compensation of negative consequences of mining, but also it offers some improved efficiency which ultimately helps cut labour and material costs and reduces detrimental impact on the environment.

With the increase in depth of opencast mines, slope stability problems increase especially maintaining pit walls and bench stability in the final configuration when slope angle increases. In this direction, enough attention is being paid and for this purpose, more reliable data on geology and related engineering are being collected at the time of exploration and exploitation as well. In some mines, pit wall slope angles have been realised up 2-4^o and at one mine, final pit wall slope could be increased by 5^o, which resulted in decrease in the overburden removal by 96 million cubic metres.

3.2.2.2 Mining Machinery

To meet the requirement for huge production of iron ores and removal of waste rock in much higher quantity from deep opencast mines, a compatible fleet of equipment has been developed and now is being used. Roller cone drill rig of bit dia 320 mm has been developed and deployed for drilling at flexible angles of 45 - 75^o for smooth blasting. On the basis of satisfactory results from rigs, higher capacity rig of bit dia 400 mm has been developed. Their productivity exceeds that of the existing rigs by a factor of 1.5 due to automatic control of drilling. Another module of roller cone drilling rig has been developed and preliminary trial results showed increased drilling rate by factor of 2.5 - 3 and reduction in power consumption by factor of 1.5 - 2.

The most vital activity in opencast mines is the extraction and loading operations which need, for iron ore mining, shovels. Different types of shovels manufactured in the CIS are in use including hydraulic shovels. These are the world class products so far s operating cost and service life are concerned. In the CIS, loading equipment, namely 'Uralmash', Izhorsky Zarod" and "Krasmash" are specialised excavators for ferrous metal opencast mines. Bucket capacity of these shovels is 12 to 16 cu m and boom/arms can be extended for heavy and tough working condition.

As the transportation expenses at some mines is 60 percent of total mining cost, one of the thrust area of equipment development goes to this field. From the experience gained over the years, it is concluded that effective transport system is the judicious combination of railway transport, trucks haulage and conveying.

In the CIS opencast mines, certain characterisations have been attained and these are large - scale production, favourable ecological condition and relatively low transportation cost. The main trends in the opencast mines are –

- Improvement of facilities already available as well as development of new ones, such as locomotives and self - cleaning cars which will provide high technical levels and efficiency of mining operations;
- Technical requirements of transport systems for deep opencast mines.
- Using railway transport at deep levels of existing open-pits (up to 350 - 450 m depth) by introduction of heavy gradients and in pit tunnels. Locomotives of 450 tonnes are required to be manufactured in that group of countries as their application in deep opencast mines will result in increasing the rolling stock productivity by 20-23 percent, improving a conveying capacity of transport inclines by 20-25 percent and decreasing power consumption by 5-7 percent. Further, in the CIS carriage, wagon factories are going to manufacture the reinforced self-closing cars with capacity in the range of 105 - 200 tonnes.

In Russia and Ukraine, where diesel locomotives were traditionally in use, now electric locomotives of higher traction force are replacing them. This substitution results in increase of the railway transport efficiency, expanded field of application, reduced fuel consumption, and improvement of ecological conditions at opencast mines. Construction of in-pit tunnels and inclines has augmented the application of electric locomotives further. Locomotives are being used in inclines having grade up to 50 - 60^{o}. A tunnel in a particular mine, allowed the railway transport up to 280 m depth to have reached to the pit bottom. Further, off highway trucks of 75 - 110 tonne capacity are being commonly used in deep pits, but 120 - 180 tonne capacity trucks are also now deployed. In the CIS, now multi - drive conveyors are also developed and are in use. The main advantage of this system is that rock mass can be transported from deep levels to surface without rehandling. Further, high inclination conveyors upto 45^{o} are developed, which can handle/transport up to 2,000cu.m/hr. In the CIS, high capacity crushers (over 2000 cu.m/hr) are being manufactured at present.

Environment

Environmental problems associated with the ultra-large mines are stupendous as vast expanse of land is destroyed, occupied or disturbed by mining and related activities, especially lands are disturbed by overburden/tailings dam, and ambient air and groundwater are polluted. To mitigate these problems to some extent, more than 3,000 ha disturbed land is being withdrawn from mining operation for rehabilitation purpose. It is heartening to note that more than the half of this land is being made suitable for agricultural use. Further, to reduce the negative consequences, some specialised research institutes have been carrying out studies for further improvement of environmental degradation caused by mining operations. Air normalisation in deep opencast mines is the single most environmental hazard. Due to lack of natural ventilation, dust content at work place sometimes goes as high as 28 mg/cu m and carbonic oxide and nitric oxide go up to 14 mg/cu m and 5.8 mg/cu m, respectively. This unnatural ambient air at deep pits not only takes 10 - 15 percent of working time, but also leads to equipment breakdown. These problems are now being solved by taking following measures:

- Effective suppression of dust at their source;
- Use of air-conditioning system in cabins of mining equipments
- Introduction of rational means of artificial ventilation for 'stagnation zones'

In future, the CIS will be planning for returning alienable lands which will be rehabilitated after mining operations to the permanent land users at the rate of 900 -1000 ha per year.

3.2.3 Sweden

Among all the leading countries producing iron ore throughout the globe, opencast mines are the major sources of minerals (80-90 percent), but Sweden is the only exceptional country where practically the entire production comes from underground mines and that too from two mines only- Kiruna Mine of northern Sweden and Malamberget near Kiruna. During 2005, Sweden has produced 24 Mt of iron ore by underground method of mining.

3.2.3.1 The Kiruna Mine

The Kirunavaara (Swedish language) ore deposit has north-south and it dips to the east at 60^{o}. The extent of the deposit along strike is 4 km and average thickness about 80m. The ore body has been explored to the depth of 2 km.

The predominant method of mining is sublevel caving and about 25 percent of total ore has been extracted by this method. Of the total yearly production by sublevel, caving yields 12 Mt, sublevel stopping 4 Mt and the remaining comes from development work.
The sublevel interval of 27 m has been introduced in 1990 and in 1993 about 70 percent of the ore was produced by this method. Starter raise of 760 mm dia is normally drilled on the hang wall side for the purpose of stoping with the help of LKAB made large dia drill or an Alimak driven raise. The plane of the ring drill is maintained at an angle of 80o with the horizontal and the ring consists of 9 - 10 holes. Production drilling is carried out by five rigs capable of drilling 115 mm dia holes. Four of these have top hammer drills and fifth has an in the hole hammer. A fleet of 18 electric toro LHDs, each of 15 tonnes capacity has been deployed for loading ore which is discharged to 44 ore passes, leading to the current main haulage level at 775 m horizon (levels at Kiruna are counted downwards with reference to the top of the original mountain which had been mined out long back). The mine used to operate on two shifts, but seven days a week with blasting in the night shift. Recently, 3 shift working has been introduced. Now 100 percent blast holes in development tunnels are loaded with emulsion explosives. For the purpose of reinforcement of roofs, three bolting jumbos are deployed and some 55,000 rock bolts are being installed every year, but shotcrecting is carried out by a subsidiary company of M/s LKAB, the owner of the Kiruna Mine.

Ore is removed by remote - controlled trains to a discharge station on the main haulage level, where the bottom discharge rail cars are emptied and ores are delivered to a crushing station. The crushed ore passes to ore pockets from which skip in seven (out of eight) shafts carry the same to the surface. Selective mining is practiced and blending is done on the main haulage.

So far, 820 Mt ore has been mined and only 100 - 110 Mt of mineable reserves remains above the current haulage level (775 m). So, it has been planned (and partially executed) to develop the ore-body between 775 m and 1045 m horizon, called " the KVJ 2000 Development" which will add some 330 Mt reserves for sustaining production for another 20-25 years at the present level of production.

The deposit plunges to the north and its northern part in depth has boundary under the lake luorsajarvi. To exploit the deposit in a better way, a proposed dam may be constructed beside the lakeside train terminal for the purpose of draining part of the lake. The proposal could make available extra 25 Mt ore.

As mentioned above, 3-shift production system has been introduced with phased blasting which has been made possible by the introduction of new network of ventilation which divides the mines into eight sections. Some, 16 new ventilation raises of 3 m dia having total length of 16,000 m are being raise-bored into the footwall, to ensure that they are not affected by rock movement as the caving practice has already gone to greater depths. These raises are arranged in eight pairs out of which four pairs are angled in such a fashion that all of them connect at surface with just four fan house buildings.

3.2.4 Australia

3.2.4.1 Overview of Iron Ore Mining in Australia

Iron ore is Australia's fourth largest minerals earner, has produced 270 Mt in 2006, almost 16% of the world's production. About 92% of its annual production is exported to integrated steel markets in Asia. In order to cater for expected demand from Asian markets, iron ore exported in the year 2006 was 248.4 Mt out of its production of 270 Mt The Hamersley Range in the Pilbara region of the northwest Australia is host to 98% of Australia's iron ore mines, with minor production from Tasmania, New South Wales, Queensland and South Australia. The big two producers in the Pilbara are BHP Billiton and Rio Tinto. Australia's iron ore resources have been estimated at 32 billion tons.

BHP Billiton's wholly owned subsidiary, BHP Iron Ore Pty Ltd. is Australia's largest iron ore producer, with total reserves estimated at 3,200 Mt. BHP operates three primary iron ore operations that produce in the region of 70 Mt of ore per year, most being destined for steel makers in Japan, South Korea, China, Taiwan and Europe.

The Mount Whaleback ore body at Mount Newman mine alone contains 750 Mt of ore grading at 64.7% of which 33 Mt of high-grade iron is produced per year. Other mines proximal to Mount Newman are the Ore-bodies 29, 23 and 25. BHP Billiton has other mines at Goldsworthy, Yandi and Jimbledar. Goldsworthy comprises the Yarrie and Nimingarra ore bodies that have an annual capacity of 5.6 Mt. The Yandi Mine produces approximately 23 Mt per year and is also located close to the MAC (Mining Area C) that has resources estimated at 800Mt of high grade ore ranging from 60 - 64% iron. Jimbledar is located 40km east of Mt Newman and is wholly owned by BHP Billiton. The decision to develop the MAC has been given the go ahead, following negotiations with local Aboriginal groups. The mine has already started production since 2003 reaching capacity of 15 Mt/year. BHP Billiton is the world's second largest iron ore exporter, after Brazil's CVRD. BHP Billiton also has operations in South Australia, where hematite ore is mined at Iron Duke and Iron Knob in the Middle-back Ranges by BHP Steel and used in iron and steel making at Whyalla.

The Mining Area C development has the potential to increase iron ore production by up to 15 million tonnes per annum (Mtpa) by 2011. Rio Tinto's Hamersley Iron produced a record 70 Mt of iron ore in 2001 from its five wholly owned mining operations in the Pilbara region, making it Australia's second largest iron ore producer. The Yandicoogina mine has ore reserves of 310 Mt grading at 58.5% iron and has a rated capacity of producing 15Mt/year. Other mining operations are Mount Tom Price, Paraburdoo, Brockman and Marandoo, all situated in the Hamersley Ranges, Pilbara region. All of Rio Tinto's production is railed to the port of Dampier on the North West coast of Australia. Rio Tinto is developing its sixth mine, Nammuldi, located next to the Brockman mine, which it is also extending. Through Hamersley, Rio Tinto also owns 53% of Robe River, Australia's third largest producer. Robe has resources between three and four billion tonnes containing greater than 57% iron - enough to last 100 years at current production levels. The major deposit currently being mined is Mesa J near Pannawonica. Robe River produced 27 Mt iron ore from its mines at Pannawonica. Production is shipped from the port facility at Cape Lambert. Robe River's West Angelas deposit is remote from its Pannawonica operations and about halfway between Newman and Paraburdoo. The nearest port facilities to West Angelas at Cape Lambert are 400km away. West Angelas has a resource of at least 1 billion tonnes, including a proven and probable reserve of over 440 Mt grading at 62% iron. Rio Tinto and Robe's partners have finally reached an agreement of the development of a rail link to West Angelas that is anticipated to have development costs in the region of A$ 800 million.

South Africa's Kumba Resources are evaluating one of the last major deposits in Australia, Hope Downs. A feasibility study is underway at Hope Downs that will have to include a 360 km railway link from the project to the nearest port facilities. Over 50% of planned capital expenditure for the development of this project hinges on developing the infrastructure to service the mine. The deposit has a recoverable resource of 442 Mt grading at 61.7% iron. Production has already been started at 6 Mt /year and is planned to be increased to 25 Mt per year in 2008 with an estimated life of mine of around 30 years.

Ivanhoe Mines have reopened the Savage River mine in north-western Tasmania. The mine has proven and probable reserves of 105 Mt which will sustain operations for the next 25 years. Ivanhoe intends selling 50% of its production to BHP, with the remainder sold to steel companies in South Korea and China. ABM and Ivanhoe Mines have merged their operations. Ivanhoe are to acquire the Long Plains magnetite deposit from Pasminco. Long Plains is located just south of the Savage River operation and has resources estimated at containing 30 Mt of magnetite.

Portman Limited is currently expanding its operation at its Koolyanobbing Iron Ore Project, which has indicated and inferred resources totalling over 95 Mt grading at an average of over 63% iron (using a cut off grade of 58% iron).

3.2.4.2 Geological background

The Proterozoic occurrences of iron ore in Australia include the Middle-back Range in South Australia, Yampi Sound in north-west WA and the major Hamersley Iron Province in the Pilbara Region of WA. This is an 80,000 km^2 sedimentary basin, which contains in its structure two Banded Iron Formations, the Brockman Iron Formation (670 m thick) and the Marra Mamba Formation (180 m thick) which are host to economic deposits of iron ore. These occurrences have been succinctly described as strata bound sediment hosted deposits.

Open cut iron ore mining at Koolanooka, (courtesy Western Mining Corporation)

The Province also contains a number of Tertiary Age pisolitic limonite deposits of considerable significance. They have resulted from deposition in ancient drainage channels of weathering products of the outcropping primary ore.

More than 33 billion tonnes of iron ore with a grade in excess of 55 per cent Fe have been proven in the Pilbara region comprised mostly of hematite and hematite geothite ores but with some major occurrences of limonite

3.2.4.3 Operations

The major deposits currently developed and the installed production capacities of the respective operations include:

- Mt Tom Price and Paraburdoo
  -Hamersley Iron (46 Mt/a)
- Mt Whaleback
  -Mt Newman Mining (40 Mt/a)
- Deepdale Limonite deposits
  -Robe River Mining (20 Mt/a)
- Shay Gap/Sunrise Hill area
  -Goldsworthy Mining Associates (8 Mt/a)

Prospective operations include the Yandicoogina (CRA) and Marillina Creek (BHP) limonite deposits and McCamey's Monster (Hancock/BHP Joint Venture).

In the Brockman deposits large scale conventional open pit mining operations precede three stages of crushing and screening to produce two products, lump (-30+6 mm) and fines (-6 mm). Limonite is sold as an all fines product.

Due to the relatively heterogeneous nature of the ore bodies sophisticated selective mining practices and quality control procedures have been developed at each mine site to optimize mining efficiency and to ensure product quality specifications are achieved.

At the time of the commencement of exports (mid 1960s) the market demand was predominantly for lump ore which accounted for approximately 50 percent of output. To minimize excess fines stocks, Hamersley built a plant to convert the fines to a prepared blast furnace feed pellets. A second plant was commissioned by Cliffs Robe River in 1972 to convert portion of its limonite fines into pellets -a first for the industry. However, the oil price rises of the 1970s and the rapidly advancing technology of Japanese iron makers established sinter as the preferred blast furnace burden material with the resultant drastic reduction in the use of pellets as a raw material. Pellets are no longer produced in the Pilbara and the idle plants stand as a grim reminder of the effect of changing technology in the steel industry.

3.2.4.4 Technology trends

The general philosophy adopted by all levels of management is to do things 'smarter' and to maintain a position 'at the cutting edge of technology'.

Technology advances in the mining arena have focussed on the development of large units of plant and equipment (e.g. shovels, trucks, drills, etc.) and the industry has been quick to introduce new models and innovations. In the areas of fixed plant, transportation and port operations the emphasis has been on improvements in such things as

- wear resistant materials
- maintenance planning and procedures
- process control through use of computers
- quality control techniques
- improved communications
- automation and so on

During the short history of the Pilbara iron ore industry there have been numerous examples of major technological innovations on the part of the industry itself and of companies working in conjunction with equipment manufacturers to adapt the results of advanced and developing technology to best suit local conditions.

Mount Tom Price open cut iron ore mining, (courtesy Hamersley Mining)

Two somewhat diverse examples are found in the areas of communications and in haul truck technology. In the early 1960s exploration teams in the Hamersley Ranges depended upon pedal radio via the Royal Flying Doctor network for communications. At the start of construction in 1965 HF radio was used between Dampier, Mount Tom Price and Perth with a full time operator required at each location. Later automatic PABX systems provided a company network with restricted and oft times difficult access via two VHF radio links to the public telephone network. This was superseded by the extension to Dampier of the Perth/Carnarvon co-axial cable which in addition to improved telex and telephone services brought national TV to the town. A tropospheric scatter system connected Mount Tom Price (and Paraburdoo) to the national network. Later with the advent of microwave technology communications between the mine sites and the coast were further upgraded.

With the increasing demand for data transmission between all sites and head office, PABX obsolescence and improving technology, the latest in communications systems viz. digital SPC (stored program controlled) PABX units which can switch both voice and data were installed in the Hamersley operation in 1987. Together with Telecom's expanding national digital network the Hamersley facility will provide one of the largest and most modern company systems capable of providing efficient and flexible communications into the foreseeable future.

The example of changes in haul truck technology is no less impressive. The major haul units at the Mount Tom Price mine in 1965 were the largest and latest 'state of the art' 100 short ton articulated 3-axle, ten wheeled mechanical drive 700 HP (520 kW) diesel engine trucks - behemoths of the day! At present 240 tonne, 2 axle, six wheeled 2400HP diesel electric (Electric wheel) tracks with air conditioned sound proof operator’s cabin are in use. The use of 'electric wheel' transmission, increased capacity dynamic braking systems, solid state circuitry and an on-board computer to monitor loads, log general performance factors and provide maintenance diagnostic information, have all resulted from improved and new technology and result in easier maintenance, more efficient and better controlled, lower cost operations. The latest trucks in the Hamersley fleet are effectively custom made for the local conditions and applications.

Similar developments are evident in other major pit equipment including drills (i.e. change from 230 mm down hole hammer drills in the 1960s to 380 mm rotary percussive automatic drills at present with sound proof temperature controlled operator’s cabin and wet drilling arrangements are in use. 7.6 – 20m^3 shovels (diesel electric in 1966 to all electric modern units at present), high capacity front end loaders, graders, bulldozers are already in use in Australia. Noteworthy technologies are the Global Positioning System (GPS) monitoring for HEMM used in high precision, their applications on a board a variety of mining machines, blast hole drills, shovels, scrappers and dozers.

To cope with the need of higher production of iron ore, blasting materials are also being developed / manufactured at the same pace. Use of slurry, emulsions, ANFO and HANFO in bulk explosive systems has been well established with considerable benefit to the iron ore mining industries in Australia.

In the field of blasting accessories, the introduction and adoption of “non-electric delay initiation system” contributed significantly to the improvement in blasting results and reduction levels of blast induced ground vibrations and air blast. Electronic delay detonators (Prototypes of which are under trial in Australia) are considered to be the next stage of evolution due to accurate timing, it has the potential to provide better noise and vibration control, increased selectivity, improved fragmentation and reduced blast damage, less fly rock and thus makes the blasting environment friendly.

The use of high speed cameras to photograph blasting operations to enable the analysis of blast dynamics has led to more efficient use of explosives, drill hole spacings and better rock fragmentation. Modern explosive emulsions enhance the effects of the simple ANFO (ammonium nitrate/fuel oil) mixtures.
Customized conveyor belting reflects the manufacturer's and the operator's recognition of the specific requirements of conveying abrasive iron ore over long distances in the plus 45° hot dry conditions of the Pilbara summers.

Use of X-ray fluorescence spectrometry for analysis of iron and other constituents of drill hole samples, plant products, etc. has replaced the traditional wet chemical methods in many applications. Spectrographic oil analysis and other condition monitoring techniques have assisted in minimizing loss of equipment availability due to premature failures.

On-stream analysis of iron and alumina by measuring the back scatter gamma radiation of irradiated ore has been developed in conjunction with CSIRO and is in the prototype testing stage on product conveyors in the Hamersley system. Integrated with weightometers, its potential lies in operational product quality control during blending and ship loading functions replacing the more time consuming sampling, sample preparation and assaying. Similar application for down hole *in situ* analysis is under investigation.

Some of the more spectacular use and development of modern technology has occurred in the iron ore railway operations. These systems operate the largest and heaviest trains in the world utilizing head-end power only. They have increased in Hamersley from combinations of one head-end locomotive and 76 wagons with 9000 t gross load to the current configuration of three head-end locomotives and 200 wagons with a gross of 25,000 t. This improvement has resulted in part from the local development of a train simulator which enables prediction of the forces generated in the long and heavy trains, knowledge of which enables the formulation of appropriate operational driving strategies. These are further refined by analysing the drivers' actual control actions recorded on locomotive data loggers.

Asymmetrical rail profile grinding to ensure better wheel and rail interface, developed in conjunction with Mt Newman Mining, is now almost standard practice world-wide. Another development with CSIRO is a semi-continuous rail profile measuring device. The equipment mounted in a rail car measured rail profiles at 5 m intervals along the track whilst moving at speeds of up to 80 km/hr. Locally developed computer programs produce 'real-time' results.
The days are now long past when large rail gangs are required to work manually in almost intolerable conditions to replace sleepers. In a major sleeper replacement program in which modern technology concrete sleepers are substituted for the original wooden ones, Hamersley's rail maintenance contractor employs an automatic sleeper laying and track relining machine which automatically, whilst travelling along the line,

- spreads and lifts the rails
- removes the old sleeper
- positions a concrete sleeper
- replaces and fixes the rail and
- tamps the ballast

New and old sleepers are stored on a trailing section of the machine. Other innovations in the rail system include

- 'hot-box' detectors to identify high bearing temperatures on ore wagons 'on the move'
- track side detectors to locate dragging equipment such as broken axles, air hoses, etc.
- track research wagon to monitor track conditions
- stream flow level detectors which warn of high-water levels in culverts via the CTC system.

In the exploration field conventional methods are now being supplemented by the latest geophysical methods (gravity, aeromagnetic, sedimentology, etc.) to select hidden or 'blind' drilling targets. Use of Landsat imagery has greatly facilitated exploration planning, map making and geological interpretation.

A significant technological development of the late 1970s was the application in the Pilbara of advanced process technology (principally developed in the diamond mines of South Africa) to the upgrading of otherwise unsaleable low grade ore (e.g. less than 60 per cent Fe). This has permitted significant extensions to the total ore reserves at two existing mines (Newman and Hamersley). The principal process involved (heavy medium separation) utilizes the difference in specific gravity between the heavy hematite mineral and the lighter shaley contaminant to effect the separation. Alumina levels of approximately 4.5 per cent in the low grade feed are reduced to the order of 2.3 per cent in products.

Mount Tom Price iron ore beneficiation plant, (courtesy Hamersley Mining)

Goldsworthy Mining has advanced plans (1987) to apply gravity separation techniques of jigging and cone concentration to lower grade ore adjacent to existing mining areas.

Over-riding the specific introduction of new technology has been the almost awe-inspiring rates of development and application of computers, especially personal computers. Mine and geological planning, maintenance planning, technical, commercial and personnel data manipulation and recording, communications, PLC systems in the operations, diagnostic applications and so on have all received a major fillip by the use of computers -the future applications are almost inconceivable.

In a developing industry the rate of implementation and the number of applications have been relatively high as new techniques and applications became available. Until major breakthroughs and innovations are introduced to iron and steel making technology it can be assumed that overall progress will continue to be steady rather than spectacular as the industry consolidates into a more mature phase commensurate with the current market and economic situations.

3.2.5 Brazil

3.2.5.1 Over View of Iron Ore Mining

Brazil is the one of the world's largest iron ore producers and exporters. Iron ore has traditionally been country's largest export product, accounting for 82 % of the total iron ore production of the country. Iron ore production during 2006 was 300 Mt and exported 246.6 Mt. Japan, Germany, China and South Korea were the main importers of Brazilian iron ore. CVRD and MBR (Mineracao Brasileiras Reunidas) are Brazil's largest iron ore exporters. Other major iron ore producers include Samitri, Ferteco, Samarco Mineracao and CSN (Companhia Siderurgica Nacional). Ferteco is Brazil's third largest iron ore producer - and was purchased by CVRD in mid 2001. Ferteco operates the Fabrica and Feijao mines that are located in the Iron Quadrangle of the State of Minas Gerais. Annual production capacity from the two facilities amounts to around 15 Mt with mineable reserves estimated at 260 Mt.

Samarco Mineracao is a joint venture between BHP Billiton and CVRD that operates the Alegria opencast mine and the Germano concentrator. Alegria has measured reserves containing 701 Mt grading at an iron ore content of 47%. The Samarco project produced 10.4 Mt of pellets and has a capacity to produce 12 Mt/year. Rio Tinto own 80% of the Corumba mine located in the State of Mato Grosso do Sul. The mine produces 1Mt of lumpy destined for markets in Argentina. Production and export trend of iron ore of Brazil for the calendar year 2000 to 2005 is shown below:

Table No. 3.2.5.1.1 Iron Ore Production & Export, Brazil

(Unit : Million tones)

Year	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Production	208.8	210.0	225.1	212	220	292.4	300
Export	160.1	155.7	170.0	184.4	237.0	225	246.6

3.2.5.2 Mining Companies

BHP Billiton - Through its 49% interest in Samarco Mineracao S.A. (Samarco), BHP Billiton operates the Alegria iron ore complex in Brazil.

Companhia Vale do Rio Doce - CVRD is on of the world's largest iron ore producers with several large scale operations in Brazil.

Rio Tinto - Rio Tinto produce iron ore from the 80% owned Corumba mine in the state of Mato grosso do Sul.

3.2.5.3 Technology Trends

The methodology of extraction of Iron ore and over burden being adopted in Brazil is Open Cast mining methods either by shovel - dumper combination or Shovel - Dumper-Conveyor transport systems. The bench heights are being maintained varies from 15 m to 17m and the mines are deploying wide variety of HEMM. Drilling is done by Bucyrus Eric and Tamrock's rotary drills (microprocessor based) having bit diameter 380 mm or 445 mm with sound proof temperature controlled operator's cabin and wet drilling arrangements. For excavation high capacity electric rope shovels (22yd^3 capacity), Demag H485 hydraulic excavators, high capacity electric wheel loaders and caterpillar 9920 wheel loaders. Note worthy technologies are Global Positioning System (GPS) monitoring for HEMM used in high precision, three application on a board a variety of mining machines, blast hole drills, shovels and dozers etc. At present 240 tonne, 2 axles, six wheeled 2400 H.P diesel - electric (Electric Wheel) trucks with air-conditioned sound proof operator's cabin are in use in Brazil. All the truck movements are controlled by a modular mining dispatch system.

To cope with the need of higher production of Iron Ore, blasting materials are also being developed/manufactured at the same pace. Use of slurry, emulsions, ANFO & HANFO in bulk explosive systems have been well established with considerable benefit to the Brazilian Iron Ore industries.
In the field of blasting accessories, the introduction and adoption of "non-electric delay initiation system "contributed significantly to the improvement in blasting results and reducing the levels of blast induced ground vibration and air blast noise. Post blast analysis is also being done through high speed video camera. As few opencast Iron ore mines have gone deep more than 200m in Brazil, In-pit crushing-conveying transportation (using mobile/semi-mobile crushers with High angle belt conveyors) of Iron ore and Over burden materials are already in use successfully.

A significant technological development was the application of WHIMS for treating hematite and limonatic ores in order to produce concentrate. At CVRD, 28 Jones separators (WHIMS) have been installed to treat > 25 Mt/y to produce 10 Mt/Y concentrate.

3.3 TECHNOLOGICAL DEVELOPMENTS IN IRON ORE MINING

3.3.1 Drilling

As an universal practice, iron ore is dislodged by drilling blast holes according to a particular pattern which depends on the bench height, the hole diameter, nature of rocks, the drilling machinery deployed and the types of explosives used.

Generally two types of drills are being deployed for open cast iron ore mining i.e. Down the hole percussive drills & Rotary drills.

- At global level use of high speed large diameter rotary drills up to 500 mm started several years ago. Bucyrus International, a world leader in Blast Hole drills are making 49R series of drills, which are known to have features as chainless rack and pinion pull down, state of the art drive system, and a chainless hydrostatic propel with planetary drives. Bucyreus continues to focus on the comfort, safety of the machine operator and maintenance personnel by providing a pressurised sound dampen, temperature controlled operator's cabin and automatic labelling system with four labelling jacks.

- In India, 10 inch rotary drills are being used in Bailadila Iron Ore Mines of NMDC and $12^1/_4$" high speed rotary drills are being used in Kudremukh Iron Ore Mines. Further, large diameter holes allows expanded drilling patterns in general and help in reducing generations of fines in softer iron ores. Drilling with 150 mm diameter blast holes has been the common practice in Indian iron ore mines.
- Now the present trend is towards large diameter blast holes along with expanded drilling pattern in conjunction with appropriate energy explosives, tall mast to match with single pass drilling, Dry dust extraction / Wet dust suppression systems to prevent the air pollution due to dust, and automation of large diameter rotary drills is one of the major innovations. Noteworthy technologies are the Global Positioning System (GPS) monitoring for HEMM used in high precision, three applications on a board a variety of mining machines, blast hole drills, shovels, scrappers and dozers.
- In the process of making drills, an environment friendly, recently Sandvick Tamrock has tackled the problems of noise and dust in drilling with supplying the drill machines, which uses Shroud that completely encloses a drilling rig's mast. The shroud would be easily detachable following maintenance access to its various components. However, one major problem which almost all the drills are facing, particularly the days when the technology is progressing faster and the mining industry is switching over to automation, is one of environmental pollution. In most of the drills dust extraction system provided is of rotocone type of dust collector, which invariably does not work satisfactorily. The Russian drills have adopted a system of using blowers. But, this is of no avail except that it helps only when the drilling is going on, dust is blown away from the drill location, but generally pollution problem in the area continues, as the dust gets disseminated and distributed in the atmosphere. Even we have observed at times, when the drill is operated in the upper bench the dust obscures the vision for the shovel in the lower bench and thus some times forcing the stoppage of the shovel. Wet drilling may be considered to be one solution to work on dust problem. Considering the pollution problems and particularly when this has become the talk of the day, it is absolutely necessary for the drill manufacturers to pay special attention to this aspect and see that an appropriate technology is introduced to ensure the dust suppression without restoring to wet drilling.

3.3.2 Blasting

To cope with the need of higher production of iron ore, blasting materials are also being developed / manufactured at the same pace.

- Recent developments in explosives have revolutionalised their application from Alfred Nobels' nitro glycerine (NG) based explosives. Today emulsion explosives have largely replaced nitro-glycerine and water gels throughout the world. Recently emulsion based non-permitted small diameter cartridge explosives were introduced in India and the results have been quite comparable with NG/slurry based explosives. Electronic delay detonators (Prototypes of which are under trial in Australia) are considered to be the next stage of evolution due to its accurate timing, it has the potential to provide better noise and vibration control, increased selectivity, improved fragmentation and reduced blast damage, less fly rock and thus makes the blasting environment friendly.
- In the field of blasting accessories, the introduction and adoption of "**non-electric delay initiation system**" contributed significantly to the improvement in blasting results and

reduction in levels of blast induced ground vibrations and air blast, Raydets of IDL and EXEL system of ICI are already in use in Indian Iron Ore Mines.

- Introduction of "**bulk explosive systems**" in India like global experience, use of slurry, emulsions, ANFO and HANFO in bulk explosive systems have been well established with considerable benefit to the mining industries.
- Introduction of "**Opti-blast**" and "**Air decking**" by gas bags blasting techniques are already in use in Kudremukh Iron Ore Mines successfully reducing consumption of explosives by 15% to 20%, considerable reduction in ground vibration, air blast and back break.
- Analysis of Blasts through latest **Video equipment** methods are in use in the world and in India too.
- Introduction of Controlled Blasting Technique - As the quantum of rock / minerals blasted in a single shot has increased considerably, controlled blasting technique has also come to play an important role in the iron ore mining, especially in the area of optimum blasting principal for reducing boulders and formation of toe, reduction of shock waves, fly rocks, noise, dust, etc., and for increasing the utilisation factor of explosive energy.
- Innovations in **Blast initiation system** coupled with sequential blasting machinery's. Sophisticated seismograph for monitoring of blast vibrations and controlled blasting techniques will reduce vibration with better fragmentation besides advances in special blasting techniques.
- A new **quarry face survey equipment**, based on **laser transit** and **computer technology**, offers improved control over rock fragmentation and blasting efficiency.
- Measurement of detonation velocity in the blast hole through **fibreoptic system** introduced in India, like global experience. Since the amount of energy released from an explosive is related to the detonation velocity, the measurement of in the hole VOD can provide information about the performance of the explosives.
- ICI's most advanced computer blast model, **SABREX**(scientific approach to Breaking rocks with explosives) has been used all over the world, including many Indian mines and is widely recognised as best model to predict blasts for the end results required.
- ICI's **VIBREX** computer model has helped to control blasting vibration, assists in selecting best delay intervals and charge weight per delay at many Indian mines, besides other advanced countries.
- Considerable advances have been made recently into the understanding of **high stress dynamic rock / explosive interaction** which in turn enabled the development of computer based blasting tool. Such tools are also being used by some explosive manufactures in India to assist drilling and blasting engineers to modify blast output and improved productivity through more consistent and reproducible results.
- **Electronic delay detonators** (Prototypes of which are under trial in Australia) are considered to be the next stage of evolution due to its accurate timing, it has the potential to provide better vibration control, increased selectivity, improved fragmentation and reduced blast damage.

3.3.3 Excavation

As the quantum of excavation in iron ore mining has increased year by year the technology has undergone a sea change in all aspects of mining activity like loading, hauling and transportation.

- Most of the surface mine is following the conventional shovel dumper combination, the concept of “bigger is better” has successfully percolated in the mineral exploitation technology. For example, bucket capacity and size of conventional machines have increased. Electric rope shovels with bucket size over $38m^3$, diesel- electric front end loaders with $15m^3$ buckets and hydraulic shovels with buckets over $23m^3$ are now available in the world market. Recently P & H has come up with 4100BOSS model of excavators having $47.5m^3$ bucket capacity, it has got some other features like higher payload capacity and cycle time expected to be 3 or 4 second faster than the other old versions. It uses latest digital drive technology for highest label of mining productivity compared to the other electric or diesel powered excavators available in the world market. In India, shovels of $10m^3$ and $20m^3$ bucket capacity and dumpers of 85 ton and 120 ton are seen.

- During last three decades the introduction of high level of mechanisation in large capacity opencast iron ore mines have led to a dramatic change in the utilisation trend of HEMM. The 5 m^3 rope shovels which were in common use are now being replaced with $10m^3$ and $20m^3$ - 25 m^3 rope shovels. 10 m^3 hydraulic shovels are finding wide application in a number of Indian mines for raising coal and metal due to its lower capital cost and high mobility. Biggest hydraulic shovels so far built in the world are of 42 m^3 bucket capacity.

- At Global level, large conventional shovels with bucket capacity $20m^3$ - $30m^3$ have been in service for several years now. In our country, 4.6 m^3 electric shovels are in use of Bailadila - 14, 14 cu. yd. electric shovels are used at Kudremukh project and 10 m^3 P& H shovels are being used at Malanj Khand copper project, CIL etc. It is a fact that electric rope shovels in opencast mines are much easier to maintain, environment friendly and are widely accepted throughout the world.

- Deployment of material handling equipments using electric shovels and dumper combination is very much popular in Indian Iron Ore Industry, which is being followed successfully over the years. Use of $10m^3$ bucket capacity electric rope shovel along with 85 tons dumpers is the best combination, presently adopted in big Indian mechanised iron ore mines. In order to achieve higher production, a trend is emerging for deploying $20m^3$ capacity rope shovels along with the combination of 120tons or 170 ton dumper. Electrically driven shovels in place of diesel driven shovels substantially reduce operating cost, besides having favourable effects on environmental requirements.

- Introduction of high capacity Ripper Dozer (700 HP) are already in use in the western zone (Goa region) as an alternative to drilling and blasting, especially in case of over burden (OB) and soft iron ore. This ripping / dozing operation is eco-friendly, noise / vibration is practically nil and generation of dust is very less. Back hoe excavators are also used in western region of India (Goa) for excavating and loading of virgin soils/ soft iron ore without blasting where the blasting is not necessary after removing the laterite capping or logistics factors like human inhabitations nearby.

- Redesigning of Buckets of loading equipment to improve digging, to achieve higher fill factor and to lower the dead weight by geometric redesign and use of higher and stronger materials for fabricating buckets. New designs of **"Stealth"** bucket are now available in the world market. Longer booms for shovels are being made available giving a 15% to 30% increase in digging force from the same hoist pull.

- In the case of hydraulic shovels, Syncrude Power, O & K Mining, Canada has delivered the world's largest hydraulic excavator, class RH 400 with bucket capacity 42 m^3, Dual engine concept, a centrifugal oil filter system replaces the traditional paper filter, improved Pump Managing System (PMS) assures optional usage of engine output, controlling the pumps to achieve the required hydraulic performance in the most economic way.
- Use of sound proof and air-conditioning systems in cabins of all HEMM equipments are already in use in the world as well as in India too.
- Introduction **"Surface Miner"** machine manufactured by M/s WIRTGEN GMBH, Germany for excavating minerals in a Environment friendly manner. In India surface miner SM - 2100 are in operation at Gujrat Ambuja limestone mines. This has not yet tested in the Indian iron ore mining.

The surface miner offers following advantages over conventional mining by Shovel- Dumper:

- Higher productivity and lower costs for multi-seam mining.
- Elimination of Drilling and Blasting, which avoids the chance of dilution of pay minerals and offers more safety. It will also create the possibility of mining in the areas where administrative regulations are imposed against blasting.
- Possibility of combined operation both dumpers and conveyors. For bigger haul length and dipper seams conveyor transport can be more economic than dumper transport.
- Pre crushing and elimination of separate crushing plant.
- Higher yield of pay minerals

Trying this new technology in Indian iron ore mines shall open a new era in iron ore mining. It shall be proven to a boon in mining technology in 21st Century. Introduction of Global Positioning System (GPS) Technology to enhance the Shovel productivity is one of the major innovations. The use of GPS technology on shovel provides a number of benefits to the mine:

- The ability to determine actual location of each dipper load, which may be required when operating near pit limit.
- The capability of continuous grade control, eliminating the needs of the survey stacks that are destroyed with the constant mine advancement. The elevation of the shovel track or bucket can be displayed within centimetres of the desired bench grade. This allows the operator or pit supervisors to instantly determine whether the shovel is excavating at the designed grade and correct for any deviation resulting in improved pit floor profiles.
- Improves the ability to control dilution and ore quality when blending is required from various areas of the mines.

3.3.4 Haulage and Transportation System

- At global level, high horse power (2400hp) and large capacity dumpers up to 350T have already been in service. In our country, in order to match the increased production requirements by deploying bigger shovels, Dumpers of 35 T and 50 T are being replaced gradually with 85 T, 120 T and 170 T dumpers. Presently combinations of $10m^3$ shovels with 85 T, 120 T dumpers and 20 m^3 shovels with 170 T dumper is proving effective and is being preferred for achieving higher productivity in India. The Current trend however is towards larger equipment which matches excavator, primary crusher and wheel loader capacities and enables mines to increase productivity by hauling more material in fewer cycles.

- In advanced countries, trolley assisted dumpers of 120 T and unto 170 T are in use in view of the spiralling fuel costs, faster cycle and better productivity. Conventional electric drive dumpers can be converted after few years of operation into trolley assist with minor modifications which can finally result in fuel savings. The feasibility of trolley assisted truck haulage system in the future deep open pit in India should be studied and explored. This type of trolley assisted trucks are operating presently at USA, Canada , Australia and Brazil etc.The major advantages are:
  - Reduction of fuel consumption unto 35 %.
  - Increase productivity 14 to 15 % due to increased truck speeds, shortened haulage cycle times etc.
  - Increased engine life.
- Introduction of statically excited electric control drive system eliminating rotating field in case of 170 T dumpers. In India, electric drive control systems of 120 T dumpers are operating at Kudremukh iron ore and 170 T dumpers are operating in coal mines of Singrauli coal fields, Rajmahal and Amlohri project.
- Deployment of Articulated Dumpers for negotiating uneven topography and sharp bends are already in use Goa region of India.
- Introduction of haul road geometry (i.e. Design construction and maintenance etc.) concept throughout the World in order to improve cycle time, life of the tyre to improve the fuel consumption per hour, to reduce the maintenance cost and to improve the productivity of the mines. Use of large capacity vibrating rollers and impact rollers will be imperative to lay high compaction haul road more quickly. For haul road construction, the overall dimension of the dumpers, its weight distribution, volume and traffic are taken into consideration.
- In-pit crushing and conveyor transport technology have been in service for several years in the advanced countries. Today, Indian mining industries, aim at minimising dumper haulage and maximisation of belt conveying of materials due to increase in oil prices, increasing mine depths of more than 100 Mts., increased prices of tyres and from the environmental point of view.
- The use of **computer aided truck dispatch system** has been an innovative development in enhancing productivity in open cast operation. World - wide it has been reported that large mines have accrued a productivity gain to the tune of 15% after using this system. The pioneering developments made in communication technology have resulted in the system transforming to a completely operator independent system using Global Positioning Systems (GPS).
- Concept of **Condition based maintenance** using monitoring techniques such as vibration shock pulse monitoring, oil debris and temperature analysis are being used world wide and India too to increase the operating life of the costly equipment. In recent years, the idea of relating a machines condition to its level of performance, vibration,

noise, temperature rise machine condition. Advance method of condition monitoring are being adopted which have proved advantageous in giving uninterrupted production cycles and in cutting down the cost of maintenance by minimising unwarranted replacement of spares

3.3.5 Ore Crushing & Screening

In earlier mechanised opencast mines, processing involved was crushing to required size and separation of various products by dry screening. With the increasing emphasis on cleaner product, wet screening has come in vogue in place of dry screening. Small capacity crushers have now given place to large capacity crushers with improved reduction ratio. From Jaw crushers, mine operations have switched over to gyratory and cone crushers where closely sized materials are required. Since steel plants are switching over to sinter, iron ore fines are now finding market and full recovery of these fines, classifiers, hydro cyclones and filters are increasingly used. For obtaining iron ore concentrates from low grade ore various processing routes of gravity separation, flotation and magnetic separations are in practice through out the world and India too.

3.3.6 Ore Beneficiation

Currently the demand of high grade Iron ore is being met, basically by selective mining of high grade ore and / or by simple method of washing. The method of washing results in minimal quality up gradation and high loss of values in slime posing environmental problems. The practice in other countries like Australia emphasise on optimum Fe up gradation and high recovery of concentrates using the state of art technologies. The technological improvements include introduction of Air - Pulsated jigs, spirals and slow speed classifiers, hydro cyclones, log washers, recuperates, floated density separators and wet high intensity magnetic separators and a wide range of process controls. This coupled with the computerised mine planning and blending through intermediate stockpiles and stackers, allows mining of low grade ores with 50 to 54% Fe content and yields iron ore lumps and fines with 64% Fe and recoveries as high as 90%. Iron Ore recovery from tailings using high gradient permanent magnetic separator is one of the major innovation now a days. It is developed by Eriez magnetic, LISA, termed as Ferrous Wheel Separator (FWS), is a matrix type separator employing permanent ferrite ceramic type magnetic to generate high magnetic field gradients capable of separating magnetic / Paramagnetic material from non - magnetic. Ferrous Wheel Separator (FWS) is used for beneficiation of ultra fine hematite and taconite ore samples drawn from around the world. These ultra fines are presently thrown away as tailings.

3.3.7 Slurry Transportation of Iron Ore

A notable development in transportation is slurry transport of fine ore concentrate in pipelines. The first such pipeline (225 mm diameter) was put into operation in Tasmania (Australia) for transporting 2.25 Mt of magnetite concentrate over a distance of 85Kms. It is generally preferred when other modes of transport are cost prohibitive. M/s Kudremukh Iron Ore Company, India, is transporting by slurry pipeline about 7.5 Mt of fine ore concentrates from Kudremukh to Mangalore over a distance of 65 Kms.

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4.1 ENVIRONMENTAL IMPACTS – OPEN CAST IRON ORE MINING

It is recognised that minerals and metals are the mainstay of the economic development and welfare of the society. However, their exploration, excavation and mineral processing directly infringe upon and affect the other natural resources like land, water, air, flora and fauna, which are to be conserved and optimally utilized in a sustainable manner. The mineral sector in India is on the threshold of expansion with more and more open cast iron ore mines being opened-up in the state of Jharkhand, Orissa, Karnataka and Chattisgarh. Under such scenario, systematic and scientific exploitation of iron ore, compatible with environment is essential for survival of our future generation.

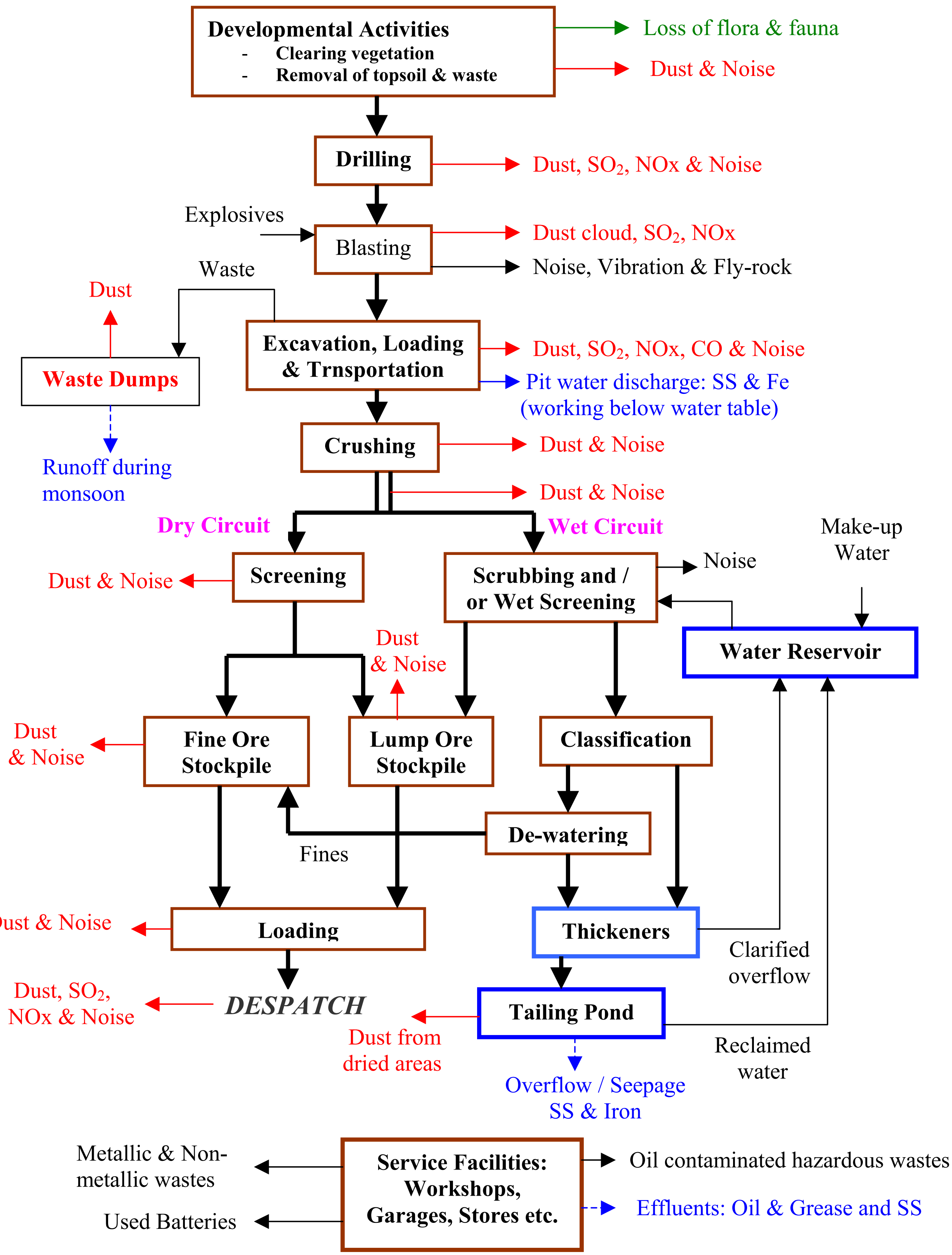
Mining being site specific activity, excavation is bound to be done at a place where mineral actually exist. Hence, the mining process changes the landuse of the area and is of no use to the mining companies once mineral is exhausted completely. In the process, mining affects all the components of environment and the impacts are permanent/temporary, beneficial/harmful, repairable/irreparable, and reversible/irreversible. Mines especially open cast iron ore mines, due to its own peculiarities can cause disturbance in ecology, resulting in various pollution problems. The environmental problems are more significant in India, as most of the iron ore mines located on top of hills and in dense forest areas.

The environmental problems associated with the iron ore mining are diverse. The removal of vegetation, top soil, overburden/waste and ore, brings about the inevitable natural consequences, which manifest in many ways, deforestation, climatic change, erosion, air and water pollution and health hazards. Iron ore mining and processing of ore, affects the environment in myriad ways causing:

- Land disturbance and change in land use pattern
- Affecting floral and faunal habitat
- Disturbing the natural watershed and drainage pattern of the area
- Disturbing the aquifer causing lowering of the water table
- Air pollution due to dust and noxious fumes
- Water pollution due to surface run off from different areas of mines, spoil dumps, seepages/overflow from tailings dam leads to siltation of surface water bodies and blanketing the agricultural fields.
- Noise and ground vibrations due to blasting.
- Socio-economic impacts

The magnitude and significance of these impacts on environment and ecology due to mining will depend on the size and scale of mining activity in conjunction with the topography & climatic conditions of the area, the nature of mineral deposits, method of mining & capacity of mines, agricultural activities in the region, forest reserves etc. A line diagram showing various unit operations of iron ore mines and its associated environmental aspects is given below in Figure No. 4.1.1.

Fig. No. 4.1. 1 Environmental Aspect of Iron Ore Mines



4.1.1 Impact on Land

Mining is a temporary land use of the area. Being a site specific industry there is no choice in siting a mining project, a luxury available to most other industries. Land is required not only for the mine excavation proper and laying approach / haul roads, but also for beneficiation plant, ore handling & dispatch units, waste dumps, tailing ponds etc. Land is also required for ancillary facilities and statutory buildings (workshops, stores, offices, canteen, and crèche). In addition to these, residential colony and related welfare amenities like school, hospital, shopping centre, recreation centre etc. also require land.

The major impact on the land use during the pre-mining phase is removal of vegetation and resettlement of displaced population. During mining and post-mining phases, drastic changes in landscape with landform take place. The major associated impacts are soil-erosion, loss of top soil, creation of waste dumps and voids, disposal of wastes, deforestation etc. The impacts of iron ore mining on land are as outlined hereunder;

- Topography and land scenario changes due to excavation of open pits and dumping of overburden rock mass in the form of land heaps.
- The land-use pattern undergoes a change due to the use of the land for mining, dumping, and other mining and associated activities.
- The land-use in the surrounding areas may get affected due to the impacts of mining on water regime.
- Leachates from overburden dumps and other rock masses and polluted water from the pits affect the characteristics of the top-soil affecting the land-use.
- In the mines having mineral concentration/processing plants, it is required to make tailing's pond to store the tailings generated from the processing plants. These tailing ponds require massive area and may cause pollution of ground and surface water bodies, if proper care is not taken.
- The drainage pattern of the area undergoes a change due to the alterations in the surface topography due to mining and associated activities.

It is evident from the above that the mining and associated activities can significantly change the land use and drainage pattern of the region. These changes can be minimized by careful planning the surface layout of the mining areas and by integrating the environmental aspects of each and every unit operation of mining activity. Another important aspect of the land management is the planning and design of the land reclamation programme right from the inception, including the development of the post mining land use planning for optimum utilisation of land in an efficient manner and for overall improvement in environmental scenario.

4.1.2 Impact on Ecology

The mining activities like excavation, transportation and processing of ore, disposal of overburden & tailings etc, are posing various complex situations for managing the ecology. Over the years the large scale mining operations in the forest areas, have caused substantial impact on the ecosystem like degradation of land, deforestation, displacement of wildlife, effect on aquatic eco-system etc.

The major adverse impacts due to premining and mining phases are loss of habitat, biodiversity, rare flora & fauna, other aquatic life, migration of wildlife and overall disruption of the ecology of the area. Major impacts of iron ore mining on ecology are as follows;

- Removal of vegetation (flora) from the area required for mining and other purposes, and thereby displacement of fauna.
- Pollution of water in the surrounding water bodies due to leaching from overburden dumps, seepage/overflow water from tailings pond and from the other activities. These affect the aquatic ecology of surrounding water bodies.
- Dust in the atmosphere, contributed by mining and associated activities, when deposits on the leaves of the plant in the surrounding area hampers the process of photosynthesis and retards their growth.
- Noise and vibrations due to blasting, movement of HEMM/vehicles and operation of fixed plants and machineries drive away the wild animals and birds from the nearby forests.
- Water scarcity caused due to the impacts of opencast mining on water regime affects the growth of vegetation and agricultural crops in and around the mines.
- Discharge of mine effluents to the nearby surface water bodies without proper treatment may affect vegetation in the surrounding area.

It is evident that mining and associated activities have considerable impacts on the ecology of the mining and surrounding areas. The ecological impacts are more severe in India as most of the iron ore mines are located in the dense forest areas and on hill tops. These impacts are evident in most of the iron mining zones in our country. By proper reclamation of mined out areas and rehabilitation of waste dumps through massive afforestation with local saplings, the ecological impacts can be minimised.

4.1.3 Impacts on Water Regime

Mining and associated activities have quantitative and qualitative impacts on the water regime in and around the mines. These are briefly outlined hereunder;

- All the surface water bodies have to be removed from the area designed for the mining and associated activities.
- All the aquifers, including the water–table aquifer, above the mineral deposit to be extracted are damaged
- If there are high pressure aquifers below the mineral deposit it becomes necessary to pump the water from the aquifers to reduce the water pressure to facilitate mining
- Water in the nearby water bodies gets polluted due to leaching from the overburden dumps, discharge of pumped mine water, and other activities in the vicinity of the water bodies
- During rainy season the run off water from the areas surrounding the mines carries with large quantity of the suspended solids into the nearby water bodies.

It is evident from the above that the mining and associated activities changes in ground water flow patterns, lowering of water table, changes in hydrodynamic conditions of river/underground recharge basins, reduction in volumes of subsurface discharge to water bodies/rivers, disruption and diversion of water courses/drainages pattern, contamination of water bodies, affecting the yield of water from bore wells and dug wells etc. Therefore, it is necessary to plan the mining and associated activities in such a manner that their impacts on the water regime are as minimum as possible.

4.1.4 Impacts on Society

It is generally believed that all the activities of the human beings are for the benefit of the society. Hence, the impacts of the human activities, specially mining and associated activities, on the society assume a great importance. As soon as a mineral is discovered and proved, and its mining potential is established, the impacts on the society start as with this the value of the land increases, people from outside start buying land and establish business etc. Mining and associated activities cause the following impacts on the society.

Displacement of the people: For mines, it is required to clear the surface of all the buildings and structures along with the vegetation not only in the area designated for mining purposes but also in a large area nearby which is required for making external dumps and placing associated activities. Therefore, all the people lining in this area get displaced.

Loss of livelihood: The people living in the designated areas depend generally for their livelihood on the land. Since, in mining areas the land is taken for mining and associated activities these people loss their livelihood.

Changes in population dynamics: Invariably all the managerial, skilled and semi-skilled manpower required for mining and associated activities come from outside as such trained manpower in usually not available in ethnic population. In addition, people come to the mining areas for trade etc. Thus, the population dynamics of the area undergoes a major change over the years resulting in dilution of the ethnic population and their culture and religion, reduction in sex ratio etc.

Cost of living: Societies dependent on agriculture and forests usually have a lover level of economic scenario. The development of industrial and other associated activities in such areas increase the level of the economic activities manifolds. Increased industrial and economic activities generate more money and increase the buying power of the people directly and indirectly associated with these activities. This leads to an increase in the cost of living, which adversely affects the other people, including ethnic people, who are not associated with these activities.

Water scarcity: Mining by open cast methods damages the water regime and thus causes a reduction in the overall availability of water in and around the mining areas. In the sedimentary deposit mining areas the water table and aquifers are damaged and thus the availability of water from these sources reduces.

Health impacts: Health and well being of the people living in and around the mining complexes got affected due to the pollutants in the air and water, noise and vibrations. In fact, the society in the mining complexes has to bear the various costs of abating the affects of environmental pollution in various ways. The people working in the mines and associated facilities also get affected by the work place environment, which can cause various problems, e.g. skin problems, lung diseases, deafening etc.

Infrastructure facilities: The mining and associated activities in the mineral bearing areas bring about infrastructural development, i.e. roads are constructed, schools and hospitals are established, and communication facilities are developed etc., which tend to improve the quality of life of the complexes.

Employment opportunities: The mining and associated activities offer opportunities of employment to the eligible people from the ethic population. The Project Affected People (PAPs) are given jobs and are trained for self employment as a result of the provisions in the Rehabilitation and Resettlement (R&R) Schemes. People also get employment in the other developmental activities and also the mineral based activities in and around the complexes.

Increase in aspiration: The ethnic people of the mineral bearing areas, with the advent of mining and associated activities are exposed to various developments and this tends to increase their aspirations. In fact, this is necessary for the overall community development in the mining complexes.

4.1.5 Air Pollution

The air quality in the mining areas mainly depends on the nature & concentration of emissions and meteorological conditions. The major air pollutants from mining include:

- Particulate Matter (Dust) of various sizes
- Gases, such as, Sulphur Dioxide, Oxides of Nitrogen, Carbon Monoxide etc. from vehicular exhaust.

Dusts are the single largest air pollutant observed in the iron ore mines. Diesel power stations, diesel operating drilling machines, blasting and movement of HEMM/vehicles produce NOx, SO_2 and CO emissions, usually at low levels. Dust can be a significant nuisance to surrounding land users and potential health risk in some circumstances. Dust is being produced from a number of sources and through number of mechanisms such as land clearing, removal of top soil (during opening up of new areas), removal of OB/ore, drilling, blasting, crushing & screening, processing of ore, loading & unloading of material on site & subsequent transport off the site etc. In addition to this, wind action affecting stockpiles, dry tailings, exposed mining areas and waste dumps also generate significant amount of dust. Dust emissions from these operations manly depend on moisture content of the ore and type of control measures adopted.

The major gaseous pollutants of concern in iron ore mines are sulphur dioxide and oxides of nitrogen. Sulphur dioxide can cause respiratory problems. Oxides of nitrogen can react in the atmosphere with hydrocarbons to produce photo-chemical smog. In addition to this, the sulphur dioxide and oxides of nitrogen can generate an acid rain harmful to vegetation and materials.

4.1.6 Noise Pollution

Mining operations usually generate noise during different stages of mining and handling of ores. In open cast mines, noise is due to drilling, blasting, excavation, sizing and transportation of ores. In case of ore processing, noise is due to operations like crushing, screening, washing, storage and dispatch of ores. These noise generating sources can be grouped into two categories viz fixed plant and mobile plant sources. Fixed plant machineries such as crushers, grinders, screens, conveyers, etc., generate noise & vibration. Similarly, the mobile plant used on-site associated with drilling, blasting, loading, haulage or service operations cause noise.

4.1.7 Water Pollution

Water pollution from the mining operations mainly depend on topography of the area, intensity of rainfall, type of ore, method of mining & ore processing, etc. The major impacts are water pollution from erosion of waste dumps/mining areas, oil & grease, contamination of water bodies due to discharge of mine water/effluents, pollution from domestic effluents, and sedimentation of rivers and other stored water bodies, solid waste disposal sites, etc. The following are the major sources of water pollution from the Iron Ore Mines.

- Effluent generated from the Ore Processing Plant
- Pit water discharge from mines operating below water table
- Surface run-off from various mining areas during monsoon e.g., waste/reject dumps, tailings pond seepage/overflow etc.
- Oil and grease pollution from workshops effluent

Effluent from Ore Processing Plant: In most of the mechanised iron ore mines, ore is being processed either in dry or in wet circuits depending on the quality of ore feed. Ore having high alumina and silica are generally being processed in the wet circuit mainly to improve the quality of the ore and to remove the impurities for smooth Blast furnace operation. In wet circuit, the ore is being crushed, scrubbed, washed, wet-screened, classified etc. Water requirement for this purpose is in the tune of 1 m^3 per tonne of ROM for adding at various stages. A line diagram showing the general layout of the wet processing of ore is given below.

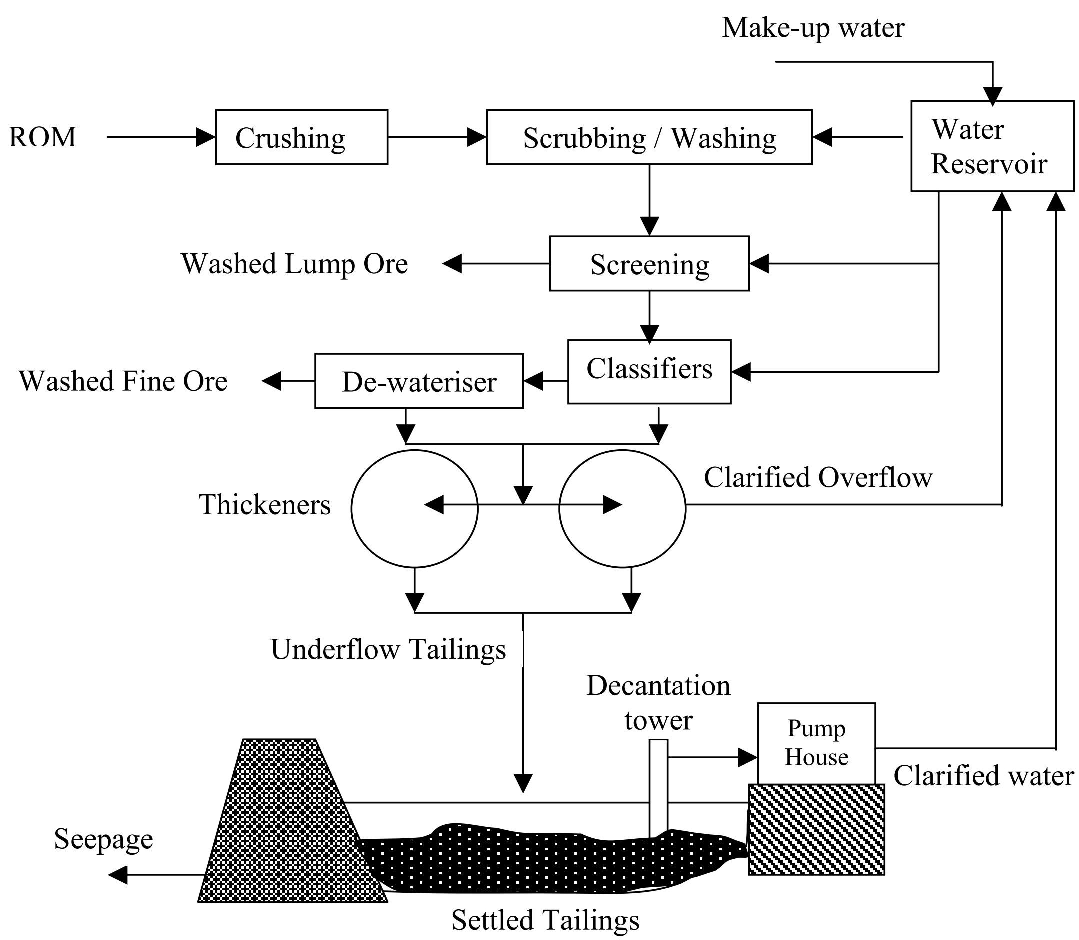


Fig. No. 4. 1.7.1 Ore Washing Efflunet Handling System

Effluents generated from the ore washing mainly consists suspended solids. The effluent is initially treated in classifier to recover the coarser particles as ore fines. The overflow of the classifier, mainly consist of finer solids i.e. tailings, is sent to thickener for solid liquid separation. After settling of the tailings at the bottom of the thickener, clarified overflow water (about 60 %) is reclaimed and recycled to the system. Underflow tailings are discharged to Tailings Pond for further solid - liquid separation. Clarified water from the Tailing Pond are also reclaimed and recycled back to the system in most of the major iron ore mines in India. In some mines, where there is no provision of reclaiming water from the pond, the clarified water is discharged through a weir.

Pit water discharge from mines: Iron ore mines, which are operating below water table or just above the confined aquifers, water accumulated in the mine pit is required to be pumped out to facilitate the mining operation. The pit water is normally laden with suspended solids, derived from within the pit and generally used for ore washing purposes or discharged to the nearby water bodies, which is not a major concern. However, pumping of pit water creates a cone of depression around the mine area, which give rise drying of nearby wells and springs in the neighbouring villages. A large percentage of iron ore in the Goa region is located below the water table and a number of mines are now operating below water table. In most of the big mines, the pit water is being discharged to the exhausted pits and being utilised for ore washing purpose.

Surface runoff: The single most important environmental aspect of mines is the surface runoff from various areas during monsoon, as most of the iron ore mines in India are located in hill tops with steep slopes and in dense forest areas, and sometimes in areas with high rainfall. Surface run off from the mining and other areas gets laden with aluminous lateritic soil from mine benches, exposed outcrops etc. As the iron ore contains only traces of sulphur, the surface run off water does not get acidic, but become highly turbid due to loosening of soils by the mining activities. Direct discharge of the surface runoff to the natural nallas will certainly affect the water quality of the nallas as well as rivers in the region. Major sources of runoff from the mines are as follows;

- Waste dump areas
- Ore handling and stockpile areas
- Mine proper and haul roads
- Other areas like workshops, garages, service centres etc.

In most of the big mines, sedimentation basins have been provided for treatment of the surface runoff or diverting to the tailings ponds. In addition to this, garland drains around the waste dumps along with retaining walls & toe bunds and check dams across the nallas were provided to arrest the runoff, besides establishing vegetation cover over the waste dumps.

Effluent from Workshops and Garages: The effluent generated from the Workshop and Auto Garage mainly consists of oil and solids. Separate effluent treatment plants have been provided for treatment of these effluents in most of the big iron ore mines. The effluent is treated in series of sedimentation tanks with oil traps. As the effluent generation is very low, these treated effluents are discharged to the nearby lands where it is evaporated.

4.1.8 Vibration & Air Blast

Vibration and air blast are among the most significant issues for communities located near the mining industries. The vibration and air blast from blasting can lead to community concern primarily due to fear of structural damage. This fear occurs because people are able to detect vibration at levels which are well below those which result in even superficial damage to buildings and items of heritage value.

Vibration is the term used to describe the reciprocating motion in a mechanical system and can be described by the frequency and amplitude of the oscillations. When an explosive charge is detonated in a confined drill hole, tremendous amount of pressure and temperature develops with in a very short time interval. The process melts, flows, crushes and fractures surrounding rocks. After some distance from the explosion site, inelastic process ceases and elastic effect starts. The excess explosive energy, not utilised in shattering the rock is transferred to elastic zone and thus propagates the disturbance away from the explosion site. The disturbance is known as seismic wave or ground vibration. It is generally measured as Peak Particle Velocity (ppv) in mm/ sec at a specified frequency.

The use of explosives creates airborne pressure fluctuations (air blast) over a vide frequency range. When in the higher frequency range, this energy is audible and is perceived as “noise”. At frequencies of less than 20 Hz, the sound energy is inaudible but it is capable of causing objects to vibrate such as rattling of loose windows and crockery. Low frequency waves (<6HZ) causes more damage to structure particularly in case of multi-storeyed buildings.

Damage caused by ground vibration is dependent on the frequency of ground motion. In order to safeguard the nearest residential buildings and other important structures, various countries have set the limits for blast vibrations depending upon the socio-economic values of life. All the vibration standards till date are based on the resultant peak particles velocity (PPV) of ground vibration because this is accepted as the best criterion for assessing levels of damage due to vibration. In India, DGMS prescribed 10 mm/sec as the safe limit of ground vibration at the foundation level of the structures within a distance of 300m, depending on dominant excitation frequency and nature/construction of the building/structure.

4.1.9 Solid Wastes generation from mines

The major solid wastes generated from the mining operations are topsoil, over burden & inter burden, tailings from ore processing and wastes generated from the maintenance and repair of the HEMM and light vehicles. The wastes generated from the mines and associated activities have been classified into following categories:

- Top Soil
- Waste / Rejects
- Tailings from Ore Processing Plant
- Wastes from Service Facilities

Top Soil: In virgin mining areas, after clearing the vegetation, the top soil (generally up to 30 cm thickness) is generally stripped and stacked separately in most of the mines. The top soil is vastly superior in quality and contains plant nutrients, microbes and humes, which can be used in future for stabilisation / rehabilitation of waste dumps and reclamation of mined out areas.

Mining Wastes/Rejects: As a measure of quality control, generally a cut-off point for Fe is fixed depending on the type of ore to ensure ROM feed of acceptable quality to the Ore Processing and handling Plants. All the ores having Fe below cut off point are classified as waste / rejects/subgrade material, and mined out separately and dumped in designated waste dump areas, keeping in view of the future use if techno-economics permit.

The iron ore deposits of the Eastern, Central and Southern zone do not contain much waste / rejects, except laterite and some low grade ferruginous shales and BHQ patches. Whereas, in Western zone (Goa region), the waste generation is vary high to the tune of 2.5 to 3.5 times per ton of ore excavated.

Tailings from Ore Processing Plant: The iron ore extracted from the mines are beneficiated to separate out the valuable mineral content. The prime function of beneficiation of iron ore is to improve the Fe content and to decrease the Alumina / Silica ratio for smooth Blast Furnace operations. The left over residue of the iron ore after the beneficiation in the state of fine particles mixed in water in a slurry form, known as tailings and are needed to be disposed of in the tailings pond for containment. The disposal of tailings is a major environmental problem, which is becoming more serious with increasing extraction of lower grade deposits. The tailings are usually transported and deposited as slurry of high water content into a massive pond for containment, which are generally called as tailing ponds / tailing dams.

Wastes from Service facilities: There are three types of wastes, being generated from the service centres viz, metallic, non-metallic and oil contaminated wastes. The metallic wastes generated in the workshops mainly iron & steel scrap, are collected & stored and sold. The non-metallic saleable wastes like, tyres, tubes etc. are also stored separately and sold. The oil contaminated wastes like waste cotton, oily muck oil filters etc., are categorised as hazardous wastes. In some of the big mines, secured hazardous waste landfills are provided for disposal of these wastes. In most of the mines these are being dumped or burned.

4.2 ENVIRONMENTAL IMPACTS FROM IRON ORE MINES - INDIA

Iron ore mining industry is one of the oldest industries in this civilized world. Its contribution to the growth of nations and economic prosperity worldwide is immense. However, their exploration, exploitation and associated activities directly infringe upon and affect the other natural resources like land, water, air, flora and fauna which are to be conserved and optimally utilized in a sustainable manner. The single most important factor that is responsible for environmental degradation due to iron ore mining is inadequate landscape management during operation stage and improper rehabilitation during and after the mining.

The iron ore demand is expected to be increased at a greater phase and this will lead to opening up of new mines and expansion of existing mines as discussed in Section 2.0 of this report. It is, therefore, necessary that the environmental concerns be integrated right from the beginning. To achieve this, the industry has to have a framework of policies that are environmental friendly. The concern for environmental issues, is well reflected in the new National Mineral Policy 1993 (non fuel and non atomic minerals) as reproduced below:

"The New National Mineral Policy 1993 prohibits mining operations in identified ecologically rich areas and strip mining in forest areas should as far as possible be avoided. The latter could be permitted only when accompanied by a comprehensive time bound reclamation programme.

It states further that no mining lease would be granted to any party, private or public, without a proper mining plan including the environmental management plan approved and enforced by statutory authorities. The environmental management plan should have adequate measures for minimizing the environmental damage, restoration of mined areas and for planning of trees in accordance with the prescribed norms. As far as possible, reclamation and afforestation will proceed concurrently with mineral extraction. Efforts should also be made to convert old mining sites into forests and other forms of land use."

Realising the importance of the impacts of iron ore mining on environment, most of the big iron ore mining companies have established a systematic organisation structure, solely to look after environmental impacts and issues, both at their corporate level and mines. Now a number of Indian Iron Ore mining companies have implemented Environment Management Systems (EMS) linked to ISO-14001 and certified. For example Noamundi of TISCO, all the mines of M/s Sesa Goa in Goa, and Dalli, Kiriburu, Meghahatuburu & Bolani Iron Ore mines of SAIL, few mines in NMDC, KIOCL and a number of mining companies have already been certified. The details about the existing environmental management practices of some of the selected mines covered under "In-depth" study in the four different zones have already been discussed in the Interim Report submitted during December, 2001. But while discussing the environmental impacts of Indian iron ore mines in the following sections of this chapter, a brief of the existing environment management practices has also been discussed, at present.

4.2.1 Study Area

The entire iron ore mining areas in India is divided into the following four zone / sectors which is mainly based on the distribution of iron ores

- Western Zone
- Central Zone
- Eastern Zone
- Southern Zone

The distribution of the iron ore deposits have already been discussed in detail in the section 2 of this report. However, for the purpose of in-depth study, selected mines were studied in detail. The representative mines were selected to represent all the cross-section of mining companies with respect to the geological condition, geographical locations, nature of the deposits, scale of operation, capacity, product profile, mode of operation and the present environmental management practices. Due importance was given to select mines having proven environmental management practices for the in-depth study. The following mines and mining companies were covered during the in-depth study:

Mining Zone	*Company*	*Mining Site*
Western Zone	1. M/s Sesa Goa Limited	1. Codli Iron Ore Mines At: Codli , P.O: Kirlapale Taluk: Sangeum Dist.: South Goa – 403706 2. Sonshi Gaval Iron Ore Mine At: Sonshi, P.O: Honda Taluk: Sattari , Dist.: North Goa 3. Besides, two closed and rehabilitated mines of M/s Sesa (one at Cudnem and the other one at Sanqleium) were also visited

Mining Zone	*Company*	*Mining Site*
Western Zone (contd..)	2. M/s Dempo Mining Corporation Ltd.	4. Bicholim Mine At/P.O.: Bicholim, Dist.: North Goa – 403504
Central Zone	1. M/s National Mineral Development Corporation Limited	1. Bailadila iron Ore Project, Deposit-5 Bacheli - 494553 Dist.: Dantewada,Chhatisgarh 2. Bailadila iron Ore Project, Deposit-14 &11C Kirandul - 494556 Dist.: Dantewada,Chhatisgarh
	2. M/s Steel Authority of India Limited	3. Rajhara Iron Ore Mines P.O. Rajhara District – Durg, Chattisgarh- 491001
Eastern Zone	1. M/s TATA Iron and Steel Company	1. Noamundi Iron Ore Mines, Mines Division, Noamundi-833217 Dist.: West Singhbhum, Jharkhand
	2. M/s Steel Authority of India Limited	2. Meghahatuburu Iron Ore Mines, Raw Materials Division, P.O. Meghahatuburu,Dist.: West Singhbhum Jharkhand – 833223 3. Kiriburu Iron Ore Mines, Raw Materials Division, P.O. Kiriburu, Dist.: West Singhbhum Jharkhand – 833222
	3. M/s Orissa Mineral Development Company Limited.	4. Thakurani Iron Ore Mines At/P.O.: Thakurani Via- Barbil, Dist.: Keonjhar , Orissa
	4. M/s Essel Mining & Industries Ltd.	5. Jilling Langalota Iron and Manganese Mines P.O.: Jajang Barbil – 758052 Dist.: Keonjhar, Orissa
Southern Zone	1. M/s Kudremukh Iron Ore Company Limited	1. Kudremukh Iron Ore Mine Kudremukh – 577142 Chikmagalur District, Karnataka
	2. M/s National Mineral Development Corporation Limited	2. Donimalai Iron Ore Mine Donimalai – 583118 Sandur, Dist. Bellary, Karnataka
	3. M/s R Pampapathy	3. Aarpee Iron Ore Mines 19/43, Bellary Road, P.B. No. 64 Hospet – 583 201 Bellary District Karnataka

4.2.2 Study Methodology

The following methodology was adopted during the in-depth study in each mine, the findings of which was already elaborated in the interim report submitted during December 2001.

Mining area

1. The present practices of mining were looked into,
2. The condition of benches, haul roads, drilling pattern, blasting practices, condition of the HEMMs and other equipments, transportation practice of Ores & OB, incidences of back breaks on blasting, over loading of dumpers, etc. were observed.
3. The associated Environment management problems like dust control methods used, water management practices followed during monsoon, any problem of dewatering, monitoring locations, etc. were studied.
4. Photographs of the salient features were taken.

Ore Processing/ Beneficiation

1. The process flow studied.
2. All the key operational locations like hopper, crushers, screens, etc were visited and the working condition observed.
3. The conditions of the PC equipment were observed, if provided.
4. The associated environment management issues like dust control methods used, water management practices followed, etc were observed.
5. The tailings pond visited and the condition of the over flow, dam, etc observed. Discussed about any incidence of dam failure, non-compliance, etc with the concerned official

Loading / Transfer Point

1. The process and associated environmental problems studied.
2. Near by area was visited to find out reaction of the inhabitants in close proximity, if any.

OB Dump

1. Both old rehabilitated and new waste dumps visited.
2. The methodology being adopted for top soil preservation, waste dump stabilisation, slope stabilisation, terracing, afforestation, any innovative methods followed were studied.
3. The precautions adopted for runoff management and silt arrestation practices during monsoon were observed and the check dams visited, if provided.
4. Discussed about - if they have any mine closure plans, plan for rehabilitation of mined out benches.

Workshop and Stores

1. Workshop visited and observed about the general house keeping, waste management practice for used oil, used tyres/tubes, used cottons/papers, metallic wastes, used filters, used batteries, asbestos materials, PCB oils for transformers, packaging materials, etc.
2. The ETP (Oil catchpit) provided for HEMMs and light vehicles washings were studied.
3. Stores visited to observe the stockings of the materials and discussed the methodology followed for waste management.

Environment Laboratory and Monitoring Locations

1. The environmental laboratory visited to assess the adequacy of the facilities.

2. All the monitoring and sampling locations studied to assess the adequacy of the requirements.
3. General reconnaissance survey of the area conducted to get a feel of the receiving environment and habitants around the mines and allied facilities.

However, for the evaluation of regional impacts of iron ore mining clusters in the above four identified zones, various study reports by the agencies like IBM, TERI, CMRI, NEERI, State Pollution Control Boards, State Govt. Agencies, concerned mining companies were also consulted. Four season environmental quality monitoring was conducted at Meghahatuburu & Kiriburu iron ore mines of SAIL. Detailed study of fugitive dust emissions from various unit operations has also been conducted at Kiriburu & Meghahatuburu Iron Ore Mines. Besides the environmental quality monitoring data collected from the mines covered under in-depth study, regular monitoring results of other SAIL mines, monitoring data generated by different outside agencies like IBM, NEERI, TERI, CMRI, State Pollution Control Boards etc. were also collected. All the data are summarized and placed in a separate booklet as addendum to this report.

4.3 WESTERN ZONE (GOA REGION)

4.3.1 Natural Setting

4.3.1.1 Location and Topography

The State of Goa, with an area of 3700 km^2, is located along the mid-west coast of India between coordinates 14^{o}53'57" to 15^{o}47'59" N and 73^{o}40'54" to 74^{o}20'4"E. Land use is dominated by agriculture (35%) and forest (39%). The map of the state is shown below:

The territory is divided into four physiographical subdivisions and three terrains, the hilly region towards east, the intermediate undulating tracts and the level and low-lying lands along the coast. It consists of a chain of high and imposing hills cut by deep gorges, steep valleys and ravines, constituting Western Ghat in the east, the coastal plains in the west and intermediate undulating tracts and planes and low lying land in the centre.

4.3.1.2 Climate

The climate of the area is generally tropical and influenced to a large extent by conditions in the Arabian Sea. There are four seasons corresponding to winter (December to February), summer or Pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October and November). The climate is characterised by high humidity and temperature varying between 20^{o} and 35^{o}C. Annual rainfall varies from 3000mm to 5000mm and the average number of rainy days is 110. The bulk of rainfall is received during the southwest monsoon (June to October). Average relative humidity is 70 – 90%. The 1980 – 1991 wind records show that wind speed is generally higher in the afternoon than in the morning. In the morning, the prevailing winds are northeast to east (wind speed below 10km/h), except in June, July and August when they are westerly (wind speed above 20km/h), whereas in the afternoon, the winds are easterly or south easterly (wind speed often above 20km/h).

4.3.1.3 Land and Soil

The state is endowed with a wide range of physiography, landforms, geology and vegetation, which have influence on the genesis of the soils. Depending upon elevation, slopes and ruggedness of terrain. Goa has been divided into two major physiographic regions, i.e. Konkan Coast and Central Sahyadri (NBSS & LUP, 1995). Based on relief and geology, Konkan coast, in turn, is subdivided into fluvio-littoral landform and dissected hilly landform. Central Sahyadri is subdivided into granite-genesis landform, quovestite schisyose landform and basalt landform.

Nearly $2/3^{rd}$ of Goa is covered by laterite ranging in thickness from a couple of meters to over 25 meters. Generally the maximum thickness is observed along the west coast and minimum along the ghat section in the east. The laterite is generally vermicular and cavernous and sometimes prisolitie. There are rock outcrops and laterite crusts associated with the soils. The soil units associated with rock outcrops cover 0.25% while soil unit with laterite crusts cover 4.4% of geographical area.

4.3.1.4 Water Resources

The state is drained by a number of rivers mainly Mandovi, Zuari, Tiracol and Chapora flowing westwards in to the Arabian Sea. The Mandovi originates in the main Sahayadris of Karnataka and its various tributaries i.e. Bocholim, Mapusa, Kudne, Khanderpar and Madai Rivers contribute directly or indirectly to its in charge. The Mandovi has the largest drainage basin of Goa. The Kushavati River is the major tributary of the Zuari. The river basin of Mandovi and Zuari cover of about 69% of the total area of the state.

4.3.1.5 Hydrogeology

The entire state of Goa is underlain by crystalline and metamorphic rocks belonging to Pre-Cambrian age, comprising granite, gneisses, metagray-wackes, phyllites and metabasalts. These rocks are overlain by laterite, lateritic soils and alluvium. Structurally, the area has been subjected to folding and faulting. These fractured rocks represent favourable locations for groundwater storage. Ground water is related to topography and shows a close relationship with the various geological formations in the area. It is stored in two main types of aquifers:

- The top lateritic layer, which is quite extensive in the area, has undergone major denudation, and stripping or extraction due to mining and other human activities. Where preserved, this layer holds groundwater in perched aquifers, which can be either confined or unconfined.
- The powdery iron ore formations worked at the mine site close to the surface also existing at depth. The friable powdery iron ore is highly porous (30 to 35% porosity), permeable and completely saturated with water, whereas the hard rock formations only bear water in their network of clefts and fractures.

4.3.2 Mining Operation in Goa

The state is rich in minerals (i.e. iron ore, manganese, bauxite) and mining is an important activity for its economy and foreign exchange. Mineral production in Goa began in the late 1940s, originally for manganese and ferro-manganese. By the mid 1950s, emphasis shifted to lumpy iron ore and the 1970s witnessed a phenomenal growth in iron ore production. Iron mining is currently the major extractive industry and is concentrated along the Ghat section in the east of Goa where a mining belt extends 65 km from southeast to northwest spanning some 700 km^2. Goa is the only state in India where such a large number of iron ore mines are concentrated in such a small area. All the iron ore produced in Goa is exported to Japan, China, Korea, Taiwan and some European countries. During 2006 - 07, Goa's total iron ore production and export was in the range of around 30 million tonnes.

Entire mineral belt of Goa has been leased out to private mine operators. During the rush for mining rights in the fifties, people acquired "Mining concessions" from the then Portuguese authorities with very little knowledge of the mineral potential of the concerned land. The concessions are perpetual and gave property rights for an unlimited period. At one time, total of 868 mining leases/concessions, covering an area of 65,400 ha, existed. A number of "concessions" have since been terminated by the Government for violation of the essential condition that it would be exploited for the production of minerals. About 50% of these leases have been terminated. During 2006-07, 62 iron ore mines were operating in Goa region and produced 30 Mt of iron ore. All mines and barge loading jetties are situated in/ surrounded by human habitat/ villages.

Mining operations are essentially carried out by open cast method. Iron ore mining is fully mechanized, comprising of variety of heavy earth moving equipment. Most of the large mines also have mineral beneficiation plants comprising crushers, classifiers, hydrocyclones, logwashers and magnetic separators.

Mining operations are being carried out by conventional open cast mining method forming systematic benches using shovel - dumper combination and the pits are laterally extended in stages in all directions with increasing depths. In general, bench height and width are maintained at 7m and 15m respectively. The pit configurations are planned in such a way that the overall pit slopes remains at 30^o or less with the horizontal. Sequence of mining operations involves systematic removal of laterite over burden and mining lumpy ore zone followed by powdery ore zone. Soft laterite is removed by ripping and dozing. Drilling and blasting is practised in hard laterite and lumpy ore zone where ever necessary. To extract a tonne of iron ore, an average of 2.5 – 3 tonnes of O.B material is required to be removed. This O.B material, which consists of laterite, laterite clay, manganiferous clay and phyllites, is dumped generally within the leasehold along the hill slopes, road sides and valleys. In some cases, O.B. material is being transported to dumping sites acquired outside the leasehold area. Normally O.B. dump are up to 30 m height but because of non-availability of land, mine operators have raised the height of dumps beyond 30m, on the basis of working face sample results as well as considering the bore hole results, the quality of ore is controlled by stock - piling different grades of ore separately and mixing them at the required proportion, either at the beneficiation plant or at the loading point, to obtain the exportable grade of ore.

The demand for Iron Ore is in the form of Sinter grade fines of -10 mm size with Iron content of more 62%. The ore being generally low grade (59% - 60%) has to go through processing and beneficiation to meet the requirements of buyers. The mining companies have set up dry screening facilities at the mine and wet beneficiation plant at the mines or near loading points. There are about 18 dry screening plants with an installed capacity of 6000 t/h and 24 wet beneficiation plants with a capacity of over 17 MT/annum. The normal process of ore beneficiation as applicable to most of the Goan ore is briefed as under.

The low grade ore with oversize > 10 mm is crushed in stages in Jaw cone roll crusher to size below 10 mm and screened or scrubbed wet. The undersize in the form of slurry, is fed into the classifier where the classifier sand is collected as part of the concentrate and the classifier overflow is treated in hydrocyclone. The under flow from the hydro cyclone constitutes the other part of the concentrate. The overflow from the hydrocyclone is the tailing's rejects of the process. The oversize from screen scrubber can be treated as concentrate provided quality of the combined concentrate suits the overall grade. On the other hand, it can be ground wet in a ball rod mill and treated again in the hydrocyclone.

Ore produced and processed at mines is transported by 10 ton tippers to river jetties using public roads, for loading in to barges. These barges take the ore to Murmagao harbour for loading in to ships. Most of the barge-loading jetties are away from mines about 13 to 15 kms. from mine, on an average. Depending upon shipment program and tide timings, ore from mine is either stacked or loaded in to barges. For barge loading, tipper and wheel loader combination is deployed.

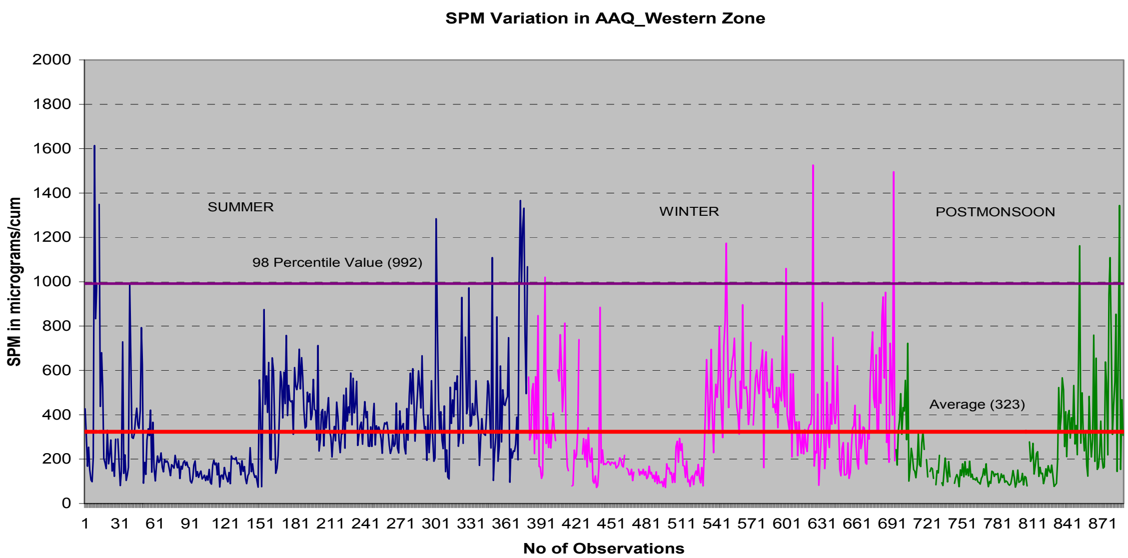
4.3.3 Environmental Impacts

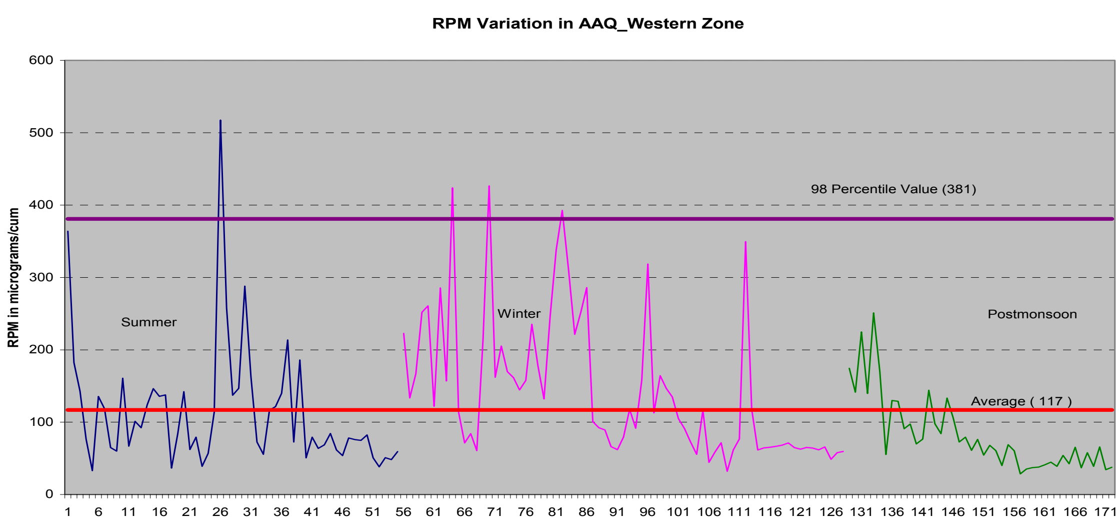
The mining industry in Goa has witnessed a number of positive and significant impacts on the economic development of the state. There are, however, also been several environmental impacts, some of which are due especially to the unique features of mining in Goa and some due to bad mining practices and poor environmental management. The Iron ore industry operates under certain difficult conditions specific to Goan iron ore mines. The production of iron ore in the future will be maintained at the existing level of more than 20 million tonnes per annum in the Goa region. Mining will lead to all associated activities such as ore transportation, dry/wet screening, beneficiation and loading operations and all these operations will continue at the present levels. All these operations would impact on the environment of the area.

4.3.3.1 Impacts on Air Quality

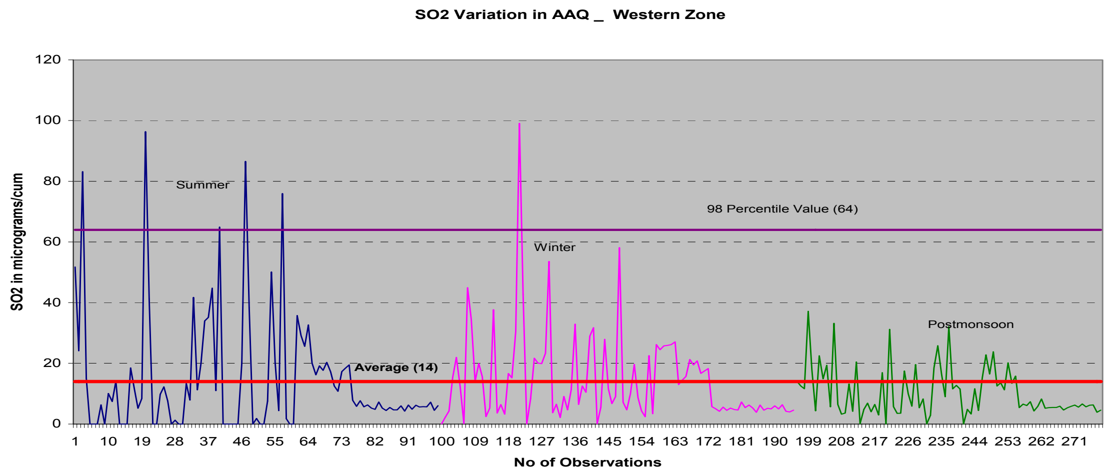
Dust is the single largest pollutant observed in any of the iron ore mining carried out in India. Dust can be a significant nuisance to surrounding land users, as well as a potential health risk in some circumstances. Dust are being produced from a number of sources and through number of mechanisms including land clearing and removal of top soil (in the beginning of a new mining project) and overburden removal, drilling and blasting operations, operation of crushing and screening equipment, loading and unloading of material on site and subsequent transport off site, transport by vehicles on access roads and haul roads, wind action affecting stockpiles, dry tailings and exposed areas of the site, processing of the minerals , etc. For most of the mining operations, the major sources of dust are mine haul roads, followed by drilling and then blasting. For many material handling facilities, the main sources of fugitive dust are stock piles.

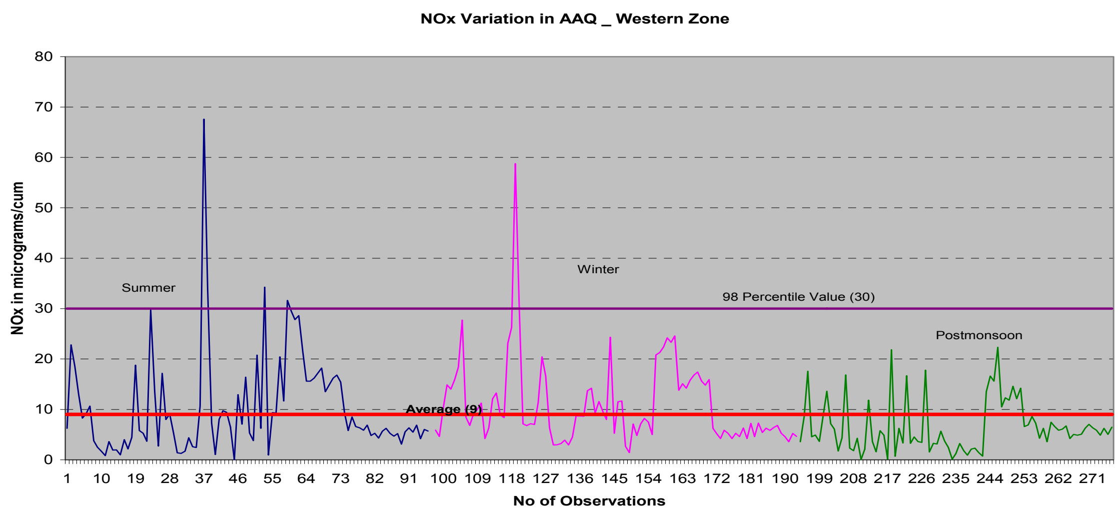
The existing levels of air quality in the region as per the air quality monitoring data collected from the individual mines visited, from different study conducted by agencies like IBM,CMRI, TERI, etc. are discussed. The annual average total dust (SPM) and RPM concentration observed in the ambient areas in the region were 323 μg/m^3 and 117 μg/m^3 respectively. The maximum SPM and RPM concentration observed in the ambient, was 1615 μg/m^3 and 518 μg/m^3 during summer season. The annual 98 percentile values of SPM and RPM were calculated to be 992 μg/m^3 and 381 μg/m^3, respectively. The annual variation of SPM & RPM is shown below in the graphs.





The concentration of SO_2 and NO_x were observed to be insignificant, though the maximum value of SO_2 and NOx were 99 µg/m^3 and 67.5 µg/m^3 during winter and summer, respectively. The annual average value of SO_2 and NOx were 14 µg/m^3 and 9 µg/m^3, respectively. Lead and CO in ambient air was also found to be insignificant. The variations of SO_2 and NOx concentration in the area are shown in the graphs below:





Regarding workzone air quality, the annual average total dust (SPM) and RPM concentration were 508 µg/m^3 and 196 µg/m^3 respectively. The maximum SPM and RPM concentration observed in the workzone, was 4955 µg/m^3 and 1077 µg/m^3 during winter and summer respectively. The annual 98 percentile values of SPM and RPM were calculated to be 1862 µg/m^3 and 811 µg/m^3, respectively. The annual average of SO_2 and NOx were 22 µg/m^3 and 12 µg/m^3 respectively.

The summarised data are given in the following tables below for Ambient Air Quality and Workzone Air Quality, where as the details are placed in a separate booklet.

Table No. 4.3.3.1.1 Summary of findings for AAQ Monitoring in the Western Zone

Parameters	*Maximum Value (μg/m³)*				*Average Value (μg/m³)*				*Minimum Value (μg/m³)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	1615	1615	1526	1344	323	351	349	240	64	73	71	64
RPM	518	518	426	251	117	114	144	83	29	33	32	29
SO2	99.09	96.38	99.09	37.17	14.03	19.04	14.48	10.3	BDL	BDL	BDL	BDL
NOx	67.56	67.56	58.76	22.3	9.32	10.41	10.86	6.53	BDL	BDL	BDL	BDL

Table No. 4.3.3.1.1 Summary of findings for AAQ Monitoring in the Western Zone (Cont'd)

Parameters	*98 Percentile Value (μg/m³)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	992	1035	930	877	869	376	305	188
RPM	381	358	410	228	172	55	73	44
SO2	64.11	84.82	54.05	32.46	257	77	96	84
NOx	30.35	34.1	28.03	19.23	275	96	96	83

Table No. 4.3.3.1. 2 Summary of findings for Workzone Air Quality Monitoring in the Western Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	4955	3151	4955	4457	508	608	475	372	100	100	105	105
RPM	1077	1077	914	817	196	236	190	156	50	51	59	50
SO2	123.21	109.8	123.21	77.03	22.28	27.5	24.6	14.5	BDL	BDL	BDL	BDL
NOx	55.06	51.3	55.06	33.1	12.41	12.1	14.3	10.3	BDL	BDL	BDL	BDL

Table No. 4.3.3.1. 2 Summary of findings for Workzone Air Quality Monitoring in the Western Zone (Cont'd)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	1862	1907	1705	1342	741	319	246	176
RPM	811	833	761	739	216	74	79	63
SO2	81.68	77	93.7	37.9	263	76	104	83
NOx	39.8	42.7	35	32.5	283	96	104	83

Most of the major big mining companies like M/s Seasa Goa and M/s Dempo are taking proper care for the dust suppression inside the mines. As the drilling and blasting in the mines are limited only during the monsoon, the dust generations are limited to the fair weather because of transportation and beneficiation (dry process). During excavation, the dust generation is much less because of high in-situ moisture content in the ore itself. The haul road dusts are normally being suppressed by using normal hired water tankers by the companies. The drilling machines of M/s Sesa Goa at their Codli mines were observed to be fitted with proper and effective wet drilling arrangements. But, still dust generation is identified as a key issue, and is mainly due to the clustered nature of the mines, the narrow uncovered gravel roads and the fact that ore is transported in open trucks normally of 10 ton capacity running thousands of round-trips per day between the mines and the beneficiation plants or loading points. This causes a direct nuisance for the nearby villagers. The situation is worse in the mining area of north Goa in comparison to South Goa, where recently the High Court has passed a order for the use of covered trucks to transport iron ores in the public road in response to a Public Litigation case. The measures taken by some mines operating in North Goa to suppress dust by spraying water has only worsened the situation by making the roads slushy and slippery. The maintenance of these roads is also generally poor. The problem is most alarming in the 6 km. stretch of Guddemol-Capxem road handling 5.4 million tonnes of ore and the 8 km. stretch of Sanguem-Curchorem road. The major cause of dust generation is overloading and over speeding of trucks. As per the estimates of TERI (AEQM, November 1997), the estimated annual ore spillage is 1385-2770 tonnes per year for handling of 5.4Mt of ore in the Codli-Sanvordem stretch and a consequent fugitive dust generation of 139 – 277 t/year (7.4 – 12.3 g/s), leading to an ambient dust concentration of 850 – 1500 $\mu g/m^3$ in the surrounding areas. In the Ugem-Xelvona stretch, the ore spillage is estimated to be 655-1310 t/yr for handling 1.5Mt of ore, and dust generation of 66 – 131 t/yr (3.5 – 5.8g/s) leading to a dust concentration of 400 - 500$\mu g/m^3$.

Existing rail yard at Curchorem for handling Bellary ore is also a source of dust generation. Because of frequent public resentment against dust pollution, the Government of Goa constituted a committee in 1994 (Fernades Committee) to assess the dust pollution in Curchorem due to mining activities and recommended suitable measures to ameliorate the effects. The committee had recommended for building alternate transport routes and shifting of loading points to control dust in the area. The study by the committee revealed that the health centre in Curchorem suffered from infections resulting from an excess of atmospheric dust. This study also revealed an increase in the number of respiratory infections in the Curchorem region. Respiratory infections due to an excess of dust were identified by the Government Goa as early as 1994.

4.3.3.2 Impacts on Water Quality

Mining is an intensive resource development industry. Its operations are often of relatively short duration and can result in dramatic impacts on the natural environment during the operational period and for many years after mining. An integral component of all mining operations is water in exploration, mine development and operation, rehabilitation and long term post mining landuse. Water is a basic requirement in the provision of worker amenities, in drilling, in conditioning construction materials and a means of dust suppression, as a medium for washing or processing the mine product and as an aid in establishing vegetation on post mining landforms. Water also plays an important role in mobilizing environmental containments and is the primary medium for the transport of contaminants off the mine site into the wider environment. Mining operations, through their mine water management systems, can impact on the environment by altering the distribution of water through the hydrologic cycle, and in turn affecting the ecological systems that rely on the established water distribution, or by adding contaminants to the environment. In an iron ore mining, these additional contaminants include an increased sediment loads from the erosion of exposed area due to mining, stock piles and waste dumps, tailings products from rainfall leaching of ore stock piles and waste dumps etc.

Tailings and their pore waters represent a long-term source of potential contaminants to the environment. Tailings are typically placed in a tailings impoundment (pond). In the long-term, tailings could be released if the containment structure failed, an issue that has received little attention to date. In the shorter term, contaminants could be transported from the tailings impoundment predominantly through the ground water system or through overflow. The mechanisms affecting the transport of a pollutant through ground water system are advective, dispersive and diffusive fluxes, solid-solute interactions and various chemical reactions decay phenomena.

4.3.3.2.1 Impact on Surface Water Quality

Mining activities in Goa contribute to water pollution mainly due to the following three activities:

- Dewatering of the mining pit water to enable to proceed the mining below the ground water level
- Effluent discharge from beneficiation plants and workshops
- Stormwater run-off from mine dumps and surrounding areas

Accidental spillages of oil by the barges during ore transportation are also another source for water pollution in Goa region.

A large percentage of ore in the region is located below the water table and a number of mines are now operating below the water table. A cone of water table depression is created around the mine area being worked and it is reported that in certain areas this has given rise to drying up of the nearby wells and springs which serve the neighboring villages. This problem is most acute during the summer months and during this period particularly the affected population will tend to resort to surface waters including the rivers and streams that are the recipients of the effluent waters from the working pits. The water discharged from the working pit is normally laden with suspended solids derived from within the pit.

Another existing water pollution concerns the management of beneficiation plants, associated loading points and stacks. Where the water containing very fine (colloidal) inorganic particulate solids in suspension generated out of washings from the beneficiation plants are discharged directly to a natural watercourse, the environmental impact is very serious. Where the wastewater is recovered and recycled through the process, the environmental impact is minimised.

The data collected from different iron ore mines on the effluent and surface water quality are summarised in the tables below.

Table No. 4.3.3.2.1.1 Effluent Quality for Iron Ore Mines in Goa

(Unit : mg/l except for pH)

	Parameters ☞	TSS	pH	O&G	Mercury	Lead	Cadmium	Cr (Hexa)	Copper	Zinc	Nickel	Iron	Sulphates	Manganese
Annual Average	**Maximum**	266	9.6	9.8	0.0018	0.032	0.007	0.022	1.03	1.397	0.59	8.85	56.28	2.6
	Minimum	2	5.3	0	0.00046	0.001	0.002	0.001	0.002	0.008	0.001	0	0.001	0
	Average	46.67	6.87	4.57	0.0007	0.0096	0.0043	0.0067	0.0431	0.1961	0.0618	0.48	12.18	0.33
	No. of Observations	60	103	98	12	9	19	10	33	48	15	99	54	98
Monsoon	**Parameters ☞**	**TSS**	**pH**	**O&G**	**Mercury**	**Lead**	**Cadmium**	**Cr (Hexa)**	**Copper**	**Zinc**	**Nickel**	**Iron**	**Sulphates**	**Manganese**
	Maximum	256	9.6	9.8	0.0018	0.014	0.003	0.022	0.008	0.263	0.034	8.85	56.28	1.032
	Minimum	6.54	5.3	0	0.00046	0.008	0.003	0.019	0.003	0.008	0.01	0	0.76	0
	Average	45.11	6.5	2.85	0.0007	0.011	0.003	0.0205	0.0046	0.0844	0.0174	0.31	15.76	0.14
	No. of Observations	41	48	43	9	2	1	2	9	14	5	47	35	47
Non monsoon	**Parameters ☞**	**TSS**	**pH**	**O&G**	**Mercury**	**Lead**	**Cadmium**	**Cr (Hexa)**	**Copper**	**Zinc**	**Nickel**	**Iron**	**Sulphates**	**Manganese**
	Maximum	266	8.6	9.2	0.0014	0.032	0.007	0.008	1.03	1.397	0.59	4.64	14.07	2.6
	Minimum	2	5.6	0	0.0005	0.001	0.002	0.001	0.002	0.022	0.001	0.03	0.001	0
	Average	50.02	7.21	5.91	0.0008	0.0091	0.0043	0.0033	0.0575	0.2421	0.084	0.64	5.57	0.5
	No. of Observations	19	55	55	3	7	18	8	24	34	10	52	19	51

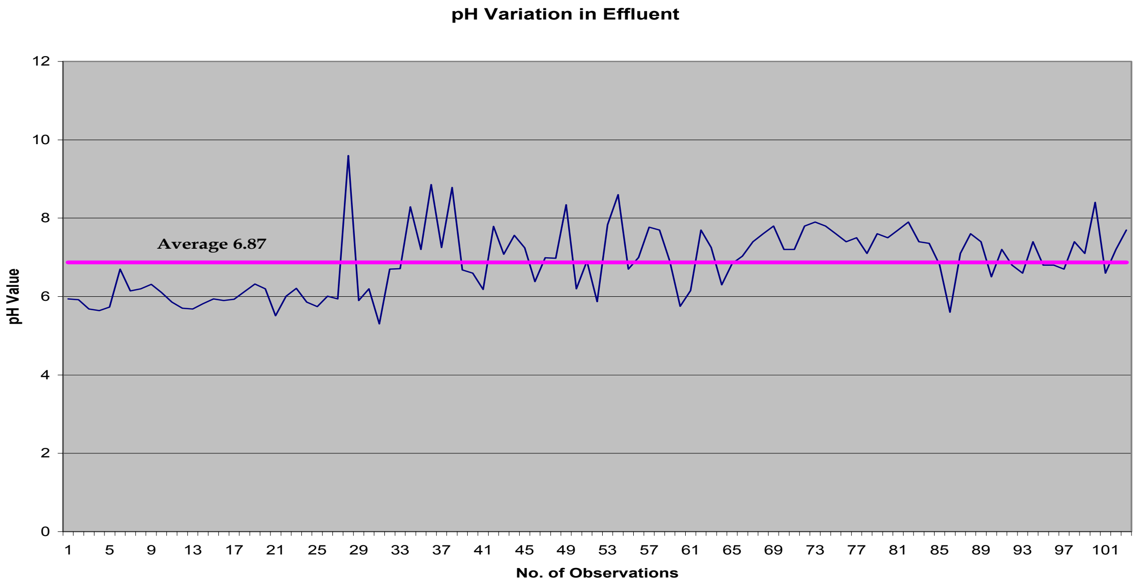
Table No. :4.3.3.2.1.2 Surface Water Quality near the Iron Ore mines in Goa Region

(Unit : mg/l except for pH)

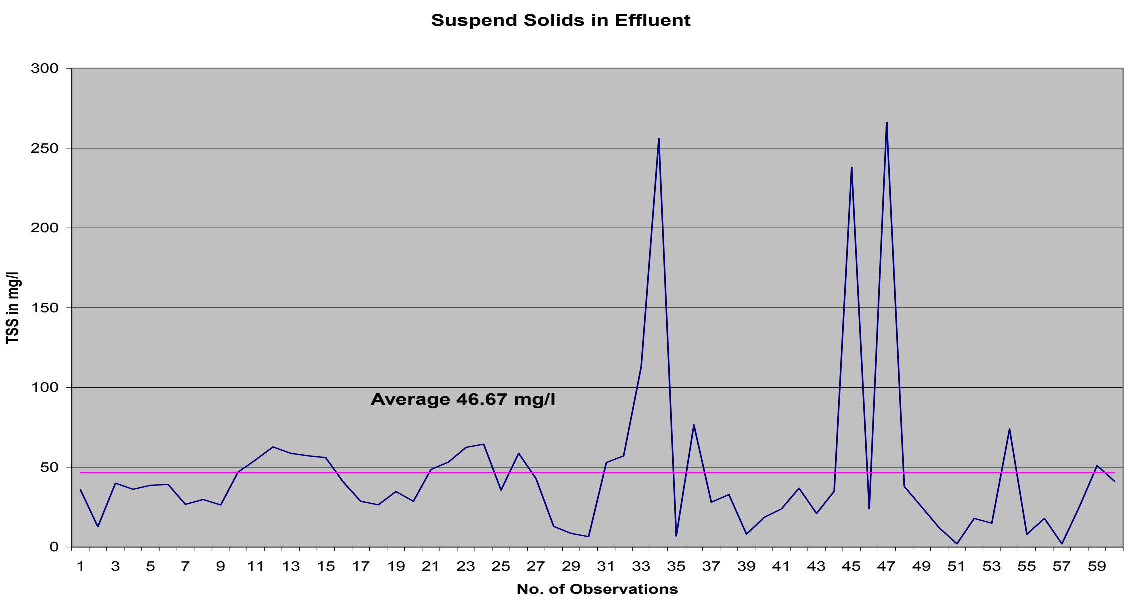
Annual Average	**Parameters ☞**	**pH**	**Copper**	**Iron**	**Sulphates**	**Mercury**	**Cadmium**	**Lead**	**Zinc**	**Cr (Hexa)**
	Maximum	8.6	0.75	2.07	2007.8	0.00046	0.04	0.06	0.971	0.018
	Minimum	5	0.001	0	0.17	0.00046	0.001	0.009	0.01	0.005
	Average	7.21	0.55	0.38	242.82	0.00046	0.0045	0.03	0.11	0.01
	No. of Observations	93	20	89	48	6	21	7	57	8
Monsoon	**Parameters ☞**	**pH**	**Copper**	**Iron**	**Sulphates**	**Mercury**	**Cadmium**	**Lead**	**Zinc**	**Cr (Hexa)**
	Maximum	7.62	0.011	0.48	12.58	0.00046	NM	NM	0.108	NM
	Minimum	5	0.002	0	1	0.00046	NM	NM	0.01	NM
	Average	6.83	0.0043	0.17	6.43	0.00046	NM	NM	0.0532	NM
	No. of Observations	30	4	30	11	6	NM	NM	17	NM
Non Monsoon	**Parameters ☞**	**pH**	**Copper**	**Iron**	**Sulphates**	**Mercury**	**Cadmium**	**Lead**	**Zinc**	**Cr (Hexa)**
	Maximum	8.6	0.75	2.07	2007.8	NM	0.04	0.062	0.971	0.018
	Minimum	6.02	0.001	0	0.17	NM	0.001	0.009	0.02	0.005
	Average	7.37	0.0573	0.49	313.09	NM	0.0045	0.0313	0.132	0.0093
	No. of Observations	63	16	59	37	NM	21	7	40	8

Note : NM – Not monitored

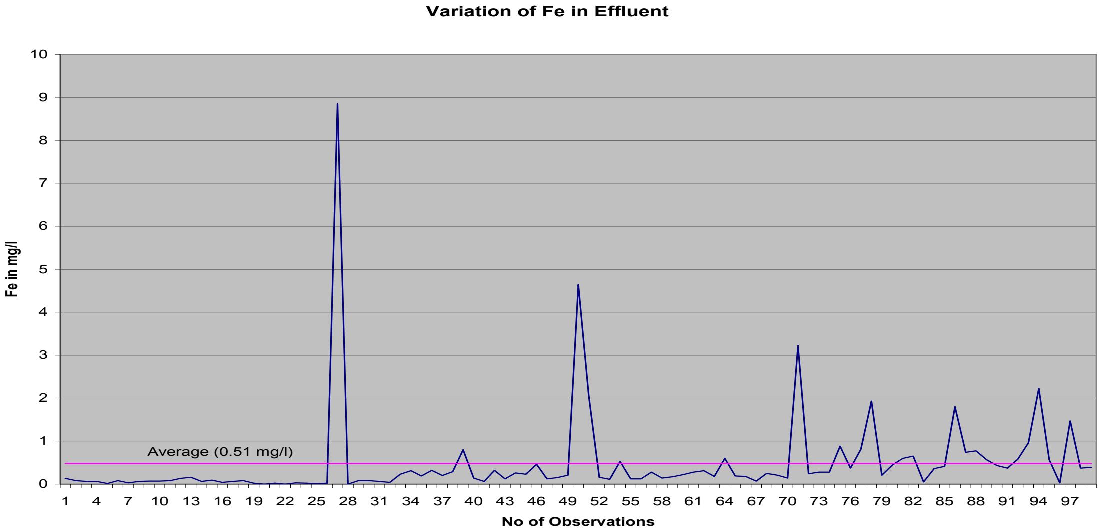
The pH varies from 5.3 to 9.6 with an average value of 6.87 out of 103 observations. The maximum pH value of 9.6 was observed during monsoon period in the pit water, whereas the minimum of 5.3 was observed during monsoon period in the waste dump run-off water. The variation of recorded pH values are shown in the graph below:



The Suspended Solids (SS) in the effluent varies from 2.0mg/l to 266 mg/l in the western zone. The maximum SS value of 266 mg/l was recorded during winter season in the pit water and the minimum of 2.0mg/l was recorded during winter in pit water. The variation of the recorded SS values is shown in the graph below:



The dissolved iron (Fe) in the effluents varies from 0 mg/l to 8.85mg/l with an average value of 0.48 mg/l. Both the maximum and minimum Fe values were recorded during monsoon from the waste dump runoff. The variation of Fe in the effluent is shown in the graph below:



The oil & grease in the effluents varies from 0 mg/l to 9.8 mg/l with an average value of 4.57 mg/l. The presence of other parameters like Sulphate, Manganese and heavy metals (mercury, hexavalent chromium, cadmium, copper, zinc and nickel) are insignificant. Erosion of waste dumps due to heavy rainfall leads to turbidity of natural drainage system because of the suspended solids carried by the run-off. Currently, however its impact on the receiving streams and rivers is invariably detrimental but varies in degree. At its worst the water course can be rendered lifeless and virtually unusable. At best the mineral solids present will cause a hazard to the river biology which would otherwise flourish. Detailed studies of the impact of these waters on the river or marine ecology have not been carried out in Goa to date and in the absence of proper base data on the situation prior to the advent of mining activities requires some speculation regarding the extent of the damage caused. It would appear most likely however that marine plants, fish, crusticans, smaller creatures and micro organisms must have suffered and the food chain might have been thus disrupted.

A study conducted by TERI reported that the most affected rivers in the region are Bicholim, Madei and Khanderpar. The prominent nullahs affected are Cudnem, Sonshi and Advoi. As a general practice, storm water run-off in the active mining area is allowed to go out of the lease area after passing it through filter bunds and /or intermediate settling ponds. In some mines, lime and other reagents are being added to accelerate the settling process. During fair season, the pumped out water from the working pits are discharged to the natural water course after passing through filter bunds. Where the beneficiation plants are present near the working pit, the pumped water is utilised in the beneficiation plant. Tailings disposal is carried out by ponding and some times by using the exhausted pits as tailings pond. The water from the tailings pond are either recycled in the beneficiation plant or being discharged to the natural water course.

Although management seems to be generally poor, certain cases of effective management are observed, i.e. water treatment followed by discharge into small pit without major turbidity effects, and the existence of efficient peripheral drainage system at different levels of the open pits. In certain mines, they have taken some good measures to reduce the adverse environmental impacts on water bodies, specifically for preventing the downwash of the overburden dumps by the way of construction of very substantial and extensive lateritic stone walls at the contour levels around and along the face of the tip face on horizontal terraces and use of geo-textiles in some of the iron ore mines.

4.3.3.2.2 Impact on Ground Water Quality

The mining belt in Goa has two proved aquifer, namely the top laterite layer and the powdery iron ore formation at depth. The top layer with laterite cover is quite extensive in the area and even though mining activities have denuded much of these areas of laterite cover, still some areas are left which have laterite cover. Here, the water is in the form of parched water table with or without any confined pressure. The friable powdery iron ore at depth are highly porous, permeable and are completely saturated with water. During mining, these ore bodies (aquifers) are exposed and water in them gushes into the mine pits under pressure. This belt is spread across a strike length of 50 km with an average of 1 m and average thickness of 30m. Considering 35% yield, the total quantity of water likely to be confined to this area alone is expected to be about 525 Mcm. It is good quality potable water and if harnesses properly can meet the demands of the surrounding villages. The present practice is that mine water is simply pumped out and allowed the natural topography. The ground water quality data of the area is presented in the Table No. 4.3.3.2.2.1. One vexed issue is the alleged impact that mining activity is having on local shallow aquifers. To evaluate and confirm the extent of these impacts, a systematic ground water investigation survey was carried out by TERI in the Cudnem river catchment areas in the mining belt of North Goa during April, 1997. The study confirms that;

- The ground water being pumped from the mine pits comes from shallow unconfined and deep confined aquifers layers.
- The shallow aquifer water levels are affected due to mining and this phenomenon is site specific and time specific. For example, the case of drying of shallow open wells around Pissurlem area is not witnessed around Kudne mines as these mines are located at the receiving end of the ground water(all ground water is flowing towards these areas) besides having local ground water barriers which are isolating the shallow aquifer water from being let into the mine pits. However, with passing of time and the spread of mining activity this may change. On the other hand mines around Pissurlem are located at the surface water divide of the catchment and therefore at the loosing end of ground water (ground water flows away from these points) and hence magnifying these effects.
- The linkage between mine pit water and the aquifer water is more than evident from the study; however at some locations it is yet to be felt.
- Under natural conditions the rain water percolates down into soil and slowly emerges at the stream banks as lean-period flow or base flow. As most of this flow emerges after the rainy season, this forms an important resource for various purposes. In Goa, most of the mines are located in close proximity of the rivers. When ground water from mine pits which are far below the river bed level are pumped, the base flow getting into the river is cut off besides the river bed itself may go dry if the mine is very close by. Mining in Goa has not only diverted the base flow component from rivers, but the nearby surface water bodies, springs and even soil moisture in nearby agricultural lands have been depleted.

However, some of the above findings have been contradicted by another study conducted by IBM during November 1999 under the study titled"Regional Environmental Assessment of the North Goa Iron Ore Mines", which concluded that;

- Piezometry is controlled by rainfall. A groundwater recharge zone was observed on the higher relief, corresponding to the mining zone in the Cudnem. Hence, pumping in the pits has no regional influence on the water table.
- Most of the ground water analysed show the presence of coliform and Manganese content above the drinking water standards.
- Interpretation of piezometric variation and conductivity data show that pit dewatering does not have an impact on sea water intrusion.

Table No. 4.3.3.2.2.1 Ground water quality data near the Iron Ore Mines in the Goa Region

(Unit : mg/l except for pH)

	Parameters ☞	pH	Copper	Iron	Sulphates	Mercury	Cadmium	Lead	Zinc	Chromium(Hexa)
Annual Average	**Maximum**	8	0.191	1.14	36.73	0.00093	0.008	0.031	0.96	0.022
	Minimum	5.4	0.001	0	0.001	0.00046	0.002	0.001	0.019	0.001
	Average	7.25	0.02	0.23	6.81	0.0006	0.0035	0.0043	0.36	0.01
	No. of Observation	45	57	65	37	11	35	34	61	39
Monsoon	**Parameters ☞**	**pH**	**Copper**	**Iron**	**Sulphates**	**Mercury**	**Cadmium**	**Lead**	**Zinc**	**Chromium(Hexa)**
	Maximum	6.6	0.191	0.51	17.46	0.00093	NM	0.008	0.893	0.006
	Minimum	5.4	0.002	0	0.001	0.00046	NM	0.002	0.035	0.005
	Average	6.05	0.0276	0.18	3.73	0.0006	NM	0.0052	0.291	0.0053
	No. of Observation	4	17	24	19	11	NM	13	20	3
Non Monsoon	**Parameters ☞**	**pH**	**Copper**	**Iron**	**Sulphates**	**Mercury**	**Cadmium**	**Lead**	**Zinc**	**Chromium(Hexa)**
	Maximum	8	0.18	1.14	36.73	NM	0.008	0.031	0.96	0.022
	Minimum	6	0.001	0.05	1.39	NM	0.002	0.001	0.019	0.001
	Average	7.37	0.0202	0.26	10.07	NM	0.0035	0.0038	0.393	0.0055
	No. of Observation	41	40	41	18	NM	35	21	41	36

Note : NM – not monitored

4.3.3.3 Impacts on Land, Topography and Forest

Goa has a total surface area of 365,000 ha out of which approximately 6,000 ha is covered by the mining concessions (about 70 mines) which are active and contribute more than 80% of the total iron ore production from Goa. It is estimated that the land required for mining of 1Mt of ore will be 9 ha and about 1850ha of land would be affected by mining operation during 1997 – 2012. The land requirement is basically for expansion of mining pit area, dumps for ore and waste material and tailings pond.

The topography of all the areas to be utilised for mining will obviously be altered. The small sizes of the dumps with steep slopes and the pits changes the landscape of the area, substantially. Most of the waste dumps are up to 50 meters high with steep slopes due to scarcity of land availability near the mines. The wastes are estimated to be generated at a rate of around 45Mt each year and the dumps are either located on flat land or hill slopes. The high over burden-to-ore ratio in the region makes the waste disposal a problem and coupled with scarcity of land availability (as normally the leases are restricted to 100 ha) near the mines, it results in a tendency to scatter the dumps wherever land is available in an unplanned manner. The waste dump rehabilitation has become an integral part of the mining activity of Goa. This is normally been accomplished through surfacing, terracing, final shaping and developing the drainage network and the practice vary from very rudimental to good, depending on the concerned mines. Some of the mines like Codli and Bicholim are using some excellent innovative methods like use of geo-textiles and stone pitching for the slope stabilisation , while most of the mining companies are adopting plantation on the natural slope dump having more than 30^o slope angle, without reducing the dump slope to around 20-23 degree. From a study of satellite imagery (1997) and aerial photographs (1988), it was reported that an area of approximately 300 ha of waste dumps have been partially or fully vegetated. There was a backlog of 833ha of dump area for rehabilitation and in-addition 315 ha of land likely to be damaged during next 10 years needs to be rehabilitated.

The surface run offs from the waste dumps affect the agricultural lands nearby due to saltation and it was estimated during eighties that around 250ha of agricultural land located close to the mines had been adversely affected. The estimate increased to 320ha that have been affected due to surface run off from the waste dumps during 1997.

Forest ecosystem in Goa, according to the latest land use classification (Govt. of Goa, 1995), occupy an area of 125,473 ha constituting over one third (34.8%) of the total geographical area of the state; forestry being a major land use next only to agriculture (138,091 ha). The actual forest cover in the state, however, is of the order of 125,000 ha (Forest Survey of India, 1996). Almost 94% of the total forest area in the state is confined to the four Talukas of Sanguem (56.924 ha), Satari (28.099ha), Canacena (18.581 ha) and Quepem (11.491 ha), while the three talukas of Sanguem (56.924ha), Satari (28.099 ha) and Bicholim (808 ha) contain about 70% of the total forest area. Goa presents a wide range of altitudes, slopes, drainage which coupled with abundant rainfall and high humidity give rise to a variety of locality factors reflected in the occurrence of a number of forest types from tropical evergreen to mangrove forests. The coastal tracts with marine alluvium are mainly covered by palms. The borderline of Arabian Sea and the west coast are thickly palm-fringed with a small area covered by mangroves. Patches of scrub vegetation with other xerophytic species are found in association with tropical fruit trees like jackfruit and cashew.

Most of the mining areas in the state are confined to Laterite Thorn Forest type, which consists of irregular open scrub of stunted trees of deciduous habitat and thorny trees. The undergrowth is thin and xerophytic. Soils are dry and shallow with outcrops of laterite. At places the underlying laterite is soft and extracted for commercial purpose. Mainly the species of this type are *Terminalla paniculate, Careya arborea, Buchanania lanzan, Bridelia retusa, Lannea coromandalica, Strychonos nux-vomica, Randla dumatorum*, and *Phyllanthus emblica*. However other important species like Shisham, *Terminalias,* bamboos, canes, *Xylia xylocarpa, Adina cordifolia, LagerstroeMta paryflora*, teak, *Rhizophora mueronata* are also found in the various forests types.

The total forest area affected by the mining during 1988-1997 has been estimated at about 2500 ha and about 100 ha. more of the forest area will be affected by mining during next 10 years. Department of forest under the State Government is aware of the problem and insisting the mining authorities to pay for the compensatory afforestation in double of the forest land leased for the mining activities.

4.3.3.4 Impacts on Community

The development of Goa is mainly related to mining activities between the Second World War and the 1970s when some 12% of Goa's economy was related to mining. In 1994, this figure had dropped to `8%, although ore production saw an increase from 13Mt in 1990 to 18Mt in 1997. Most of the iron ore is exported (Japan – 56%; Europe – 21%; Korea – 9%). Since the 1970s, Goa's economy has been diversified as given below (figures are in %):

Sector	*1971*	*1991*
Agriculture	23.6	25.9
Forestry and fishing	2.9	5.9
Mines and quarries	54.9	14.5
Secondary	12.9	29.6
Tertiary	12.9	26.8

The employment created by mining activities concerns 37% of the working population (65% directly and 35% indirectly), compared to 35% for the agricultural sector.

The inhabitants of this region have a high percentage of literacy (62%). Population is relatively stable with more than 60% present in the region since more than 20 years and a recent immigration rate is less than 12%.

The views of the villagers near the mining areas of Goa indicate that they would not like increased mining activity in their areas, however the economic dependence of the locals on mining can not be ruled out. Besides direct and indirect employment in the mines, the mining companies are also involved in lot of community development projects in the area. Many of the villages in Bordem, Sangod, Sigao, Darbandora, Cormonrm, Surla, Pale, Velguem and Ponocem area, where presently extensive mining is being carried out, are supporting the mining because of the following reasons:

- To the people of these villages, mining is a means of providing employment to the local people and thus it is felt that by encouraging mining in village; local people are likely to prosper through greater employment opportunities.

- The dependence of people on mining is largely due to the lack of other avenues for employment.
- Large tracts of the village are either owned or leased to mining companies; therefore, there is insufficient availability of land to undertake other forms of development activities.
- Some of the mining companies have provided the local community with certain of amenities which has led to an improvement in the relationship between the community and the mining companies. For example, the water pipeline provided to Ponocem by a mine company. Besides, some mining companies have made their pit water available for irrigation of village fields.

However, majority of the population has expressed their concern over expansion of mining in Goa. Normally, the villages located below the mining areas like that of the village Mulgao, oppose mining activity because of siltation of their agricultural fields from the surface run-off from the waste dumps. In addition to the problem of siltation, there is another more real fear that of mine related accidents. There is incidents that due to the collapse of the Dempo mine benches that led to a flood of water which caused the death of 5 persons of the nearby village. The villagers also have perceived that the shortage of fuel wood is the direct consequence of increased mining activity in the area. Besides, the local people also suffer from dust pollution, water pollution and shortage of water availability. For example, Sonshi village is located in the very heart of the mining activity in the village. The houses are surrounded by mine dumps, most agricultural fields and cashew plantations are destroyed and dust pollution caused by the continuous movement of trucks and the proximity of dumps has made the lives in this village an ordeal. Households of Vaguriem view mining as an activity that has provided no benefits for the people of the village and only contributed in terms of greater water and dust pollution and destruction of land. Most of the villagers, those who oppose mining activity, have identified the increased incidence of ill health and morbidity as one of the negative impacts of mining.

4.4 CENTRAL ZONE (CHHATTISGARH)

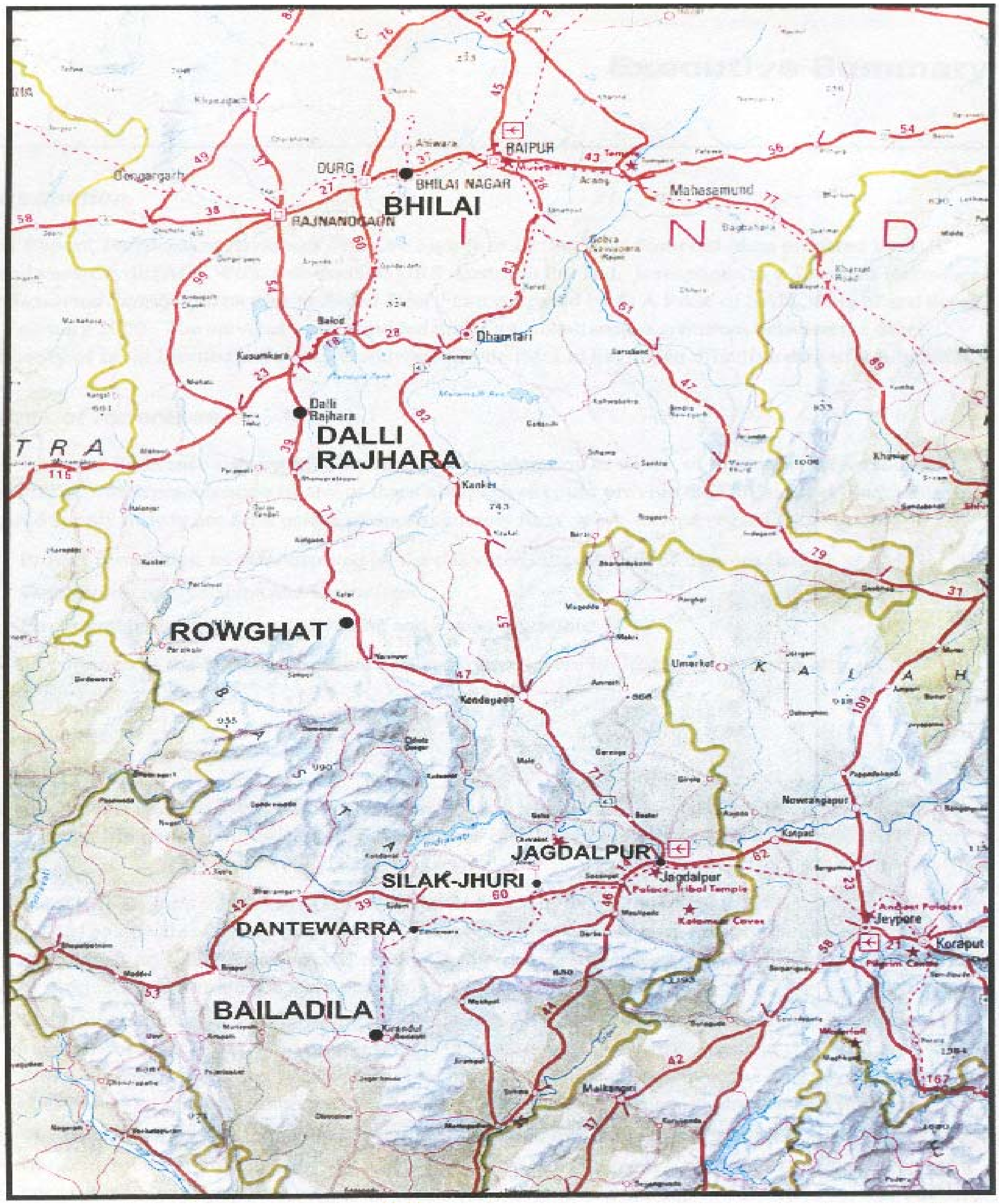
Geographically, the state of Chattisgarh is located in the middle of India and is a part of the erstwhile Madhya Pradesh. Large deposit of excellent quality iron ore are found in the Bailadila (Bastar), Durg and Rowghat regions of the state. Presently the working iron ore mines in this area are all public sector undertaking, belonging to Bhilai Steel Plant (BSP) of Steel Authority of India Limited (SAIL) and Bailadila Iron Ore deposits of National Mineral Development Corporation (NMDC). The total numbers of working mines in this area were 11, 6 numbers belonging to NMDC and rest 5 to SAIL. Out of these, 3 mines of NMDC (all are highly mechanised) and 5 of SAIL/BSP (2 highly mechanised, 2 semi-mechanised and one manual) reported production during 2005-06. These are mostly mechanised opencast mines, the production of which ranges from 3.5 Mt to 6.6 Mt per annum.

4.4.1 Natural Setting

4.4.1.1 Location and Topography

Bailadila range is a group of hills about 40 km in length and 10 kms wide existing in southern part of Dantewrara district of Chattisgarh. The Bailadila iron ore complex is situated about 414 kms away by an all-weather road from Raipur (MP) and 115 kms from Jagdalpur, the district head quarters of Baster. The area is connected with Visakhapatnam city by rail extending to about 475 kms and 444 kms by road.

Dalli-Rajhara area is located 95Km south of Bhilai Steel Plant. The Mines formed in continuation with a series of hills of Bastar Area. Geologically the deposits are Hematitic rich with iron ore with iron grades of +64% Fe. The location map of the area is given below. The area is connected by State Highway no.9 through Rajnandagaon and Jagdalpur and also linked to Durg by a broad gauge railway line. The location map is given below:



The topography of the area covered by these iron ore deposits is mostly hilly terrain with undulating plains.

Geo-morphologically, the terrain of the Bailadila is characterized by relict hill ridges with cliffs due to hard resistant ore body or iron formations, terraces formed by lateritisation at elevations of around 1000 to 1100 metre above MSL and deflected profile due to the above. These reflect a more mature topographic feature. The highest peak of the area is about 1276Mts above MSL and the entire range approximately forms a Y shape, with the tip pointing north direction. The total range lies between $18^0$40'6"N to $18^0$41'45"N latitudes and $81^0$11'00"E to $81^0$12'23"E longitudes. The Bailadila range is divided into 14 deposits, Deposits 1 to 5 occur in the western range. Deposits 6 to 12 in the eastern ridge, while Dep-13 and 14 in the southern closure of the ridges. The lower undulating plains of elevation varying from 300 meters to 400 metre have occasionally hills rising up to 600 Metres above MSL.

The Dalli-Rajhara area is of hilly terrain. The general ground level is located at 425m RL and the topmost ore benches are at 543m RL. The drainage of the region is controlled by Jharana Nullah, cutting across the Rajhara pahar and Dalli hill. The main iron ore body occurring in the Pandradalli and Rajhara pahar lease area is running in an almost east-west direction with a varying dip of 40^0 to 60^0 due north, extending along the dip slope. The resistant outcrops of iron ore bodies in Rajhara area form conspicuous hillocks and ridges in the general peneplain, giving rise to a saddle type of topography.

4.4.1.2 Climate

The climate of the area is of Sub-tropical type. Rainfall in the Dalli-Rajhara area is strongly seasonal, which averages about 1200 to 1600mm per year; most of it occurring during the monsoon season which extends from June to September./mid October. The temperature ranges from 9^oC in winter to 47^oC in summer.

The climate of the Bailadila area, while similarly seasonal, is much wetter than that of Dalli-Rajhara, with average annual rainfall of 2660 to 3000mm. Low cloud commonly shrouds the mountain tops during July and August, lowering visibility and disrupting mining activities. The temperature of the region is generally moderate with annual day average recording about 24 to 35^oC and the night average to 11- 17^oC. During summer seasons, the climate turns slightly arid with Relative humidity dipping down to about 20% and the temperature rising to about 40^oC. The predominant wind velocity is ranging from 19 to 29 KMPH with SW and NE directions. During monsoon and pre-monsoon seasons, the wind velocities touch as high as 60-70 KMPH.

4.4.1.3 Hydrology

4.4.1.3.1 Bailadila Area

The entire region is a part of the Godavari river basin. There are a number of perennial streams flowing from the hills. The eastern slope of the area drains through streams, which flow towards north east to Sankani river. Drainage in between the eastern and western ridges is through two streams flowing in opposite direction, i.e. Galli nalla towards south and Sankani nalla towards north and their division point exists near Deposit no. 14. Sankani nalla cuts across the eastern ridge near Jhikra village and flows down east and north-east and becomes Dantewada river which ultimately flows west and joins Indravati river. The western slope of the area is drained by Mari nadi, Berudi nadi and other small streams, all of which meet river Indravati at different points. Southern part of the area is drained through Malinger nadi joining Sabori river and Galli nalla to Talperu river, all again flow in to Godavari river.

4.4.1.3.2 Dalli Rajhara Area

The drainage of the region is controlled by Jharana Nullah, cutting across the Rajhara pahar and Dalli hill. Mining and processing activities over a long period have modified drainage patterns in the Dalli-Rajhara area. Large quantities of sediment are removed through erosion of waste rock dumps and other disturbed areas. Numerous catch dams have been established along streams though out the area of operations. These dams, from which sediment is removed each year prior to monsoon season, have proved to be effective in reducing sediment loads in downstream areas.

4.4.2 Mining Operation

Mining is being done with the formation of systematic benches by open cast method with deep-hole drilling (150mm to 250mm dia), blasting with heavy explosives and muck removal with heavy-duty earth moving machines. The overburden and side burden wastes generated are dumped mostly along the hill slopes. A generalised land use in the mines is that 25 to 35% is under quarrying, 2 to 10% under waste dumps and 4 to 15% under plant and other infrastructure facilities. The generation of waste ranges from 0.15 to 0.35 tonnes per tonne of ROM. Waste rock (overburden and intra-burden) is taken by dumpers to the nearest waste rock dump, where it is end-dumped behind the face and then pushed over the face by bulldozer. This "top down" method of waste rock dumping results in marginally unstable slopes at or close to the angle of repose. Presently no simultaneous backfilling operations are being done to accommodate the wastes generated. Mineral processing plants, which include crushing, grinding, screening and classification plants, are also attached to the large mines. For these mines tailing impoundment/dams are also located, mostly outside the mining lease area. These slimes/tailings generated are of the order of 3 to 5% of the ROM produced. The production from the state of Chattisgarh during the year 2005-06 was around 24.75 Mt.

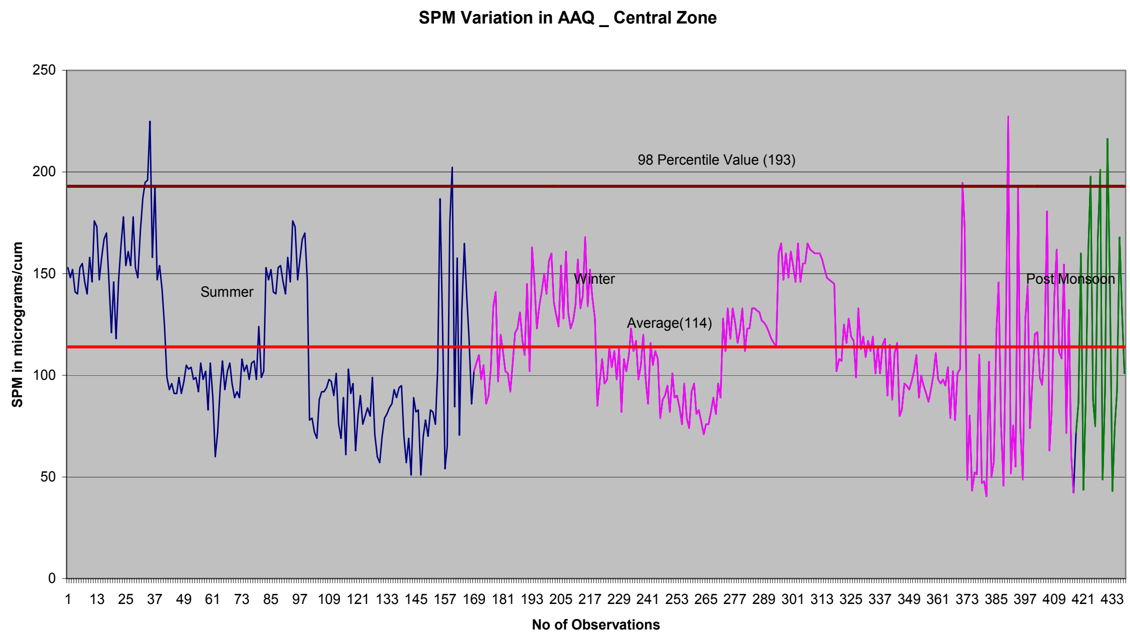
4.4.3 Environmental Impacts

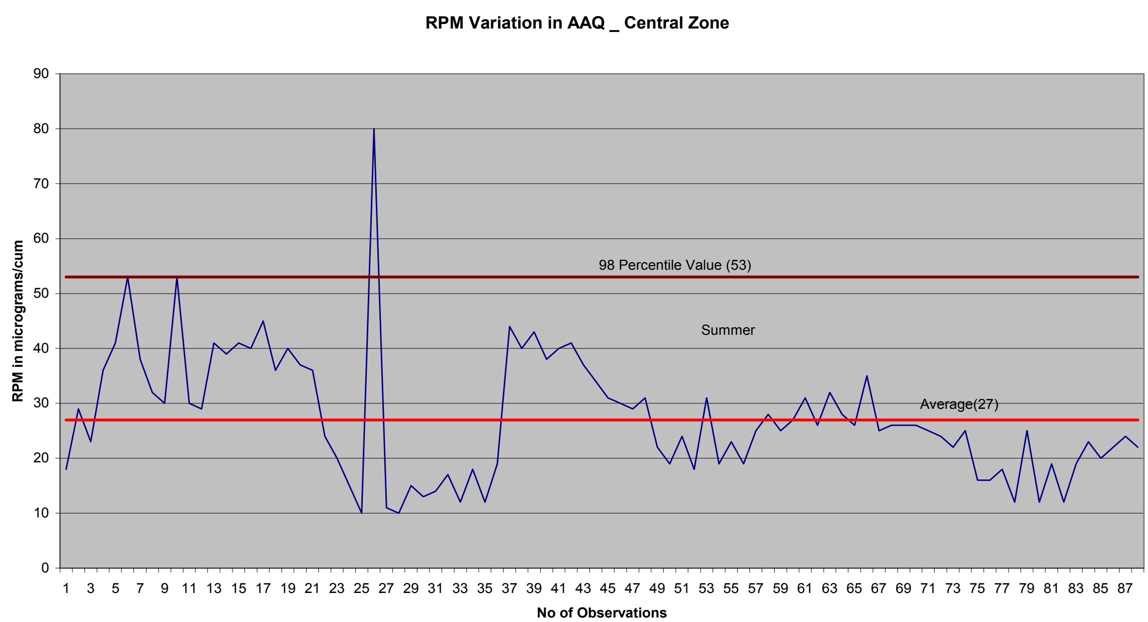
The main significant negative environmental impact due to mining in Chattisgarh (Bailadila and Dalli-Rajhara area) is deforestation, whereas the positive impact being the economic upliftment of these predominantly tribal dominated area.

4.4.3.1 Impacts on Air Quality

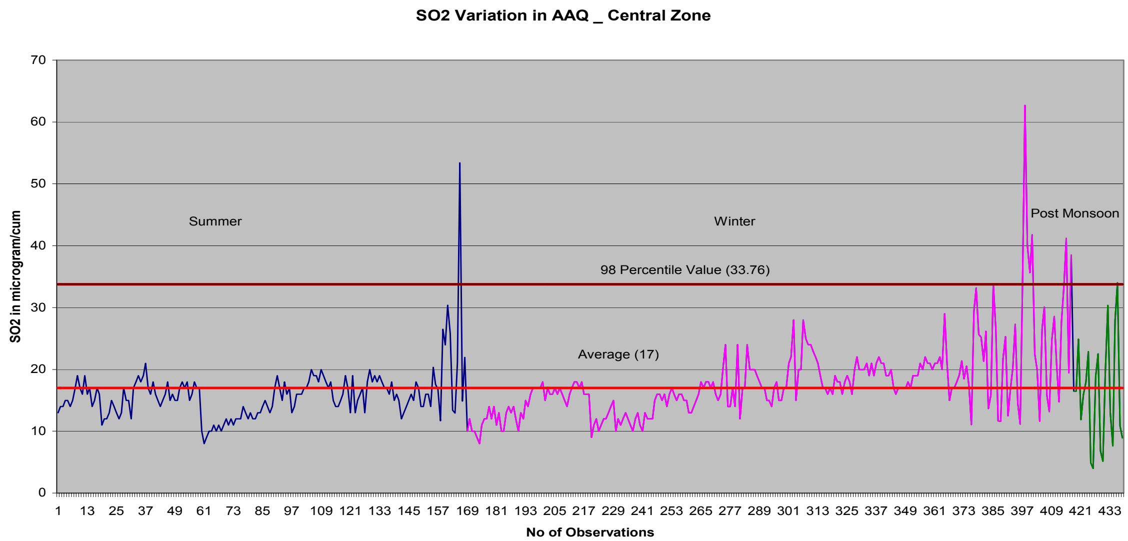
The major air pollution in this region is due to the movement of the earth moving machineries, blast hole drilling and predominantly by the ore processing plants. Here again the dusts are the single largest pollutant observed. The existing levels of air quality in the region as per the air quality monitoring data collected from the individual mines visited and generated by different agencies and concerned mining authorities are discussed below:

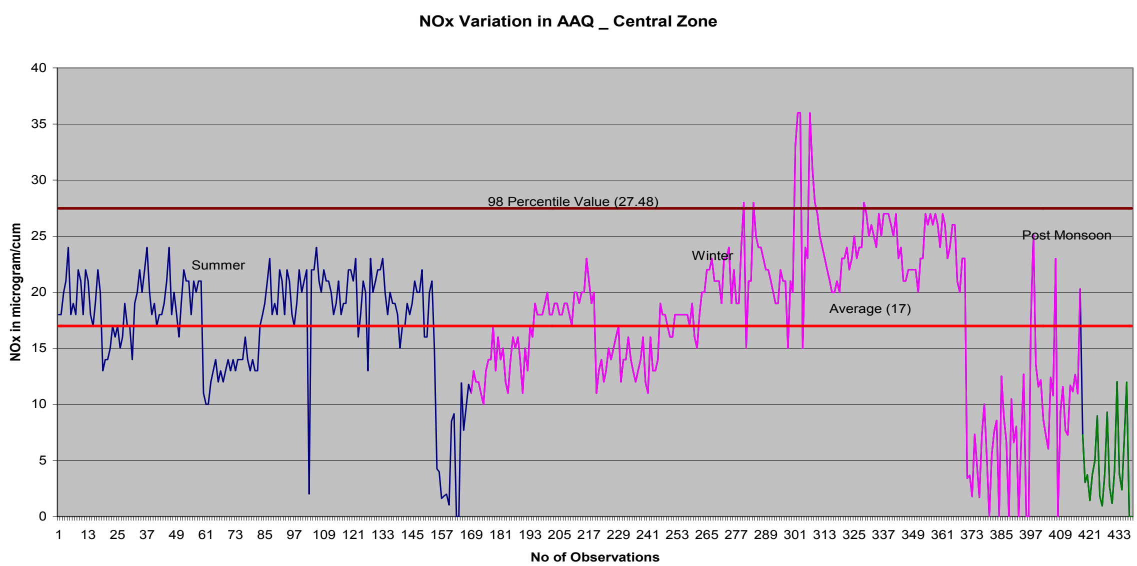
The annual average of total dust (SPM) and RPM concentration observed in the ambient areas in the region were 114$\mu g/m^3$ and 27$\mu g/m^3$ respectively. The maximum SPM and RPM concentration observed in the ambient areas were 227$\mu g/m^3$ and 80$\mu g/m^3$ during winter and summer, respectively. The 98 percentile values of the SPM and RPM were 193 $\mu g/m^3$ and 53 $\mu g/m^3$ The annual variation of SPM & RPM in the ambient are shown graphically in the following graphs.





The values of SO_2 and NOx in the ambient were observed as insignificant. The maximum values recorded in the ambient air quality for SO_2 and NOx were 63 µg/m^3 and 36µg/m^3, respectively. The 98 percentile and average values of SO2 were observed as 33.76 µg/m^3 and 17 µg/m^3, respectively. The 98 percentile and average values of NOx were observed as 27.48 and 27.48 µg/m^3 and 17 µg/m^3, respectively. The variations of SO_2 and NOx in the ambient air are shown in the graphs below:





Regarding workzone air quality in the Central region, the annual average total dust(SPM) and RPM concentration were 217 μg/m^3 and 66 μg/m^3 respectively. The maximum SPM and RPM concentration observed in the workzone, was 618 μg/m^3 and 112 μg/m^3 during winter and summer respectively. The annual 98 percentile values of SPM and RPM were calculated to be 387 μg/m^3 and 94 μg/m^3, respectively. The annual average of SO_2 and NOx were 21 μg/m^3 and 25 μg/m^3 respectively.

The summarised data are given in the tables below for Ambient Air Quality and Workzone Air Quality, where as the details are placed in a separate booklet.

Table No. 4.4.3.1.1 Summary of findings for AAQ Monitoring in the Central Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	227	225	227	216	114	114	116	117	41	51	41	43
RPM	80	80	-		27	27			10	10		
SO2	62.68	53.4	62.68	33.99	17	15	16	16.24	BDL	8	8	BDL
NOx	36	24	36	12.02	17	18	20	4.95	BDL	BDL	BDL	BDL

Table No. 4.4.3.1.1 Summary of findings for AAQ Monitoring in the Central Zone (Cont'd)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	193	194	168	210	438	168	249	21
RPM	53	53			88	88		
SO2	33.76	25.16	35.76	32.54	438	168	249	21
NOx	27.5	23.7	28.54	12	427	166	242	19

Table No. 4.4.3.1.2 Summary of findings for Workzone Air Quality Monitoring in the Central Zone

Parameters	*Maximum Value ($\mu g/m^3$)*			*Average Value ($\mu g/m^3$)*			*Minimum Value ($\mu g/m^3$)*			*98 Percentile Value ($\mu g/m^3$)*			*No. of Observations*		
	Annual	*Summer*	*Winter*	*Annual*	*Summer*	*Winter*	*Annual*	*Summer*	*Winter*	*Annual*	*Summer*	*Winter*	*Annual*	*Summer*	*Winter*
SPM	618	344	618	217	218	197	107	121	107	387	313	400	786	402	384
RPM	112	112		66	66		30	30		94	103		216	216	
SO2	37	32	37	21	22	20.21	9	9	10	28.45	30	33	784	402	382
NOx	46	41	46	25	26	21.97	12	14	12	35	38	43	786	402	384

It can be observed form the above analysis, air pollution (dust pollution) is not a major issue in the area. The mining authorities are practicing wet drilling, water sprinkling at the mine haul road, water spraying at the hopper of the crusher plants, mist spraying at the fines dumps and covered conveyors. The dust control practice at the Bailadila mines can be rated as one of the best in the country's iron ore mining industry. These have already been discussed in detail in the Interim report.

4.4.3.2 Impacts on Water Quality

Single largest source of water pollution in the area is the wash offs from the waste dumps. As most of the mining sites are located almost along the hill ranges, the waste dumps are being located along the hilly slopes. These dumps along with the exposed mining areas on the hill tops are prone for wash off during heavy rains, silting nearby water courses and damaging the soil quality of the nearby agricultural fields. Even though, the water flow in the nallahs is mostly seasonal, their flow in the monsoon season can be observed to be very turbid with reddish colour resulted from the wash of iron ore fines.

The data collected from different iron ore mines on the effluent and surface water quality are summarised below.

Table No. 4.4.3.2.1 Effluent Quality for Iron Ore Mines in Central Zone

(Unit: mg/l except for pH)

	Parameters ☞	TSS	pH	O&G	Cr^{6+}	Iron	Sulphates	Manganese
Annual Average	Maximum	200	8.1	18	BDL	2.8	8.5	0.1
	Minimum	7	5.61	0	BDL	0.04	0.6	0.1
	Average	37.05	7.21	3.25	BDL	0.51	4.04	0.1
	No. of Observations	70	79	73	77	78	71	19
Monsoon	Parameters ☞	TSS	pH	O&G	Cr^{6+}	Iron	Sulphates	Manganese
	Maximum	200	7.51	8	BDL	2.8	8	BDL
	Minimum	8	5.61	0	BDL	0.14	2	BDL
	Average	55.29	6.96	3.2	BDL	0.84	4.57	BDL
	No. of Observations	7	11	6	9	10	7	9
Non monsoon	Parameters ☞	TSS	pH	O&G	Cr^{6+}	Iron	Sulphates	Manganese
	Maximum	80	8.1	18	BDL	1.9	8.5	0.1
	Minimum	7	6.31	0	BDL	0.04	0.6	0.1
	Average	33.59	7.25	3.26	BDL	0.46	3.96	0.1
	No. of Observations	63	68	67	68	68	64	19

Although the maximum Suspended Solids in the effluents were observed as 200 mg/l during monsoon, the average was only 37 mg/l as against the norm of 100 mg/l. Similarly, the maximum Oil & Grease in the workshop effluent was observed as 18 mg/l, but the average was only 3.25 mg/l. The pH and Iron were always found below the existing standards.

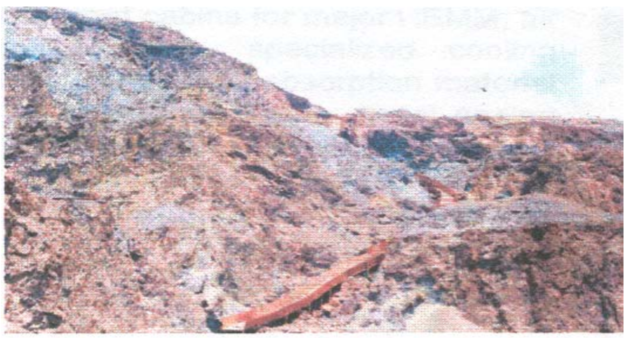
Table No. 4.4.3.2.2 Surface Water Quality near the Iron Ore Mines in Central Region

(Unit: mg/l except for pH)

	Parameters ☞	**pH**	**Sulphates**	**Zinc**	**Iron**	**Cadmium**	**Copper**	**Chromium (Hexa)**
Annual Average	**Maximum**	8.4	13.1	0.69	4.49	0.18	BDL	BDL
	Minimum	6.1	0.4	0.005	0.02	0.02	BDL	BDL
	Average	7.41	3.28	0.13	0.52	0.05	BDL	BDL
	No. of Observations	181	181	181	181	178	181	178
Monsoon	**Parameters ☞**	**pH**	**Sulphates**	**Zinc**	**Iron**	**Cadmium**	**Copper**	**Chromium (Hexa)**
	Maximum	7.5	5	BDL	0.51	BDL	BDL	BDL
	Minimum	6.26	2	BDL	0.05	BDL	BDL	BDL
	Average	7.01	3.75	BDL	0.18	BDL	BDL	BDL
	No. of Observations	16	16	16	16	13	16	13
Non Monsoon	**Parameters ☞**	**pH**	**Sulphates**	**Zinc**	**Iron**	**Cadmium**	**Copper**	**Chromium (Hexa)**
	Maximum	8.4	13.1	0.69	4.49	0.18	BDL	BDL
	Minimum	6.1	0.4	0.005	0.02	0.02	BDL	BDL
	Average	7.45	3.23	0.1284	0.56	0.0489	BDL	BDL
	No. of Observations	165	165	165	165	165	165	165

The mining authorities have taken several steps in controlling the surface wash offs by constructing check dams, buttress walls around the toe of the waste dump, chain linked boulder mesh walls around the toe of old fine ore dumps, trench cutting and provision of garland/ storm water drainage network, provision of steel launders for properly routing mine drainage etc. They have also constructed effluent treatment plants for controlling the oil and grease flow to the natural streams from their workshops. These have been discussed in detail in the Interim report for each of the mine visited. However, to prevent wash-off, causing water pollution from the mine/waste dumps, it is necessary to follow:

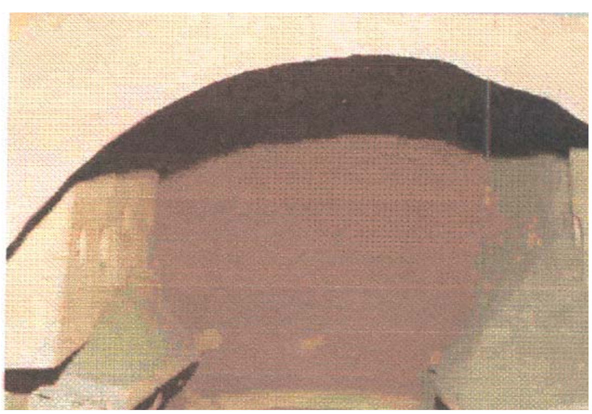
- Protecting peripheral waste dumping with suitable strong retaining walls and simultaneous afforestation over the peripheral surface.
- Design the waste dumps with intermittent berms to reduce their overall slope angles below the angle of repose.
- Creating thick peripheral afforestation around the waste dumps to prevent form of air-borne dust, due to wind blow.
- Developing garland drains surrounding the waste dumps as well as surrounding the quarries to collect the wash-off / run-off.
- Construction of sedimentation ponds for the mine / dump & plant discharge water.
- Consideration of strong check dams in all nallas, passing through the lease area, to reduce sediment pollution load and also to improve up on the recharge for the ground water system.



Discharge of mine water through steel launders

4.4.3.3 Impact of Noise and Ground Vibration

Though the mines are practicing deep-hole drilling and blasting, the blast induced ground vibrations may not affect the residential villages, as they are quite far away. But they may affect ground water aquifer system. Thus, this have an important bearing on the existing forest in this area, as these plants / trees depend upon the ground water, which occur as a water table immediately below the earth surface. Further, these blasting operations produce impulsive noise that may affect the wild life habitat existing in the nearby forest area. Also the noise produced by earthmoving machinery and the mineral processing plants, to a major extent, effect the stillness for the forest area.



Rubber Padding at Transfer Points for reducing the noise

4.4.3.4 Impacts on Land, Topography and Forest

The topography of the area covered by the iron ore mines in Baster and Durg districts of Chattisgarh is mostly hilly terrain with undulating plain. Mining in these areas results in the destruction of the existing vegetation and soil profile, thereby affecting the topography, forest and ecology of the area severely. Removal of overburden and waste rock and its replacement in waste dumps have significantly changed the topography and stability of the landscape of the area. "Top down" dumping practices are being followed in these areas for waste rock disposal, where the waste rock is dumped over steep slopes. Retaining walls have been constructed to limit the down slope encroachment of the dumps. Mining authorities have taken a lot of initiatives in the area for stabilization of these waste dumps and rehabilitation of the area mainly through afforestation.

Afforestation is carried out in the Dalli-Rajhara area, by the Social Forestry Unit of Madhya Pradesh State Government. Efforts are directed almost entirely to the establishment of trees, which are planted at the rate of 2,500 per hectare. Survival rate is reported to be 92 % to 95 %. The contract requires replacement of any plants that die within the first five years. Seeds are reported to be all obtained locally, although many of the 20 to 30 species are exotics. Seedlings are raised in a nursery located in Rajhara. Labouring work is all done by locally recruited people, under the direction of professional foresters. Seedlings are planted in 45 cm diameter by 45 cm deep holes, back filled with a mixture of transported high-quality soil, topped with cow manure. Subsequently, nitrogen / phosphorous fertilizer is applied annually. Plants are watered at intervals throughout the dry season, at a frequency that depends upon the weather, but as often as alternate days. Essentially the same techniques are used for afforestation of disturbed areas around town sites, infrastructure areas, mining areas and waste dumps, although the town site plantings include more ornamental plants. Those responsible for the work report that the results that can be achieved on waste rock dumps are comparable to those on natural sites, but that this is the case only where there is strict attention to detail.

Rehabilitation practices being followed in the Bailadila region are pretty similar to those at Dalli-Rajhara. Only small areas of waste rock dump surface have been rehabilitated, as quantities of waste rock produced to date have been relatively small. However, extensive afforestation has been done, particularly surrounding the access roads, avenue roads, colonies and processing facilities.

The Bailadila forest is fairly dried dense supported by good rainfall and is rich in flora and fauna. The hill tops, however, is barren due to rocky out crops and lack of soil, but supports only scrubs, grasses and stunted trees. The mining activity is mostly confined to these areas. Most of the mining leases in both Dalli-Rajhara and Bailadila are covered under forest area. Out of the total lease area of 6629.192 hectares (2703.62 ha of BSP and 3925.572 ha of NMDC) under the iron ore mines, 81.7 % (2021.62 ha of BSP & 3393.822 ha of NMDC) falls under reserve forest area. A study conducted by a committee constituted by MoEF during March'1998 consisting of representative from Forest Survey of India (FSI), Botanical Survey of India (BSI), Indian Bureau of Mines (IBM), Geological Survey of India (GSI), National Remote Sensing Agency (NRSA), Indian School of Mines (ISM), Federation of Indian Mining Industries (FIMI) and SAIL found out that a total of 14,111 ha of forest cover exist over the iron ore mining lease area in the state in three districts, the details of which is presented in the table below. The findings were based on using remote sensing and GIS.

Table No. 4.4.3.4.1 District wise forest cover over iron ore mining leases in Chattisgarh

District	Lease Area (ha)	Forest cover (ha)		
		Dense	Open	Total
Baster	13,470	9,839	1,818	10,657
Durg	1,942	604	150	754
Rajnandgaon	1,944	1,416	284	1,700

Corollary temporal study of satellite data showed that there is an increase in the forest cover in the Bailadila area due to the rehabilitation measures taken by M/s NMDC. The LANDSAT-TM data for October'1989 and IRS-IB LISS II data for June 1997 was analysed to detect the change in the forest cover. The study revealed about 10% gain in the forest cover in the lease area during the period. The details as given in the Table No. 4.4.3.4.2 below:

Table No. 4.4.3.4.2 Forest Cover in Bailadila Iron Ore Mine lease

Period	Lease area (ha)	Dense Forest (ha)	Open forest (ha)	Total forest (ha)	Non-Forest area (ha)
1989	8514	512	1623	6744	1770
1997	8514	5961	1474	7435	1079
Change		+ 840	- 149	+ 691	- 691

However, it is observed that the ecological principles were not taken into account while carrying out the rehabilitation of the mines out areas and the waste rock dumps in the reserved forest areas, which require a completely different approach, and the utilization of substantially different procedures from those being carried out at both Bailadila and Dalli-Rajhara. Current rehabilitation is principally directed at restoring visual amenity, stabilizing disturbed areas and growing trees that will prove useful to the future generations. Rehabilitation practices for Reserved Forests, while also meeting these objectives, should also aim to restore the native forest in all its diversity. Restoration of the forest vegetation requires re-establishment of all forest components, not only trees. The rehabilitation programme in these areas should take into account the growing of exotic species.

4.4.3.5 Impacts on Community

In terms of social and community factors, the Dalli-Rajhara and Bailadila operations are similar. Both support quite large local communities that are totally dependent on mining and the processing operations. The mining areas were mainly inhabited by the tribal people. Due to the mining operations, the tribal communities have been exposed to both the positive and negative impacts of urbanization. Better health care, education, living standards being some of the benefits the locals had got due to the mining. NMDC has favoured the recruitment and employment of the local tribal people who constitute more than 40% of the workforce at Bailadila. Similarly, SAIL/BSP employs several thousand tribal people directly and indirectly, in the mines. Besides, the mining authorities are spending lot of money on the development of the peripheral villages by providing free health check-ups, medicines, schooling, approach roads to the villages, drinking water by constructing bore well etc. However, the rights of the indigenous community and the impacts of the development on people, who by conscious choice or circumstances follow traditional life styles, constitute some of the most controversial and difficult issues facing the worldwide mining industry.

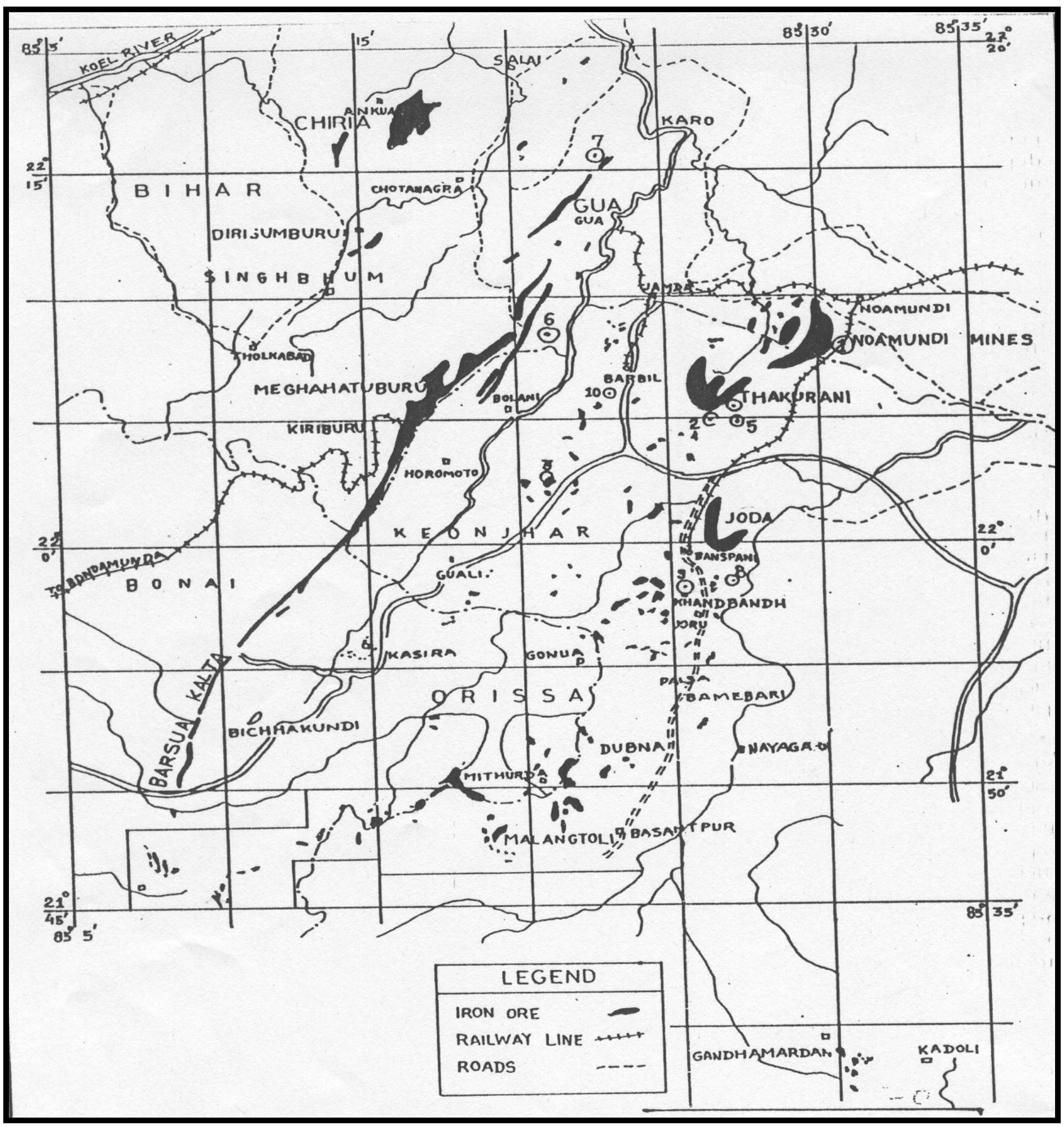
4.5 EASTERN ZONE (ORISSA – JHARKHAND)

In this area more than 67 Mt of iron ore is produced from the Eastern Region of Jharkhand-Orissa belt known as Singhbhum-Keonjhar-Bonai group of iron ore deposits during the year 2005-06. Apart from the captive mines of major steel producers like SAIL, TISCO, IISCO and Jindals, a large number of other private operators extract iron ore from this area. There are 102 reporting iron ore mines operating in Orissa & Jharkhand states at present.

4.5.1 Natural Setting

4.5.1.1 Location and Topography

The iron ore deposits of the Singhbhum- Keonjhar- Bonai group form an important group of iron ore deposits in India and occur in a series of prominent hills stretching from south - western part of Singhbhum district of Jharkhand into the Keonjhar and Sundergarh districts of Orissa within an area of 1,550 sq. km. The location of the deposits are shown in the map below:



The main Bonai iron ore range, nearly 48 km long, starts in Sundergarh district from a point near Routha to about 4.8 km south - west of Gua. This range is capped for the most part by massive haematite, which is continuous except for short breaks at three or four places. Laterisation of cappings is evidenced but not pronounced. In the northern part of this range, there are parallel ore bands, which may represent repetition of the same zone due to folding and faulting. The parallel ranges are capped by high-grade ore beyond and north of Gua and these represent the crests of parallel isoclinal folds. Some larger ore bodies of this region are situated in the hills/Pahar of Budhaburu, Bogordmburu, Kotamatiburu, Meghahatuburu, Parshriburu, Raijoriburu, Thakurani Pahar, Bara Pahar, Banspani Pahar and the hills near Kurband. The well-known workable deposits of both Keonjhar and Sundergarh districts are Malangtoli, Bolani, Banspani, Barsua, Joda Thakurani, Murgabera, Khandadhar and Kalta, where as the most important deposits of Singhbhum district are Noamundi, Gua, Barajamda, Kiriburu, Meghahatuburu, Manoharpur and Chiria. The topography of the area is of hilly undulating terrain covered with dense sal forest.

4.5.1.2 Climate

The entire area essentially comes under tropical monsoon climate. The climate of the area is characterised by three main predominant seasons in the year. The climate is with hot and dry summer having high humidity prevailing almost rounds the year. It has short humid winters. Normally there is heavy rainfall during south west monsoon and that of light rain during the pre-monsoon periods. The south west monsoon usually onsets during second week of June and retreats by mid September.

Climatically the area experiences with four distinct seasons.

1. Pre Monsoon Period: This is the hot season which starts from the month of March and remains till May.
2. Monsoon Period: South west monsoon onsets causing rain during this period and starts from mid June till September.
3. Post Monsoon Period: Though there is no distinct feeling of this period which starts just after monsoon period i.e. October and remains till November when the cold season starts.
4. Winter Period: December to March is the cold season and known as winter period.

4.5.1.3 Hydrology

The drainage of the area is controlled by two major rivers, namely Koina and Karo flowing on the West and East respectively. These rivers, perennial in nature, along with their respective feeder nallahs of second and third order, constitute the drainage system of the area. Both the river flow independently for fairly long distance till they join the main river Koel, which ultimately drains out to river Brahmani. Karo river flows on the eastern slopes for 4.8 -6 km. in Orissa State along the Orissa Jharkhand border and, thereafter, flows into Jharkhand. The important tributaries of the Koina are Sankoja, Gagirathi, Prospecting nalla, Sasangda, Pardih, Rangring and Meghahatu nalla. Many of these tributaries originate, in fact, from fresh water springs emerging at 600- 620 RL on the slopes of this range. These springs/ nallahs flow into the Koina river. These nullahs not only sustain the wild life but also supply drinking water to the township and industrial water to the mines. Most of the hill streams originating in this area maintain a flow of water throughout the year thus perennial in nature owing to the presence of large laterite plateau and dense vegetative cover as compared to other parts of the district.

4.5.2 Mining Operation

Iron Ore mining in the area is being done by opencast method and is a combination of both large mechanised mining by SAIL, TISCO, IISCO & OMC and small manual and semi-mechanised mining by private mine owners. There are around 82 operating iron ore mines in the state of Orissa and 20 operating mines in the state of Jharkhand. The large mining companies, mostly public sector and big corporate bodies are operating with their own ore processing units, whereas small manual mine owners are sometimes using common crushing and screening units or have their most rudimentary crushing units.

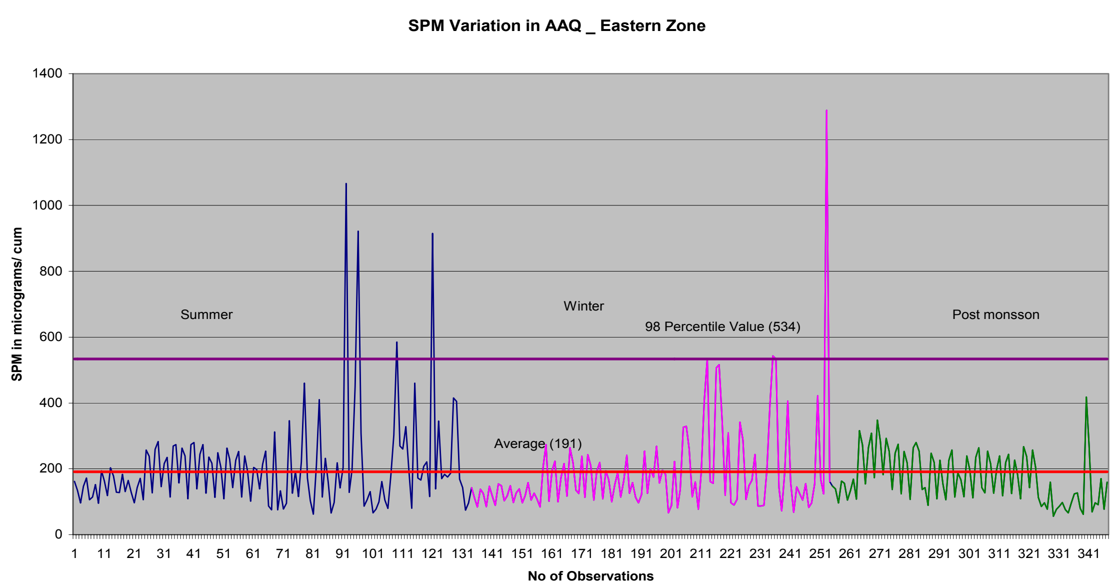
4.5.3 Environmental Impacts

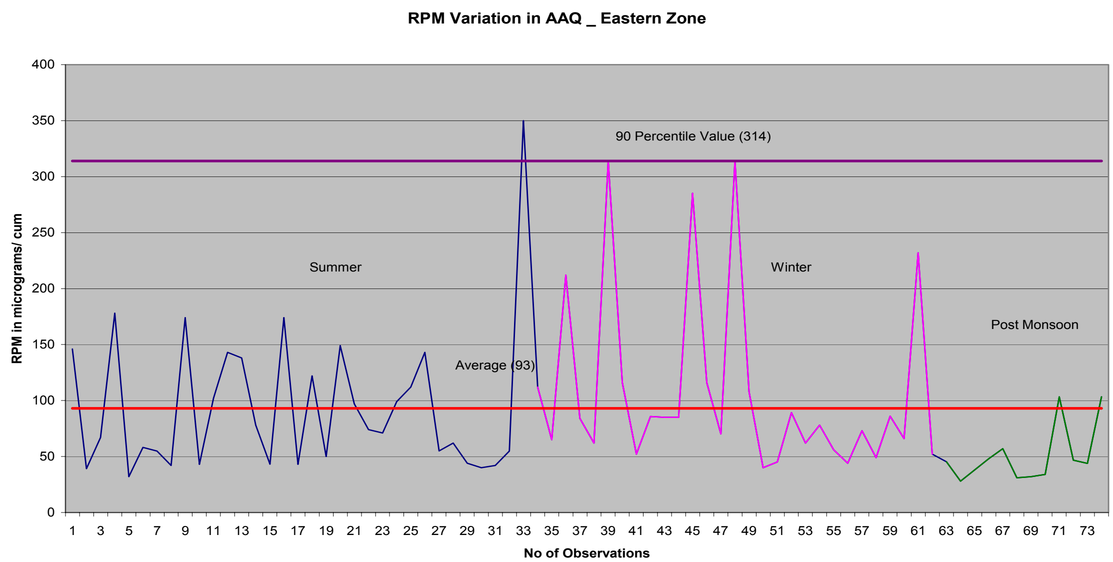
The significant negative environmental impact due to mining in this area is deforestation, change in land use pattern and land degradation whereas the positive impact being the economic upliftment of these predominantly tribal dominated area. In the following sections a generalised environmental impacts are discussed due to iron ore mining in the region based on collected information, study reports and field visits.

4.5.3.1 Impacts on Air Quality

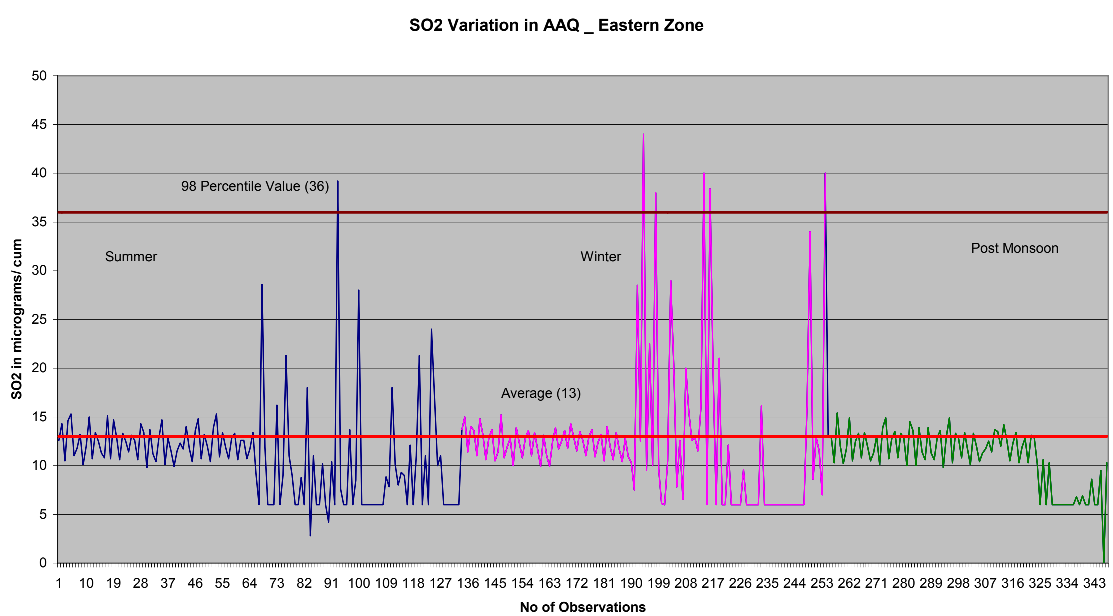
The major sources (areas, operations and activities) responsible for dust generation due to iron ore mining are from Operation of HEMM, Drilling, Blasting, Excavation, Haul roads due to ore transportation, Mining benches, Hopper due to ore unloading, Crushing Plant , Screening, Transfer points/chutes on ore conveyance, Loading into wagons, Dust around dumping areas, Stock piles, etc. Transportation of ore by tripper trucks through public roads by the private mines is the major contributor in enhancing the dust levels in the region.

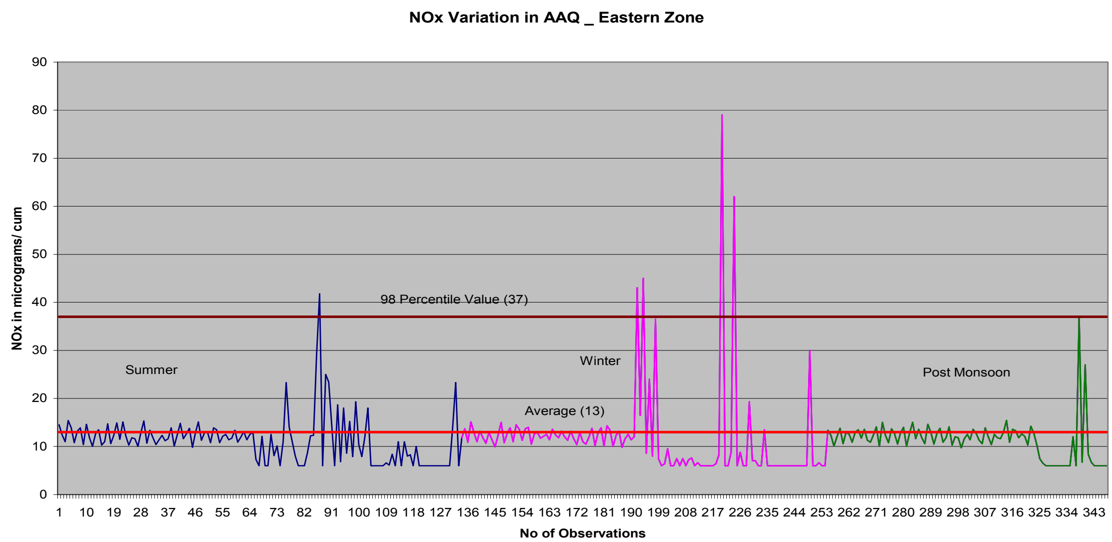
The existing levels of air quality in the region as per the air quality monitoring data collected from the individual mines visited, generated by different agencies and by the concerned mining authorities are discussed here. The annual average total dust (SPM) and RPM concentration observed in the ambient areas in the region were 191 μg/m^3 and 93 μg/m^3 respectively. The maximum SPM and RPM concentration observed in the residential areas were 1289 μg/m^3 and 350 μg/m^3 during winter and summer seasons respectively. The annual variation of SPM & RPM are shown below in the graphs.





The maximum values recorded in the ambient air quality for SO_2 and NOx were 44 μg/m^3 and 79μg/m^3, respectively. The annual average of both SO_2 and NOx were calculated to be 13μg/m^3. The 98 percentile values of SO2 and NOX were observed as 36 μg/m^3 and 37 μg/m^3, respectively. The Lead and CO levels in the ambient were also found to be insignificant. The variations of SO_2 and NOx are shown in the graphs below:





The major air pollution in this region is due to generation of dust from the movement of small private dumpers carrying iron ore lumps from the small privately owned mine to common crushers, which are invariable of dry type crushing and screening without any environmental protective measures. The small mining companies are mainly using the public road as the haul road and the dumpers are observed to be running mostly in overloaded condition. The dumpers are not covered either and the spillage of the material and repeated crushing on the roads by the truck movement add to the dust generation. The nearby villagers are most affected and these dust forms thick slurry after the first monsoon rains and add to the water pollution in the area. However the bigger mining companies are using better air pollution control and management practices like wet drilling, water sprinkling at the mine haul road, water spraying at the hopper of the crusher plants, mist spraying at the fines dumps and using covered conveyors and thereby minimizing dust dispersion to the nearby residential areas.

Regarding workzone air quality in the Eastern region, the annual average total dust (SPM) and RPM concentration were 305 $\mu g/m^3$ and 215 $\mu g/m^3$ respectively. The maximum SPM and RPM concentrations observed in the workzone, were 2531 $\mu g/m^3$ and 697 $\mu g/m^3$ during winter and summer respectively. The annual 98 percentile values of SPM and RPM were calculated to be 1321 $\mu g/m^3$ and 560 $\mu g/m^3$, respectively. The air quality in the eastern region is further deteriorated mainly due to small / private mining activities.

The annual averages of SO_2 and NOx in the workzone were 14 $\mu g/m^3$ and 13 $\mu g/m^3$ respectively. The maximum and 98 percentile values SO_2 were 82 $\mu g/m^3$ and 44 $\mu g/m^3$ respectively. The maximum and 98 percentile values NOx were 70 $\mu g/m^3$ and 29 $\mu g/m^3$ respectively.

The summarised data are given in the tables below for Ambient Air Quality and Workzone Air Quality, where as the details are placed in a separate booklet.

Table No. 4.5.3.1.1 Summary of findings for AAQ Monitoring in the Eastern Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	1289	1067	1289	418	191	205	189	175	56	62	66	56
RPM	350	350	314	103	93	95	108	51	28	32	40	28
SO2	44	39.2	44	15.4	13	13	14	12	BDL	BDL	6	BDL
NOx	79	41.8	79	37	13	13	14	12	BDL	BDL	6.4	BDL

Table No. 4.5.3.1.1 Summary of findings for AAQ Monitoring in the Eastern Zone (Cont'd)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	534	704	534	321	347	133	121	93
RPM	314	240	314	103	74	33	29	12
SO2	36	28	40	15	347	133	121	93
NOx	37	25	50	21	346	133	120	93

Table No. 4.5.3.1.2 Summary of findings for Workzone Air quality in the Eastern Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	2531	2283	2531	927	305	315	338	252	102	105	102	104
RPM	697	697	452	353	215	238	234	128	65	65	80	70
SO2	82	82	70.6	26.2	14	15	14	12	BDL	BDL	6	9.5
NOx	70	70	36	30.5	13	14	13	12	BDL	6	BDL	6

Table No. 4.5.3.1.2 Summary of findings for Workzone Air quality in the Eastern Zone (Cont'd)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	1321	1160	1584	623	476	173	153	150
RPM	560	635	440	316	56	25	20	11
SO2	44	53	40	17	475	173	152	150
NOx	29	49	22	17	475	173	152	150

4.5.3.2 Impacts on Water Quality

The identified water pollution sources due to iron ore mining in the area can be broadly categorized into the following categories:

- Mines surface run-off during monsoon
- Tailings/slimes generated from the ore beneficiation plant.
- Oil and grease pollution from workshops operating in the bigger mines
- Sewages from the mines township

Amongst these, the single largest source of water pollution in the area is due to wash offs from the waste dumps. As most of the mining sites are located almost along the hill ranges, the waste dumps are being located along the hilly slopes. These dumps along with the exposed mining areas on the hill tops are prone for wash off during heavy rains, silting nearby water courses and damaging the soil quality of the nearby agricultural fields. Even though, the water flow in the nullahs is mostly seasonal, their flow in the monsoon season can be observed to be very turbid with reddish colour resulted from the wash off iron ore fines.

The run off water during monsoon gets laden with aluminous lateritic soil from mine benches, exposed out crops etc and become highly turbid. Most of the bigger mines operating in the area having beneficiation plants have the tailings dam and the tailings generated are being led to the tailings pond through closed conduits. Normally clear water is allowed to get discharged to the natural river or stream in the area as seepage water from the dam. The normal working of the workshops operating in the mines deals with maintenance works of HEMM, drills and light vehicles etc. The identified water pollution sources from these workshops are due to washings of light vehicles and HEMMs. During washings of the light vehicles and HEMMs at the servicing bay, oil and grease gets laden with the washings. Oils also get spilled during changing of oils in transformer and Oil Circuit Breaker (OCB). The data collected from different iron ore mines on the effluent and surface water quality are summarised in the tables below.

Table No. 4.5.3.2.1 Effluent Quality form the Iron Ore mines in Eastern Region

(Unit : mg/l except for pH)

	Parameter	*pH*	*TSS*	*Fe*	*Mn*
Annual Average	*Maximum*	9	226	3.34	2.4
	Minimum	6.2	7	0	0
	Average	6.79	38.6	0.33	0.17
	No. of Observations	76	75	66	42
Monsoon	*Maximum*	8.02	226	3.34	2.4
	Minimum	6.2	9.5	0.1	0
	Average	6.77	48.36	0.47	0.35
	No. of Observations	21	21	14	8
Non Monsoon	*Maximum*	9	154	3.1	0.42
	Minimum	6.21	6.8	0	0
	Average	6.8	34.78	0.29	0.13
	No. of Observations	55	54	52	34

Table No. 4.5.3.2.2 Surface Water Quality near Iron Ore Mines in Eastern Zone

(Unit : mg/l except for pH)

	Parameter	*pH*	*TSS*	*Fe*	*Mn*	*O & G*	*Sulphate*	*Cr+6*	*Pb*	*Hg*
Annual average	*Maximum*	8.2	39.5	10.5	0.2	1.5	25	ND	ND	ND
	Minimum	6.1	2	0.11	0	0	0	ND	ND	ND
	Average	6.92	24.39	0.74	0.11	0.56	9.19	ND	ND	ND
	No. of Observations	128	127	124	76	17	17	17	17	17
Monsoon	**Parameter**	*pH*	*TSS*	*Fe*	*Mn*	*O & G*	*Sulphate*	*Cr+6*	*Pb*	*Hg*
	Maximum	7.52	31.7	10.5	0.14	1.5	25	ND	ND	ND
	Minimum	6.5	20.3	0.19	0	0	0	ND	ND	ND
	Average	6.95	26.8	1.09	0.11	0.85	13.13	ND	ND	ND
	No. of Observations	28	28	28	13	4	4	4	4	4
Non Monsoon	**Parameter**	*pH*	*TSS*	*Fe*	*Mn*	*O & G*	*Sulphate*	*Cr+6*	*Pb*	*Hg*
	Maximum	8.2	39.5	8	0.2	1.5	20	ND	ND	ND
	Minimum	6.1	2	0.11	0.08	0	0.6	ND	ND	ND
	Average	6.91	23.71	0.63	0.11	0.48	7.98	ND	ND	ND
	No. of Observations	100	99	96	63	13	13	13	13	13

ND: Not Detectable

4.5.3.3 Soil and Ground water Pollution control

Iron Ore mining in the area does not directly affect the Soil and Ground water quality, as such. But due to land degradation associated with the mining operations like top soil removal, deforestation and over burden dumping, affect the quality and the quantity of soil and ground water. Due to over turning of the soil layers, during mining and associated activities, the fertility of the soil decreases. It aggravates further due to deforestation which gives rise to deficiency in the natural biological matter replenishment, in the long term. Due to deforestation, the infiltration capacity of the soil decreases and the surface run off increases, which ultimately affect to the quantity of the ground water. As the proper mining activity does not involve any chemical process discharge, the chance of quality deterioration of ground water, is very rare.

In the absence of regular monitoring of both quality and quantity of the soil and ground water in and around the mines, it is very difficult so ascertain the exact pollution status of both soil and ground water. But it is imperative that the quantity and to some extent the quality, of both soil and ground water may change due to mining and the associated activities. Though there are no direct soil and ground water pollution control activities, but the following environmental activities indirectly act as a preventive measure for the soil and ground water pollution.

- Top soil Management
- Land Reclamation and Rehabilitation
- Afforestation and Environmental Plantation
- Silt trapping from the surface run off
- Water harvesting by ponds and ditches
- Tailings management, etc.

The monitoring results of the ground water are compiled is summarised below:

Table No. 4.5.3.3.1 Ground Water Quality near the Iron Ore mines in Eastern Region

(Unit : mg/l except for pH)

Annual Average	**Parameter**	***pH***	***TSS***	***Fe***	***Mn***
	Maximum	7.5	32.8	1.15	0.3
	Minimum	6.4	0	0	0
	Average	6.82	11.34	0.22	0.09
	No. of Observation	60	62	62	44
Monsoon	**Parameter**	***pH***	***TSS***	***Fe***	***Mn***
	Maximum	7.27	23	0.66	0.3
	Minimum	6.6	6.3	0.08	0
	Average	6.87	10.44	0.21	0.09
	No. of Observations	13	14	14	8
Non Monsoon	**Parameter**	***pH***	***TSS***	***Fe***	***Mn***
	Maximum	7.5	32.8	1.15	0.2
	Minimum	6.4	0	0	0
	Average	6.8	11.61	0.23	0.09
	No. of Observations	47	48	48	36

4.5.3.4 Impact of Noise and Ground Vibration

No specific noise control measures were observed in the iron ore mining in the area, specifically in the smaller and manual mines. However, the existence of natural forests at places acts as a natural acoustic barrier for the local villages. The following steps are being taken for minimising the ground vibrations and air blast pressure due to blasting;

- By proper blasting design and by selecting right explosives.
- Reduction of charge weight per delay between the holes
- Adopting suitable delays (millisecond delays) and initiation
- Adopting "Non-electric delay initiation system".
- Ensuring a minimum stemming length of not less than 0.7 times of the burden.
- Adopting muffle blasting and controlled blasting technique.
- Discouraging practice of collar priming.
- Avoidance of over fly confined charges and subgrade drilling.
- Orientation of the quarry faces, where possible, so that they do not face directly towards residential areas.
- Surveying fly rock distances for reference.

Though the bigger mines are practicing deep-hole drilling and blasting, the blast induced ground vibrations do affect the nearby residential villages, as apparent from the cracks developed in the residential units of the concerned mining company's townships. It also can not be ruled out that the vibrations induced due to blasting do not affect the ground water aquifer system of the area. Thus, this have an important bearing on the existing forest in this area, as these plants / trees depend upon the ground water, which occur as a water table immediately below the earth surface. Further, these blasting operations produce impulsive noise, which may affect the wild life habitat existing in the nearby forest area. Also the noise produced by earthmoving machinery and the mineral processing plants, to a major extent, effect the stillness for the forest area.

4.5.3.5 Impacts on Land, Topography and Forest

The topography of the area covered by the iron ore mines in the Singhbhum district of Jharkhand and Keonjhar & Sundergarh districts of Orissa is mostly hilly terrain with undulating plain. Mining in these areas results in the destruction of the existing vegetation and soil profile, thereby affecting the topography, forest and ecology of the area severely. Removal of overburden and waste rock and its replacement in waste dumps have significantly changed the topography and stability of the landscape of the area. "Top down" dumping practices are being followed in these areas for waste rock disposal, where the waste rock is dumped over steep slopes. Jharkhand has 3,092 ha of degraded lands constituting 21% of the total iron ore lease in this State, whereas in the three districts (Keonjhar, Sundergarh and Mayurbhanj) of Orissa 4,519ha of land has been degraded. The forest in the region comes under Champua range and is classified into two major types, namely:

- Northern Tropical moist deciduous type
- Northern tropical dry deciduous type

Sal is a major species found in the area. The other species such as Terminalia tomentosa, T. Belerica, Lagerstroemia parviflora, Anogeissus latifolia, Sizigium cumini, Magnifera Indica, schleichera oleosa, Pterocarpus marsupium, Diospyrus melanoxylon, Adina cordifolia, Terminalia chebula, Buchanania lanzan, Lannea coromondelica, Dalbergia latifolia. The common plants are wendlandia species, Emblica officinalis, cassia fistula, Morinda tinctonia and the like. There are patches of Dhaura, with other xerophytic miscellaneous species seen in the area.

A study conducted by a committee constituted by MoEF during March'1998 consisting of representative from Forest Survey of India (FSI), Botanical Survey of India (BSI), Indian Bureau of Mines (IBM), Geological Survey of India (GSI), National Remote Sensing Agency (NRSA), Indian School of Mines (ISM), Federation of Indian Mining Industries (FIMI) and SAIL found out that a total of 20,968ha of forest cover exist over the iron ore mining lease area in these area, the details of which is presented below. The findings were based on using remote sensing and GIS.

Table No. 4.5.3.5.1 District wise forest cover over Iron & Manganese ore mining leases.

District	Lease Area (ha)	Forest cover (ha)		
		Dense	Open	Total
Singhbhum, Jharkhand	5,127	2,735	1,143	3,878
Sundergarh, Orissa	4,448	1,138	1,928	3,066
Keonjhar, Orissa	25,615	7,530	6,494	14,024
Total	**35,190**	**11,403**	**9,565**	**20,968**

In this region, afforestation of land is the main means of reclamation of degraded lands or of improvement of land uses. Only about 4.5% of the degraded lands were under afforestation. In Jharkhand, about 6, 31,000 saplings were planted over an area of 138 ha of degraded lands where survival rate varies from 30-85 % (average 55 %). In Orissa, about 2, 84,000 saplings were planted over an area of 199 ha, where survival rate was found to be between 25 and 85% (average 54%)

In this region, various species were planted important ones are Ecalyptus, Neem, Seris, Gulmohar, Jamun, Mango, Teak, Karanj, Gehmar, Accasia, Sal, Sisam, Charkunda, Jackfruit and Deodar. The details of the degradation of lands and their reclamation are given below:

Table No. 4.5.3.5.2 Details of Land Degradation by Mining Industry

State	No. ML	ML area	Mining	Dumping	Others	Total	% Degradation	Afforestation	Survival rate (%)
ORISSA									
Keonjhar	50	19573	1816	335	457	2608	13	119	54
Sundergarh	23	5714	235	76	414	730	13	79	55
Mayurbhanj	25	5352	648	464	69	1181	22	1	30
TOTAL	88	30939	2699	875	940	4519	14.6*	199 (4.4)	54*
JHARKHAND									
Singhbhum	33	14698	1705	696	691	3092	21*	138 (4.5)	55* 54.4 @
GRAND TOTAL	121	45637	4404	1571	1630	7611	16.7 @	337	

Note: * Weighted average, @ overall average, Figures in the parenthesis indicates afforestation as percentage of degraded lands

4.5.3.6 Impacts on Community

The mining in the area support quite large local communities those are totally dependent on mining and the processing operations. Due to the mining operations, the communities have been exposed to both the positive and negative impacts of urbanization. Better health care, education, living standards being some of the benefits the locals had got due to the mining. Some of the smaller townships like Barbil, Joda, Noamundi, Kiriburu & Meghahatuburu, Bolani, Gua, Tensa, etc. have been come up mainly because of iron ore mining in the area. A large community now depend on it and the townships are now growing and fulfilling the educational and medical requirements of the area. The big mining companies in the area have also favoured the recruitment and employment of the local tribal people. People directly or indirectly depend on the mining activities. Besides, the mining authorities are spending lot of money on the development of the peripheral villages by providing free health check-ups, medicines, schooling, approach roads to the villages, drinking water by constructing bore well etc.

4.6 SOUTHERN ZONE (KARNATAKA)

Among southern states, Karnataka plays a dominant role in the iron ore production owing to its naturally abundant iron ore deposits spread across the state. In this state, there are two important areas where iron ore mining is being carried out since long. These areas are:

- Kudremukh (mining operation has been suspended at present) and
- Bellary-Hospet

Karnataka has produced 33.6 Mt of iron ore during the year 2005-06. Majority of the iron ore mines are located in Bellary-Hospet belt, which is in the semi-arid zone, where water scarcity and dust concentration are the main environmental issues. The environmental impacts due to iron ore mining in these two areas are discussed below.

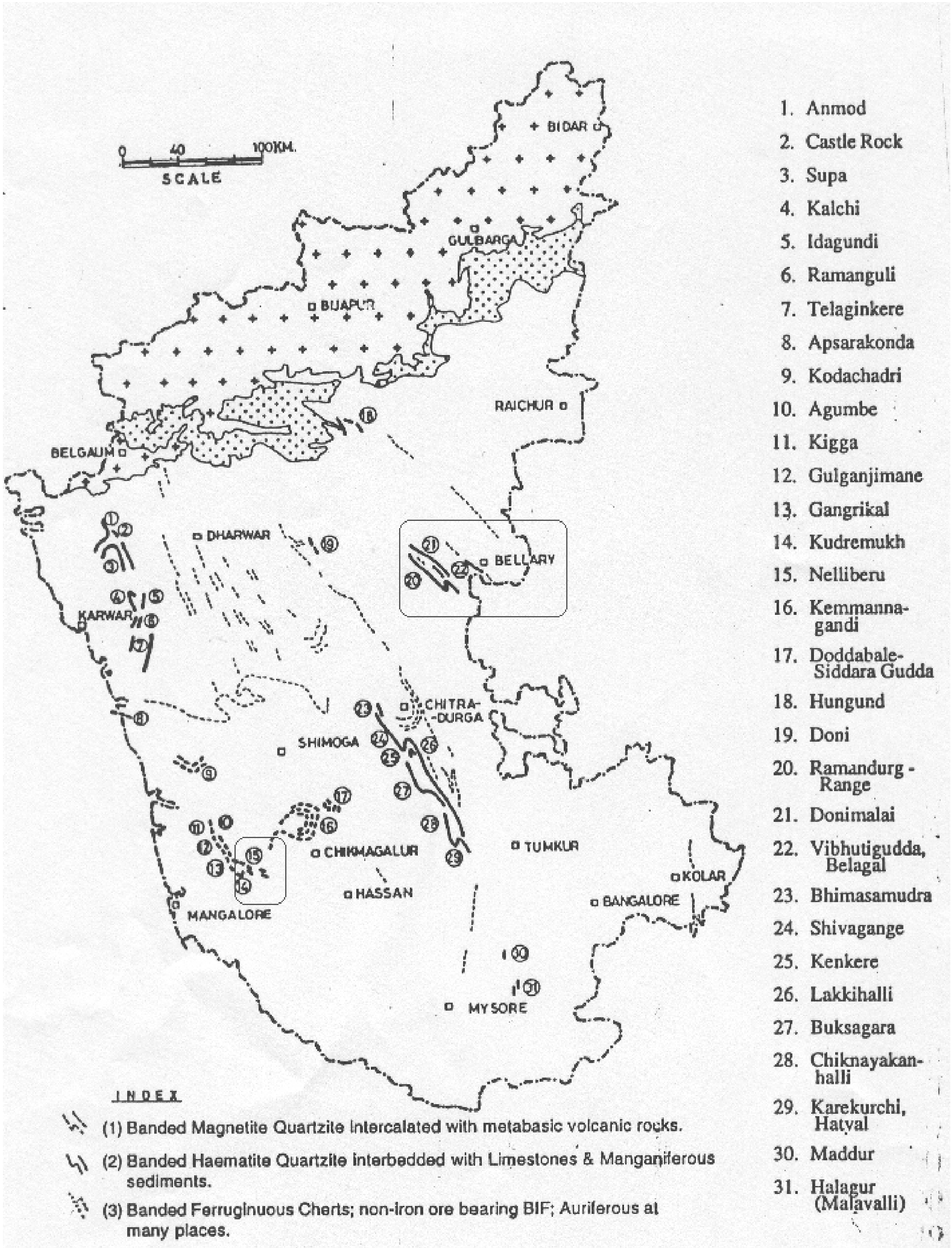
4.6.1 Natural Setting

4.6.1.1 Location and Topography

Kudremukh Iron Ore Company Ltd. (KIOCL), A Government of India Enterprise, under the Ministry of Steel, was established in 1976 to develop mine and plant facilities for production of 6.8 million tonnes of iron ore concentrate annually and were commissioned in 1980. The mine had production capacity of 7.5 Mt of iron ore concentrate and 4 Mt of high grade pellets from 22.5Mt of ROM. The project is located at Kudremukh in Chikamagalur district of Karnataka and is about 350 Kms from the capital city of Bangalore and 110 Kms from the coastal city of Mangalore. The Mining lease area is located between latitude $13^0\ 10^{'/}$ to $13^0\ 17^/$ N and longitude of $75^0\ 10^/$ to $75^0\ 20^/$ E. The topography of the area is hilly, except the valley portion through which the river Bhadra flows. The hill ranges between Kudremukh and Gangamula contain extensive deposits of magnetite ore. The hills and ridges of this region are quite rugged and often reach an elevation of 1200m above MSL. Presently, mining operation in Kudremukh is suspended on account of environmental grounds as per Supreme Court order.

Bellary district is situated in the north-eastern part of Karnataka. The western part of the district is in general a plain country with small hillocks occupied by granitic gneisses. The eastern part shows both plain and rugged topography occupied by granitic and schistose formations, respectively. The topography of the iron ore mining area consists of hillocks, mainly close to Bellary, around Hospet and in Sandur valley which itself runs over a length of 40km with a width of about 10km.

Both these areas are marked in the iron ore distribution map of Karnataka is given below:



4.6.1.2 Climate

The Kudremukh area enjoys a tropical climate and falls in high rainfall region with an annual rainfall averaging 7000 mm between June-September. The variations in temperature occur between a minimum of 4^0 C and a maximum of 36^0C and humidity varying from 40 to 100 %.

Mine area is situated on the southern side of the river Bhadra, one of the major rivers of the state.

The climate of the Bellary-Hospet region is of semi-arid type having annual rainfall of less than 750mm. The maximum temperature rises to about 38- 39^{o}C in summer and the minimum temperature falls to about 12^{o}C in winter. The predominant wind direction is from SW to NE. The relative humidity of the region varies from 38% to 95%.

4.6.1.3 Drainage

In the Kudremukh mining area, river Bhadra is the major river flowing and controls the drainage of the area. River Bhadra joins River Thunga further downstream and becomes Thungabhadra river. The River Thunga with its origin and course well away from the mining area and meets River Bhadra far away from mining area. There are two major nallahs in the area i.e. Lakya hole and Sitabhumi holey. In between these two nullahs there is another nallah Kuniya holey, which runs parallel to the other two nallahs with a lean flow. On the right bank of Bhadra River, the ore zone is bounded by Kochige holey on the western side and the Kudremukh holey on the eastern side. The ridges between these holeys (streams) are slopping northwards towards Bhadra river. Nethravati is also another river originating form the Western Ghats. However, this is a west flowing river and the point of origin is well away from the mine lease area.

The Bellary –Hospet area has three small springs one at the foot hill of Donimalai, which is known as Doni spring and the other two in Kumaraswamy hill range. A seasonal nallah called Narihalla, which s usually dry during summer traverses the major part of the Sandur valley in a direction SW to NE and covers two gorges namely Ubbalagundi on the SW and Bhimagundi on SE. Another small stream namely Narsapur nallah flows by the eastern side of Donimalai town ship which ultimately joins the Narihalla stream. Karnataka Government constructed a dam across Narihalla at a distance of 10Kms from Donimalai town ship, which caters to the industrial and domestic demands of NMDC.

4.6.2 Mining Operation

Mining operation in the Kudremukh was highly mechanised (mining operation presently suspended). The company has an annual production capacity of 7.5 Mt of iron ore concentrate and 4Mt of high grader pellets from 22.5Mt of ROM. For the planned production of 22.5Mt of ROM, this operates as a fully mechanized open cast mine by 8nos. Shovels (10.7m^{3} capacity) and 30 Nos. Dumpers (120 tonnes) in combination with advance bench blast lay Site Mixed Slurry (SMS) explosives. 12 Nos. of Drills of 310mm dia. and capacity to drill 17m deep holes in a single pass are in use. The other auxiliary equipment such as drills for secondary blasting, water sprinklers (8Nos.) motor graders, conveyors (14Nos.) etc. have also been provided. In view of stringent quality requirements for assorted feed systematic development of benches on regular basis is sometimes found to be difficult and larger number of benches need to be kept in operation simultaneously.

In the Bellary Hospet area, there are about 116 iron ore mining leases with more than 60 mines in operations covering about 16,000ha where mining operations by opencast method. Mining in this region are being carried out for more than 45 years. Mining is being done in this area in a combination of highly mechanised, semi-mechanised and manual methods. In most of the private sector mines, machinery is mainly deployed for mine development, while actual ore collection is done manually. In most of the manual mines, no systematic benches are being developed. In the mechanised and semi-mechanised mines, the bench height varies from 6 to 12m. The slope of the benches ranges from 45 to 60^o depending on the consistency and tensile strength of the ore body and rocks. Donimalai Iron Ore Mines is one of the fully mechanised Iron Ore Mines of National Mineral Development Corporation (NMDC), Government of India Undertaking operating in this sector with a production capacity of 4Mt. The iron ore produced from the mine is being supplied mainly to MMTC Ltd., for export to Japan, South Korea, China, Pakistan etc., thereby facilitating earning of valuable foreign exchange to the country. About 10% of the production is supplied to domestic consumers like Vizag Steel Plant, Bhilai Steel Plant, Lanco Industries Ltd., Southern Iron & Steel Co. Ltd., VISL Bhadravati etc. Mining is carried out by open cast method and is fully mechanised. The bench heights are kept at 12 m and the slope of the mine in longitudinal section is 4 to 5 degrees only and the pit slope is 45 degrees. At any point of time ore will be excavated by operating a total of 3 to 4 benches in south block and north block deposits by optimum blending of low grade and high grade ores to get the lump ore and fine ore of required specifications stipulated by the buyers.

4.6.3 Environmental Impacts

The mining in Kudremukh and Bellary-hospet are operating in contrasting climates i.e. Kudremukh is operating in a high rainfall area whereas the Bellary – Hospet is of semi-arid type. Dust pollution is predominant in the Bellary-Hospet region, whereas water quality management is important in the Kudremukh region. The impacts due to mining in both these regions are discussed below.

4.6.3.1 Impacts on Air Quality

Activities that cause air pollution in both these mining areas can be broadly classified in to two groups. One is the ground level area source pollution resulting from activities like vehicle movement, wind blown dusts etc. and the other is the elevated discharge of air pollutant which is due to blasting operation.

The existing levels of air quality in the nearby residential areas of Kudremukh Iron Ore mine is given in a separate booklet in detail. The gist is presented below:

Table No. 4.6.3.1.1 Summarised AAQ around Kudremukh mine.

Parameters	SPM($\mu g/m^3$)	RPM($\mu g/m^3$)	SO2($\mu g/m^3$)	NOx($\mu g/m^3$)
Minimum	*38*	*26*	*< 6*	*<6*
Maximum	*313*	*176*	*7*	*38*
98 percentile value	*301*	*171*	*7*	*33.92*
Average	*120*	*69*	*4.11*	*14.45*

It may be observed that the air quality around the residential area of the mine is relatively better. Lower levels of dust in the nearby residential areas is due to fact that the iron dusts of the area being heavy (high density of the iron ore of the area) combined with higher moisture contents due to heavy rainfall, most of the dust generated due to mining and processing gets deposited near to the generation sources. However the mining authorities have taken the following mitigating measures.

a) Water injection at drills is resorted to for dust suppression around the drill hole collar.

b) The fugitive dust generated at various locations in mines is controlled by water sprinkling during non-monsoon period.

c) Blasting is carried out during afternoon when the wind speed is moderate whereby mixing height is very high with no inversion conditions.

d) Use of controlled /opti blast technology for ore blasting to attain less air pollution, less explosive, better slope stability and increased fragmentation are achieved.

e) The techniques adopted for blasting of ore is as below:

-Opti blasting

-Split charge with gas bag with air decking

-Split charge with material deck

-SMS slurry explosives are used in blasting of ROM

f) Operator cabins in all major heavy earth moving equipment have dust proof enclosures. Regular maintenance and minimizing idle run hours are achieved.

g) Road berms and dumps are turfed and planted.

h) Extensive plantation has been done to arrest airborne dust and noise.

i) Since crushing units are installed below the ground level (at a deep of 40m) and is fully covered on top and due to a moisture content of about 6% in mined ore, dust generation from the crushing operations is almost negligible.

j) Personnel working at the mines area, crushers and beneficiation plants are provided with respirators and dust masks as a precautionary measure to avoid prolonged exposure to dust.

k) Air quality monitoring is being carried out periodically as per KSPCB directives.

l) 5 Nos. of 28Kl and 1no. of 72Kl water sprinklers are being used to suppress the dust on haul road at frequency of one hour.

m) The fugitive dust generated at various locations in the mines near mine's office, mines service station and mines control office is controlled by static water sprinklers.

n) In order to reduce the dust puffs (fugitive) emission during blasting, proper stemming of blast holes is being carried out.

But, the dust is the main pollutant in the Bellary-Hospet area. The semi-arid climatic condition (scarcity of water) combined with unscientific mining (specifically by smaller mining companies operating either manual mining or semi-mechanised mining) has worsened the situation. It has been reported that the mining companies are also facing problem in finding sufficient water in the region to use them in dust suppression through sprinkling or wet drilling. As most of the mining are being carried out on the top of the hill, water to be carried out from more than 20kms from the valley. However, NMDC operating at Donimalai has taken a number of steps to reduce the dust in the ambient air. The details of control measures, which are being adopted by them, are given below:

a. Water sprinkling/spraying on roads and other dust generating areas /centres. Water is sprinkled periodically in the areas like roads leading working face to crushing/dumper platforms, dumper platform etc. to prevent air-borne dust emissions. In order to achieve dust suppression in the mines area, dumpers have been converted into water sprinklers each with a capacity of 25,000 litres. Besides there are two TMB chassis water sprinklers of 70,000 litres capacity each.

b. Around the top of the primary crusher, high pressure water jets, filled with specially designed adapters and nozzles are provided to inject misty (foggy) water jets. This practice eliminates dust at the area of unloading into crusher as well as in transfer points as the ore passes through a system of conveyors right up to the screening plant. Washing of ore is done at the screening plant for reducing dust formation.

c. Well maintained haul roads in project area reduce fugitive dust emissions.

d. Wet-drilling suppresses dust at source in the drill holes.

e. Controlled blasting technique, effective stemming and using milli-second delay detonators during blasting.

f. Avoiding blasting during high wind period.

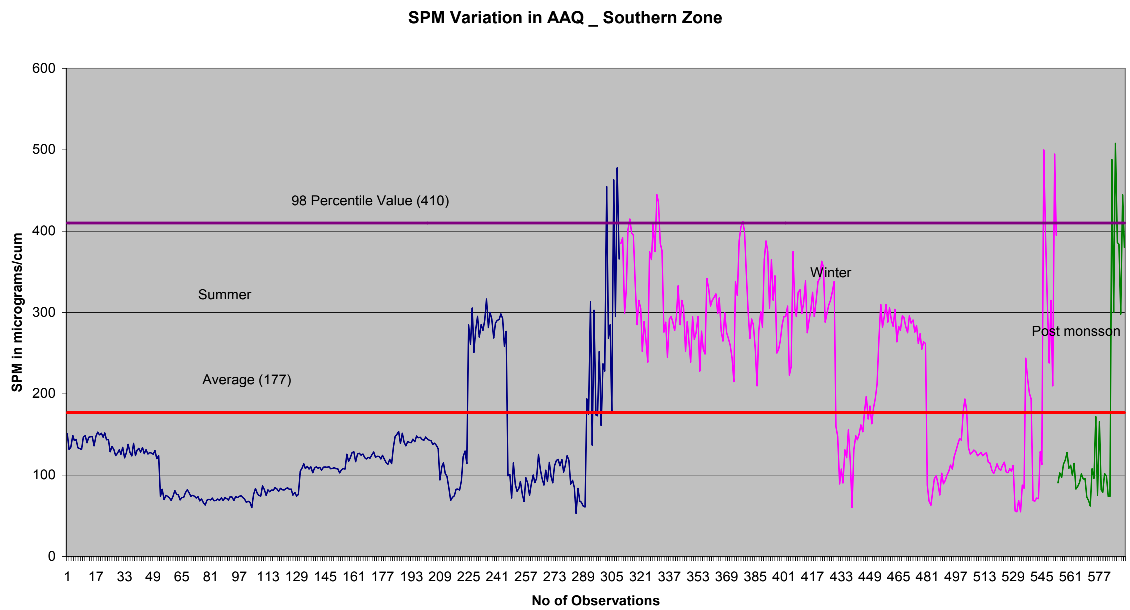
g. Enclosing conveyors to control dust emission

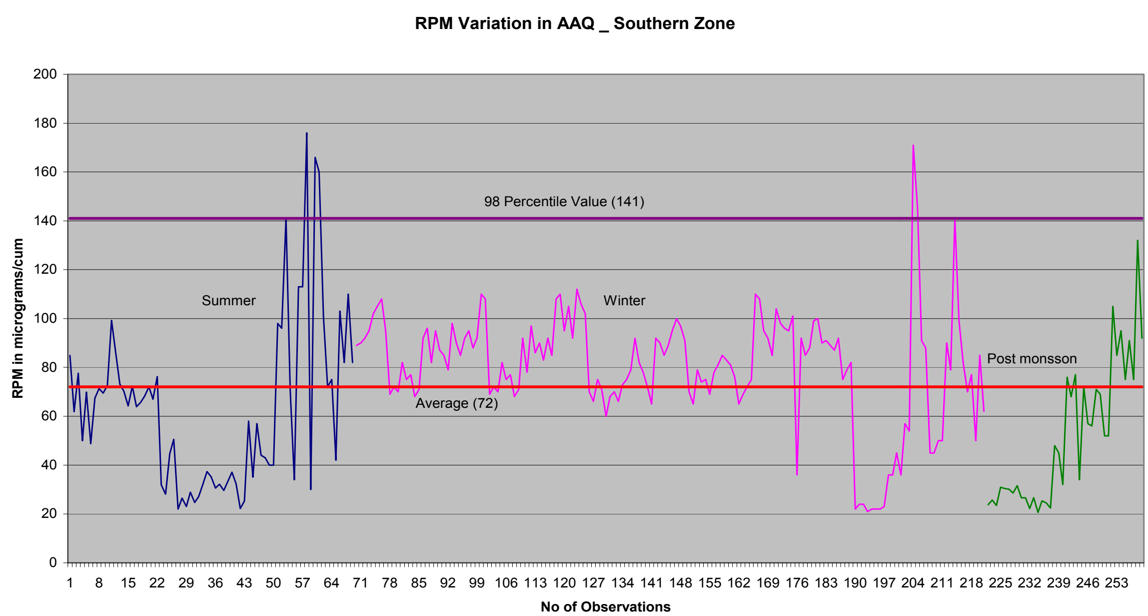
h. Regulating the feed on conveyors to prevent spillage.

i. Development of green barriers (belts) helps to prevent propagation of particulate and gaseous emissions by the trapping them suitably in the foliages.(Surface area) Already about four lakhs plants and trees have been grown by the project authorities in various areas such as waste dump hill slopes, around infrastructures, along roads and around township etc.

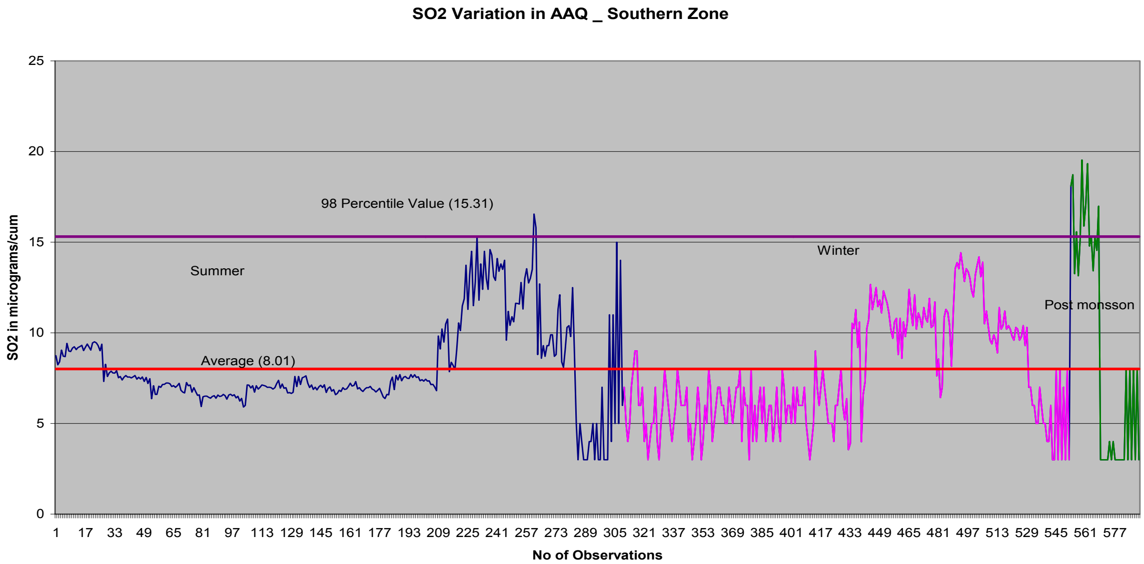
The collected ambient air quality data combined for both the areas are analysed and presented below:

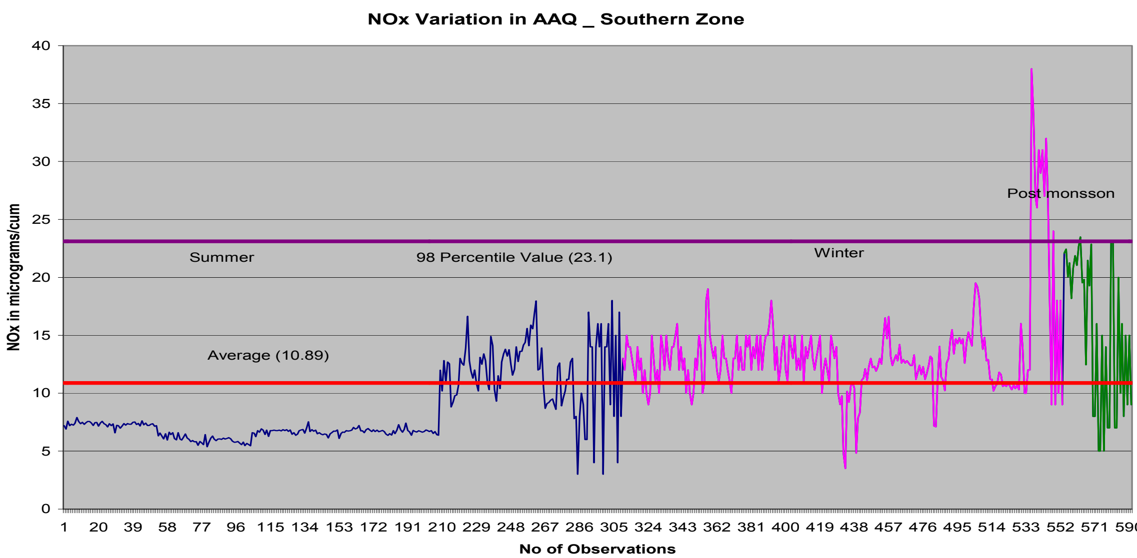
The maximum total dust (SPM) and RPM concentration observed was 508$\mu g/m^3$ during post-monsoon and 176$\mu g/m^3$ during summer season, respectively. The annual 98 percentile values of SPM and RPM were calculated to be 410 $\mu g/m^3$ and 141 $\mu g/m^3$, respectively. The annual average values of SPM and RPM were calculated to be 177 $\mu g/m^3$ and 72 $\mu g/m^3$, respectively. The annual variations of SPM & RPM are shown below in the graphs.





The concentration of SO_2 and NO_x were observed to be insignificant. The maximum annual SO_2 and NO_x concentrations observed were 19.53µg/m^3 and 38µg/m^3 respectively. The annual 98 percentile values of SO_2 and NO_x were calculated to be 15 µg/m^3 and 23 µg/m^3, respectively. The annual variations are presented in the graphs below:





Regarding workzone air quality in the Southern region, the annual average total dust(SPM) and RPM concentration were 490 µg/m^3 and 179 µg/m^3 respectively. The maximum SPM and RPM concentrations observed in the workzone, were 2979 µg/m^3 and 895 µg/m^3 during summer. The annual 98 percentile values of SPM and RPM were calculated to be 2175 µg/m^3 and 515 µg/m^3, respectively. The maximum values of SO_2 and NOx in the workzone were observed as 32 µg/m^3 and 36 µg/m^3 respectively.

The summarised data are given in the tables below for Ambient Air Quality and Workzone Air Quality, where as the details are placed in a separate booklet.

Table No. 4.6.3.1.1 Summary of findings for AAQ Monitoring in the Southern Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	508	478	500	508	177	128	241	162	53	53	55	62
RPM	176	176	171	132	72	64	80	52	21	22	21	21
SO2	19.53	16.55	14.42	19.53	8.01	8.13	7.69	9.06	BDL	BDL	BDL	BDL
NOx	38	18	38	23.48	10.89	8	13.42	15.3	BDL	BDL	BDL	BDL

Table No. 4.6.3.1.1 Summary of findings for AAQ Monitoring in the Southern Zone (contd..)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	410	305	412	493	591	309	244	38
RPM	141	164	112	112	259	69	152	38
SO2	15.31	14.47	13.71	19.38	591	309	244	38
NOx	23.1	16	29.28	23.12	591	309	244	38

Table No. 4.6.3.1.2 Summary of findings for Workzone Air quality in the Southern Zone

Parameters	*Maximum Value ($\mu g/m^3$)*				*Average Value ($\mu g/m^3$)*				*Minimum Value ($\mu g/m^3$)*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	2979	2979	2605	2936	490	327	597	337	102	102	104	110
RPM	895	895	560	429	179	98	310	88	32	49	66	32
SO2	31.7	31.7	26.24	23.38	15.44	16.16	14.36	16.35	BDL	BDL	6	BDL
NOx	36	36	32	29.56	17.74	17.31	16.51	21.72	BDL	BDL	9	BDL

Table No. 4.6.3.1.2 Summary of findings for Workzone air Quality in the Southern Zone (contd..)

Parameters	*98 Percentile Value ($\mu g/m^3$)*				*No. of Observations*			
	Annual	*Summer*	*Winter*	*Post Monsoon*	*Annual*	*Summer*	*Winter*	*Post Monsoon*
SPM	2175	1147	2287	2046	608	208	329	71
RPM	515	241	528	375	286	102	113	71
SO2	24.87	28.69	23.34	22.94	608	208	329	71
NOx	27.94	28.22	24.73	29.45	608	208	329	71

4.6.3.2 Impacts on Water Quality

Water pollution in the Kudremukh region is mainly attributed to the runoff and washouts from the mining area, dumps and other exposed areas carrying the fine silt and loose soil from the mining areas and ultimately join the surface water courses like nallahs and Bhadra river. This problem is prevalent mainly during the rainy season. Because of heavy rainfall in the region this problem aggravates and silts get carried over to the river. Another major source of water pollution is due to tailings generated from the processing units. As no chemicals are being used in the beneficiation process, no chemical pollution is expected to occur. Further, most of the water used in the processing plant is getting recycled. The make-up water is drawn from the Lakya dam by gravity system. To arrest the siltation in the nearby natural drainage areas, KIOCL has already taken appropriate measures towards controlling the water pollution of the nearby sources due to mining and other associated operations, which are briefed below:

Construction of Pollution Control Dams

Two rock filled dams are constructed across two major valleys to arrest mines washouts during monsoon season and prevent them from entering into the Bhadra river. The total catchment area of the dams is about 4.3Sq.Km. These dams are regularly desilted and processed in the beneficiation plant, whereas the material desilted from the river banks is utilised for road maintenance works.

Construction of a by pass diversion channel

Kudremukh hole (nullah) which earlier flowed through the mine lease area is by-passed or diverted slightly away by constructing an artificial channel which take the nallah to meet Bhadra river directly now. This measure was intended to prevent any mine washouts joining the nullah, thus avoiding any chances of water pollution.

Construction of Dump Pond

The ore processing and beneficiation unit, called Concentrator Plant continuously process ROM mined. There is a chance of tripping off wherever a power failure occurs or even in case of failure of some equipment. In each tripping, about 2000 tonnes of ore is flushed. In order to prevent these solids from entering into Bhadra river, two dump ponds of 50000 tonnes capacity are constructed which also enable pumping of solids in slurry form back into the process (recycling). Also a channel has been constructed in 2000 with a cost of Rs. 25 lakh to divert the flow alternatively to these ponds in series enabling easy desilting of the accumulated material.

Construction of Check Bunds

Check bunds are temporarily constructed across the areas, which usually contribute mine washouts to Bhadra river during monsoon, to check the water pollution. The accumulated material is desilted in dry season.

Construction of Contour trenches

The hilly terrain at Kudremukh is steep and the problems of siltation are compounded due to the incessant rains during monsoon season. The mining washouts from the areas beyond catchment of pollution control dams I and II is arrested by cutting of contour trenches.

Disposal of tailings and discharge of water from tailings pond

The ore mined at KIOCL mines contains only 36% Fe and rest are gangue material, which comes out as tailings during beneficiation. Production of 6Mt concentrate out of 22.5Mt ROM shows the generation of considerable amount of waste to be disposed off carefully so as to prevent the pollution of water bodies nearby. An earthen dam is constructed at a distance of 3Km from the ore processing plant. Tailings are pumped through three pipelines regularly and discharge into Lakya dam for storage.

The present accumulation of iron ore tailings at Lakya dam is around 130Mt. Lakya dam serves dual purpose as entire process water requirement is also drawn from the dam by gravity tunnel. The overflow spillway for the dam does not exist on dam body, which is the common practice in case of conventional irrigation dams, but the spillway is provided at a distance of 2Kms downstream from the discharge end of tailings close to the dam body. The solids settle down and the supernatant flows through the spillway. The discharge of excess water from the dam takes place only during monsoon season through a spillway (vertical shaft) designed to maintain enough water reserve for ore processing during summer season. The water quality is regularly monitored and found to be very good.

Proper drainage pattern

In the process of direct runoff or sub surface runoff through weathered zone, the rainwater will find its way into the benches. However, benches are suitably graded and the water is properly diverted to flow out by gravity (through proper gradient) to one of the two PC dams. Bench floors are sloped at 2% towards the high wall. Longitudinally along the toe of the high wall also, the bench is sloped at 1% along the whole length, up to the nearest culvert outlet.

On the abandoned benches, a 2m high stable berm is built along the outer edge of the bench, to prevent water spilling over to the lower bench. All roads are cross sloped at 2-3% towards the inner edge i.e. the hill side and are also sloped all along longitudinally at 6.25% towards the nearest box culvert. Box culverts have been built in adequate number to receive the runoff water that flows out to the valley towards the settling ponds behind the PC dams.

Ground water pollution

The ground water pollution can possibly arise when the top soil/ loose material contain certain chemical constituents and heavy metals and can be leached away with precipitation and percolate to ground water. In a study conducted by NEERI, it had been concluded that the concentrations of heavy metals like zinc, cadmium, lead, manganese, iron and copper are very low and are most unlikely the leaching will have any significant adverse impact on the ground water quality. With regards to the impact of the tailings from the concentrator plant, since the tailings are being sent to Lakya tailings dam and the slurry characteristics do not indicate presence of any heavy metal constituents in it, the impact of Lakya dam impoundment on nearby water bodies is negligible. Moreover, the seepage water from the tailings dam does not indicate presence of any heavy metals.

Whereas, due to less rainfall in the Bellary-Hospet region, the water shortage in the area is more acute than water pollution. However, the main cause of water pollution during the short span of the rainy season is due to wash off from the waste dumps. Due to unplanned dumping of the wastes on the higher altitudes coupled with loose and fine material from the exposed ore body, are more susceptible to erosion specially in the rainy season even with low amount of rainfall and is being carried out by the surface run off and gets deposited along the down slopes, stream courses, agricultural fields and ultimately reach the tanks and reservoirs. The study carried out by the Karnataka State Council for Science and Technology reveals that on an average of 13.96gm of silt is being carried out by every litre of water. However, big mining company like NMDC at Donimalai has taken some effective steps in controlling the water pollution in the area. They have constructed a huge tailings dam to take care of the tailing generated from the processing plant. The tailings dam has a capacity to take care of industry effluents from screening plant throughout the life of the mine. It is an exceptional fact to mention here that right from inception, there has been no overflow from tailing dam over the over-flow weir. The success of control measures adopted is evident from the fact that only clear water flows to the perennial stream location at the western side of the hill. This is also controlled by ensuring proper and systematic maintenance of classifiers, hydro-cyclones and thickeners for better recovery of solids from the wash offs. However, the continuous seepage from the tailings dam is helping in recharging the ground water of the area. It has been reported that the ground water table of the area has risen considerably benefiting the villagers of Narsapura, Ranjitpura and Navalatti.

To prevent washouts from waste dumps and degraded lands during rainy season and for soil conservation, one check dam is constructed at bottom of western slope and five check dams at the bottom of eastern slope. As waste dumping is done only in closed valleys, soil erosion is automatically minimised. Besides, provision of an upward gradient on top of waste dumps and adequate drainage channels in the mines ensures that heavy wash-outs from dumps and mines area during heavy monsoon period do not cause water pollution of natural streams. Even if some wash outs take place for any reason, it is completely contained by the check dams. Prevention of soil erosion/wash-outs at the mined out areas and dumps is also achieved by means of afforestation in dumps and excavated areas by suitable soil binding spices.

Provision of oil and grease traps and settling tanks enable to treat the oily waste water for industrial wash-outs from workshop vehicle depots.

The water quality data collected from different iron ore mines in both the area are summarized in the tables below.

Table No. 4.3.6.2.1 Summarized data for Effluent Quality in the Southern Region

(Unit : mg/l except pH)

Annual Average	**Parameters☞**	***TSS***	***pH***	***O&G***	***Lead***	***Copper***	***Zinc***	***Nickel***	***Iron***	***Sulphates***	***Manganese***
	Maximum Value	*186*	*8.6*	*18.5*	*0.05*	*0.13*	*0.3*	*0.009*	*2.8*	*114*	*0.13*
	Minimum Value	*18*	*6.7*	*0*	*0.01*	*0.03*	*0.01*	*0.005*	*0.01*	*2*	*0.02*
	Average value	*75.11*	*7.53*	*6.16*	*0.03*	*0.0756*	*0.1825*	*0.007*	*0.76*	*42.25*	*0.056*
	Number of observations	*19*	*28*	*14*	*6*	*9*	*12*	*2*	*27*	*12*	*10*
Monsoon	**Parameters☞**	***TSS***	***pH***	***O&G***	***Lead***	***Copper***	***Zinc***	***Nickel***	***Iron***	***Sulphates***	***Manganese***
	Maximum Value	*186*	*8.2*	*3.4*	*ND*	*ND*	*ND*	*ND*	*2.8*	*114*	*ND*
	Minimum Value	*48*	*7.6*	*2.6*	*ND*	*ND*	*ND*	*ND*	*0.5*	*114*	*ND*
	Average value	*95.2*	*7.84*	*3*	*ND*	*ND*	*ND*	*ND*	*1.1*	*114*	*ND*
	Number of observations	*5*	*5*	*2*	*ND*	*ND*	*ND*	*ND*	*5*	*1*	*ND*
Non Monsoon	**Parameters☞**	***TSS***	***pH***	***O&G***	***Lead***	***Copper***	***Zinc***	***Nickel***	***Iron***	***Sulphates***	***Manganese***
	Maximum Value	*98*	*8.6*	*18.5*	*0.05*	*0.13*	*0.3*	*0.009*	*2.8*	*73*	*0.13*
	Minimum Value	*18*	*6.7*	*0*	*0.01*	*0.03*	*0.01*	*0.005*	*0.01*	*2*	*0.02*
	Average value	*67.93*	*7.47*	*6.69*	*0.03*	*0.0756*	*0.1825*	*0.007*	*0.68*	*35.73*	*0.056*
	Number of observations	*14*	*23*	*12*	*6*	*9*	*12*	*2*	*22*	*11*	*10*

Note : ND – Monitoring not done

Table No. 4.3.6.2.2 Summarized data for Surface Water Quality in the Southern Region

(Unit : mg/l except pH)

	Parameters(	pH	Copper	Iron	Sulphates	Mercury	Lead	Zinc
Annual Average	*Maximum Value*	8.4	0.14	1.94	80	0.001	0.02	0.35
	Minimum Value	7.1	0.03	0.09	2	0.001	0.01	0.01
	Average value	7.6	0.08	0.35	21.75	0	0.02	0.17
	Number of observations	39	8	38	39	1	2	16
Monsoon	Parameters☞	***pH***	***Copper***	***Iron***	***Sulphates***	***Mercury***	***Lead***	***Zinc***
	Maximum Value	7.9	*ND*	1.94	38	*ND*	*ND*	*ND*
	Minimum Value	7.2	*ND*	0.14	8.1	*ND*	*ND*	*ND*
	Average value	7.6	*ND*	0.73	27.66	*ND*	*ND*	*ND*
	Number of observations	12	*ND*	12	12	*ND*	*ND*	*ND*
Non Monsoon	Parameters☞	***pH***	***Copper***	***Iron***	***Sulphates***	***Mercury***	***Lead***	***Zinc***
	Maximum Value	8.4	0.14	0.48	80	0.001	0.02	0.35
	Minimum Value	7.1	0.03	0.09	2	0.001	0.01	0.01
	Average value	7.6	0.08	0.17	19.13	0	0.02	0.17
	Number of observations	27	8	26	27	1	2	16

Note : ND – Monitoring not done

Table No. 4.3.6.2.3 Summarized data for Ground Water Quality in the Southern Region

(Unit: mg/l except pH)

Annual Average	Parameters(	pH	Iron	Sulphates	Zinc
	Maximum Value	7.9	0.803	611	0.6
	Minimum Value	6.5	0.03	6	0.45
	Average value	7.36	0.23	124.31	0.54
	Number of observations	39	39	39	39
Monsoon	Parameters☞	***pH***	***Iron***	***Sulphates***	***Zinc***
	Maximum Value	7.8	0.24	182	ND
	Minimum Value	7.2	0.15	6	ND
	Average value	7.63	0.19	58.67	ND
	Number of observations	9	9	9	ND
Non Monsoon	Parameters☞	***pH***	***Iron***	***Sulphates***	***Zinc***
	Maximum Value	7.9	0.803	611	0.6
	Minimum Value	6.5	0.03	28	0.45
	Average value	7.27	0.24	144	0.5375
	Number of observations	30	30	30	4

Note: ND – Monitoring not done

4.6.3.3 Impacts of Noise and Vibrations

Noise pollution in the Kudremukh is mainly due to the mining operations such as drilling, blasting, crushing, haulage etc. The noise levels in the nearby residential areas are being regularly monitored by the mine and shows lower noise levels. Further, the location of the concentrator has been so planned that the noise generated would be attenuated to an acceptable level by the time it traverses to the township and for the purpose, thick barriers of trees have been raised. Studies of blasting vibrations at Kudremukh mines conducted during 1998 by the Training and Safety Department of KIOCL revealed that the vibrations are well within the DGMS limits. Moreover, no building (other than those owned by KIOCL) is located with in a distance of 2Km from the mine workings. The present workings are well away from the final slopes of the pits. However, when the area being worked out comes within 300m of the final slopes, only controlled blasting will be carried out. Control in this context, implies reduction of the maximum charge per delay, from the present level of over two tonnes to less than a tonne, by judicious use of delays. Since blast vibrations are directly proportional to the charge, the already low vibration levels can be reduced to half or even one third of the present levels by such controlled blasting.

In the Donimalai, the locations of mines and plant are quite far away from the Township and other adjoining villages like Narasingpur, Ranjitpura etc., the horizontal and vertical distances being more than 3.5 kms and 400 m respectively. Due to the natural barrier like configuration of the hilly terrain, the noise levels in the mine and infrastructural areas do not affect the township and office buildings etc., as the latter are situated far away in the flat terrain down the hill. Moreover, the noise produced from various locations in the mines is also not continuous and only intermittent.

4.6.3.4 Waste Management

The major solid waste contributions from the mining and beneficiation processes are overburden, waste rocks, and soil washouts during monsoon and tailings from beneficiation. In the Kudremukh mine, the solid waste generated in the mines is negligible. This is used mainly in developmental works and maintenance of haul roads with in the mines and the balance is disposed in various identified dumps. The solid waste also generated by the way of soil erosion leading to washouts having potential for use. This is collected in Pollution Control (PC) dams constructed at the foot of the mines at suitable locations i.e. valleys with proper drainage facility and is desilted during non monsoon period. Over 1 Mt of material is desilted every year from PC dams and recycled to beneficiation plant to produce concentrate. The tailings in the form of slurry generated by beneficiation process and still contain 22% Fe. This is stored in Lakya dam about 4Km away from the mines for settling. KIOCL has already started investigations in association with M/s Mineral Technologies, Australia, the possibility of recovering iron. The total quantity of tailings deposited in the Lakya dam is about 140 Mt since inception. During beneficiation of iron ore in the concentrator plant, the waste other than tailings generated is the ore itself in case of any power trippings and mechanical breakdown of any equipment. There are 4 lines of operation and 500 T of solids (iron ore) is collected in Dump ponds of capacity 1.5 Lakh Tonnes of solids. This material is continuously pumped back to the process as an effective measure of conservation of resources.

In the Bellary-Hospet sector, most of the mining activity is confined to higher altitudes such as ridges, hillocks. To expose the ore body, the overburden which is mainly composed of shale/phyllite, manganiferous shales, ferruginous quartzites, metabasalt, lateritic capping and top soil, is being dumped after excavation on steep hill slopes and less commonly along the intermittent valleys, thus destroying the prime forest land. Similarly in some of the mines, in the interest of quick return of investment, selective mining is being done. Easy approach to ore body is being followed and after exploitation of ore body the place is being left as it is, leading to further generation of sedimentation and ultimately accelerating the soil erosion. However, the big companies like NMDC has taken proper care in waste management in their Donimalai iron ore mines. Waste dump locations were selected in the closed valleys devoid of thick vegetation, keeping in view the land degradation due to dumping and subsequent erosion due to water, wind etc so that the dumping operations will not have any adverse impact on the existing flora and fauna of the area. Moreover, to check any wash-outs of the waste dumps into the streams and surrounding areas, check dams have been constructed. Four check dams in South Block and one check dam in North Block in the eastern valley and two check dams and one tailing dam (to impound the slimes) in the western valley have been constructed. During last 5 years mining operations with effect from 1999, a quantity of over 9 million tonnes of waste has already been excavated. An additional quantity of balance 20.5 million tonnes of waste has been excavated. The present surface area occupied by the dumps is around 28.9 ha and the ultimate occupied area by the dumps will be 44.90 ha with a height of 80 m and with a slope angle of about 37 degrees. The abandoned waste dumps have been reclaimed by way of afforestation and the waste dump slopes have been stabilised by planting agave, grass etc. after suitably terracing the dumps.

4.6.3.5 Afforestation and Ecology

One of the peculiar observations made at Kudremukh is that most of the hills both on the ore body as well as on the northern side of the township are bald with only a thick mat of grass and no trees except in the "Sholas" where a thick line of trees are existing. After the successful mining operations, in the mine abandoned area plantation of acacia has been achieved during the last few years. With the guidance and assistance from other organisations such as Karnataka Forest Deptt. and Karnataka Cashew Development Corporation , the mining authorities at KIOCL has taken up large-scale afforestation resulting in achieving a cumulative plantation of nearly 75 lakhs seedlings till now, covering extensive areas within the lease area. The entire waste land extending over 2970 acres in the lease area has been fully covered with plantation.

In Donimalai mines, intensive afforestation programmes have already been adopted in successive phases based on the immediate need, priority and availability of resources. About 4 lakhs saplings were planted so far for checking of slimes flow and water pollution from distributed zones by planting soil binding species and to create effective green belt. In intervening space between the township and the loading yard, part of the area is already covered by green belt. In the vacant sites available in this area, steps were taken to cover the locations near the roadside, nullah banks etc. by planting predominantly *Eucalyptus*. In addition, other species like *Polyalthia longigolia, Accacia Auriculiformis* etc. have also been planted in order to form a protective barrier against dust between loading plant and the Donimalai town ship. In and around the township, plantation has massively and meticulously carried out, keeping in view the ecological as well as aesthetic aspects. Plants concentrated along the roads within the area creating a beautiful avenue effect along the roads, around the public buildings, schools, hospital, community centre, administrative office etc. The species in above mentioned areas consist of plants like *Eucalyptus, Auriculiformis, Gulmohar, Jacaranda* etc. Trees of ornamental type have been planted in the guest house and surrounding area, whereas, trees of less ornamental type and wider foliage have been planted along the periphery of the houses and between adjacent rows of houses. The township area contains more than 6000 fruit bearing trees like *Archars Zapota, Annona Mamelos, Emblica Managnifera Indica, Tamarindus India etc.* NMDC has carried out systematic and methodical plantation programmes at the hilltop areas in various sites such as along the haul roads, around infrastructures, around office buildings, on the east dumps and in all possible vacant areas.

Most of the small individual mines producing lass than one lakh tonnes of saleable iron ore per annum in the Bellary-Hospet region, are reported to unable to obtain required species in sufficient quantity in time during the onset of monsoon from local forest department. It would be a better to encourage these small mine owners to form a co-operative among them selves for maintaining common nurseries at convenient places like Sandur, Hospet, Toranagallu and Bellary. Many mine owners have made efforts to raise plantation in and around their mining leases. But maintaining/raising plants at these mines is becoming difficult as iron ore occurs on the top of the hills, which are at much higher levels than that of the water table and the availability of water is a problem in the area.

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5.1 CLEAN TECHNOLOGIES

As mechanised open cast iron ore mines are becoming larger, deeper and more capital intensive, continuing efforts should be made to improve upon the open cast mining activities through advances in the equipment size / design and practices and also through introduction of innovative techniques. The application of high capacity continuous surface mining techniques to harder formations, new concept of high angle belt conveying system, in-pit crushing systems (mobile and semi-mobiles), high capacity dumpers, automatic truck dispatch system, non-electric blast initiation systems etc. and developments in the area of bulk explosive systems hold out almost unlimited opportunities for upgrading the performance of opencast iron ore mining in India, while minimising the environmental impacts. In addition, the following proved cleaner technologies are need to be implemented in Indian iron ore mines, considering the suitability to the particular site:

- Adoption of Wet drilling
- Use of ripper dozer as an alternative to drilling and blasting
- Use of hydraulic hammer/rock breaker as an alternative to the secondary boulder blasting
- Use of opti blast technology and split charge blasting techniques wit air decking by the gas bags
- Use of non electric (NONEL) initiation devices (EXEL of ICI and RAYDET of IDL)
- Application of in-pit crushing and conveyor transport system as an alternative to all dumper transport system in deep mines
- Dry Fog dust control system at the crushing, screening & material handling/processing plant as an alternative to de-dusting system with bag-house
- Use of Hydro-cyclones and Slow Speed Classifiers in the wet beneficiation circuits to maximise the recovery of iron ore fines.

The details of the feasible cleaner technologies for Indian iron ore mines are discussed below:

5.1.1 Control Technologies for Drilling Operation

Presently, in most of the opencast iron ore mines in India, the drills of 100mm to 250mm diameter are being used, except for the KIOCL where 311mm dia rotary drills were in use. The drill may be electrically operated or diesel operated. Normally dust extractors can be fitted with these drills. The system runs with a hydraulic pump to run a fan. This fan creates suction in the suction chamber. From this chamber, a hose is connected to the mouth of drill bit assembly. The drill bit assembly is provided with thick cotton flaps on four sides to completely cover the drill hole when the drilling operation is going on. The drill cuttings which come out at the drill mouth on the surface are drawn to this suction chamber and get accumulated in it. In some of the larger diameter drills, there is a provision to throw the finer particles into the atmosphere which is at a level above the operator's cabin.

The main disadvantages of this system are:

i. The flaps provided at the mouth of the drill hole get missing and even if they are provided intact, the effectiveness of sucking of the drill cutting into dust extractor is only 60 %. The remaining 40 % dust particles rise above the drill hole.

ii. Though the dust extractor draws the drill cuttings, it again discharges the dust into the atmosphere at a level higher than operator's cabin. This again pollutes the entire area of drill machine and its surroundings. A cloud of dust can be seen in and around the drill machine.

iii. The operators are provided with dust mask / dusk respirators to prevent inhalation of dust particles. But most of these dust respirators are found ineffective after use of 10 to 15 minutes as dust accumulates on the filter and breathing becomes difficult. So most of the operators are reluctant to use dust mask.

The dry dust extractors are mostly ineffective. Wet drilling was first introduced in Iron Ore Mines in India during 1991-92. Initially, there was an apprehension from the management that wet drilling arrangements might not be effective due to soft nature of strata (compared to hard rock in metalliferous mines) and was difficult to adopt. However after continuous persuasion in one of the mines, the wet drilling arrangement in drill machine was introduced and it was very effective in suppressing dust. Mainly, the drill operators were relieved of the dust menace.

5.1.1.1 Wet drilling Arrangement

With very simple modifications in the existing drilling machines, the wet drilling system could be adopted.

(a) Accessories

The following accessories are required for modification:

i. A water tank of about 200 litres capacity is to be mounted on drill machine chassis. The tank should have the capacity to withhold the pressure of at least 10 Kgs. per centimetre.

ii. Hoses of 12.5mm. diameter is to be connected from the receiver to water tank and these have to withhold the pressure of 8 - 10 Kgs. per centimetre square.

iii. Water hose of 12.5 mm. diameter of suitable length to connect from water tank to compresses air delivery pipe.

iv. 12.5 mm. full flow G.M. Valve.

v. Pressure release Valve.

vi. Nozzles.

(b) Operation

Fill up the water tank (90 % of the tank) before starting the drill machine. Close the air delivery sluice valve, let the air pressure rise to 8 Kgs. per square centimetre inside the air receiver. This pressurised air will flow from air receiver to water tank and exert approximate 8 Kgs. per square centimetre pressure on the top of the water inside the tank. Due to this, water will flow through water hose from the water tank and finally will be discharged into the air delivery pipe. There is a water control G.M. valve to control the flow of water as per the requirement. Then open the air delivery slice valve. The pressurised air will carry the atomised water inside the delivery pipe through Rotary Head Drill pipes and will finally discharge through the Drill bit inside the hole. Dust generated due to the cutting action of the drill bit will be suppressed by the spray of water inside the hole itself. As a result there will be no air borne dust nearby the drill.

(c) Considerations

The following aspects are to be considered while modifying to wet drilling arrangements:

i. Adequate strength of water tank to withhold the pressure of 8 - 10 Kgs. per centimetre square and also should have a capacity to run for at least one shift.

ii. It was observed that in 100 mm. drill machines, the water consumption was about 10 litres per 8meters drill hole. As such a tank capacity of 200 litres is required for drilling 20 holes in a shift.

iii. Provision of a pump to the water tank to pump water to the air system eliminates the water tank to withhold the pressure of 10 Kgs. per centimetre square and so the tank capacity can be increased as per the space available on the chassis to the drill machine.

iv. The above suggested modifications can be done at the mine level and the cost is nominal. High pressure drums of rejected 35T/50T dumpers can be used as water tanks.

Advantages of Wet Drilling

i. In this system dust get suppressed close to its formation. Dust suppression become very effective and the work environment will be improved from the point of occupational comfort and health.

ii. Due to dust free atmosphere, the life of engine, compressor etc. will be increased.

iii. The life of drill bit will be increased.

iv. The rate of penetration of drill will be increased.

v. Due to the dust free atmosphere visibility will be improved resulting in safer working conditions after day light hours.

Line Diagram and photograph for Wet Drilling Arrangements are shown below.

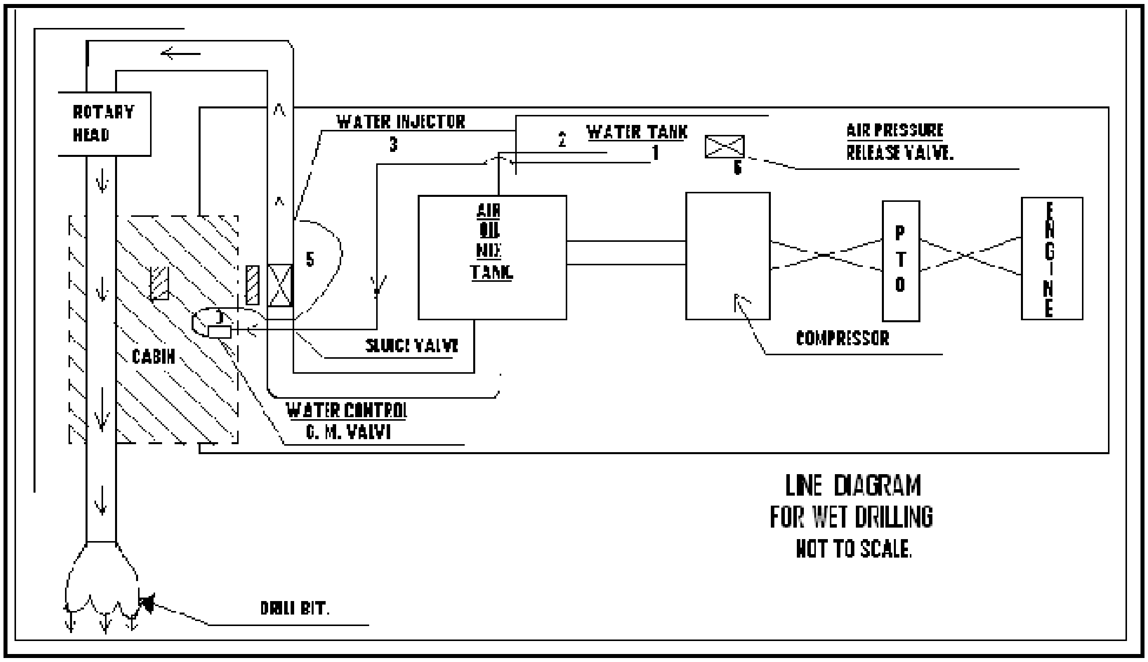


Fig. No. 5.1.1.1.1 Line Diagram for Wet Drilling Mechanism

Fig. No. 5.1.1.2.2 Wet Drilling in Operation

5.1.2 Ripper - An environment friendly alternative for Drilling & Blasting.

Basically Ripper is a farmer's plough type steel shank (furrow) mounted with tooth and attached with a beam at an interval of 1m to 2m a part - (average total numbers of shanks are 4 but 6 teeth are also available) and the whole unit is attached at the rear side of the crawler truck mounted heavy duty diesel operated tractor in case of tractor mounted type ripper. The steel plough body attachment has cutting tool at the bottom of it which dips into the ground (to be ripped) at a depth varying from 0.4 m to more than 1.2 m depending upon the design of the machine, by the thrust applied by the hydraulic system. When the tractor dozer starts moving the friable soft to medium hard rocks or mineral body breaks up properly which are then loaded either with the help of a scrapper or a loader or simply dozed with the help of bull dozer.

This type of machine is suitable for ripping alluvial surface, soft rocks, coal, laterite deposits etc. The degree of rippability depends upon the brittleness of rock, degree of stratification and lamination of rock, well defined fracture plane, moisture contenting the rock, geological disturbances like fault and other fractures, grain size, degree of consolidation and weathering, wet condition physico mechanical properties of rocks like compressive strength, tensile strength, shear strength etc. Some times pre-fracturing of the consolidated ground (by blasting) is necessary for efficient operation. The rippability of rocks can be determined by measuring the magnitude of the seismic wave velocity in the rockmass. Lower the velocity better would be the rippability of the rock. A seismic wave velocity less than 3000 m/s in the rock are - amenable for ripping. The ripping (scarification) depends upon the nature of the ground, power and type of ripper, the downward thrust to the shank tooth, weight of the tractor/dozer unit, etc. Ripper's cutting teeth is forced to penetrate into the ground with the help of hydraulic pressure and cause a sheer failure of the rock when the force exceeds - the compressive strength of the rock mass. The tractor / dozer with the ripper attachment when starts moving the draw bar pull cause tensile breakage of rocks. In case of fractured rock mass, the rock failures occur when the drawbar pull exceeds the cohesion between the fractured blocks of rocks.

In order to eliminate conventional drilling and blasting the ripper is most suitable for rock which is soft, friable and fractured. Ripper dozer (700 HP) is extensively used in the iron ore mines of Goa region, where laterite / iron ore is soft and friable. Drilling and blasting is almost nil and thereby reducing noise and dust pollution. The photograph given below depicts a Ripper Dozer working in Bicholim Iron Ore Mines in Goa region.

Fig. No. 5.1.2.1 Ripper Dozer Working at Bicholim I/O Mines in Goa

5.1.3 Hydraulic Hammer/ Rock Breaker – An environment friendly alternative to Secondary Boulder Blasting

The most convenient application in opencast iron ore mines for secondary breaking of boulders is a hammer mounted on a regular hydraulic excavator on wheels. The structure of a modern hydraulic hammer/rock breaker is very simple. There is a piston moving up and down and striking directly against the tool. To produce big energy pulses during the downward stroke, the hammer is equipped with a nitrogen accumulator which is able to supply the necessary volume of compressed oil in a very short time. The accumulator is charged continuously by the pump of the excavator or by an electrically driven hydraulic power pack.

When the quarry machinery is coupled with a hydraulic hammer unit, the following advantages can be achieved

- Drilling, loading and haulage can be carried out without interruption and production will increase.
- Fly rocks from secondary blasts do not damage the neighbouring machinery, cables and structures. Heavy hydraulic hammer can be used in open cast mines not only for boulder breaking but also for the following purposes :-

    i. When a heading blast has failed and the rockpile is so tight that cannot be loaded, the hammer is an excellent tool to loosen the pile.
    ii. In sections where the rock is very fissured, drilling and charging of blasthole is difficult, the big hammer can be used for benching.
    iii. Noise pollution due to boulder blasting can be completely eliminated by using hydraulic hammers
    iv. Toes on the quarry floor can be easily removed and faces can be cleaned by use of the hammer

Different types of hydraulic hammer/ rock breaker and its breaking capacity are given below:

Weight of the hammer and its energy	**Boulder size**	**Breaking capacity m^3/8h**
800 Kg, 2000 Joule	< 1 m^3	150 - 250
1600 Kg, 4000 Joule	< 3 m^3	200 - 400
2400 Kg, 6000 Joule	< 6 m^3	300 - 600
3200 Kg, 8000 Joule	< 6 m^3	300 - 1000

5.1.4 Environment friendly Blasting Technology

5.1.4.1 Opti Blast Technology

The Opti Blast method of blasting economises on the consumption of explosive by about 15% to 20 % as compared to conventional blasting. This method is already in use in KIOCL (figure above shows the opti-blast technology at Kudremukh Iron Ore Mines). The saving is affected by creating an Air Deck (1.0 to 3.0 m) in the top column, between the column charge and stemming. In this method in KIOCL, out of 17.0 m depth of hole, the bottom 1.6 m is back filled with drill cuttings, followed by explosive column containing 3 m of bottom charge (approx. 219 Kg) and about 5 m of column charge (366 Kg). Above the explosive column, an Air gap of 1.4 m is created by suspending a cone basket from the collar of the hole. Column above the basket is stemmed with drill cuttings. Like conventional blasting, two boosters (500 gms) are placed in the explosive column - one in the bottom and the other, about 3 - 4 m above.

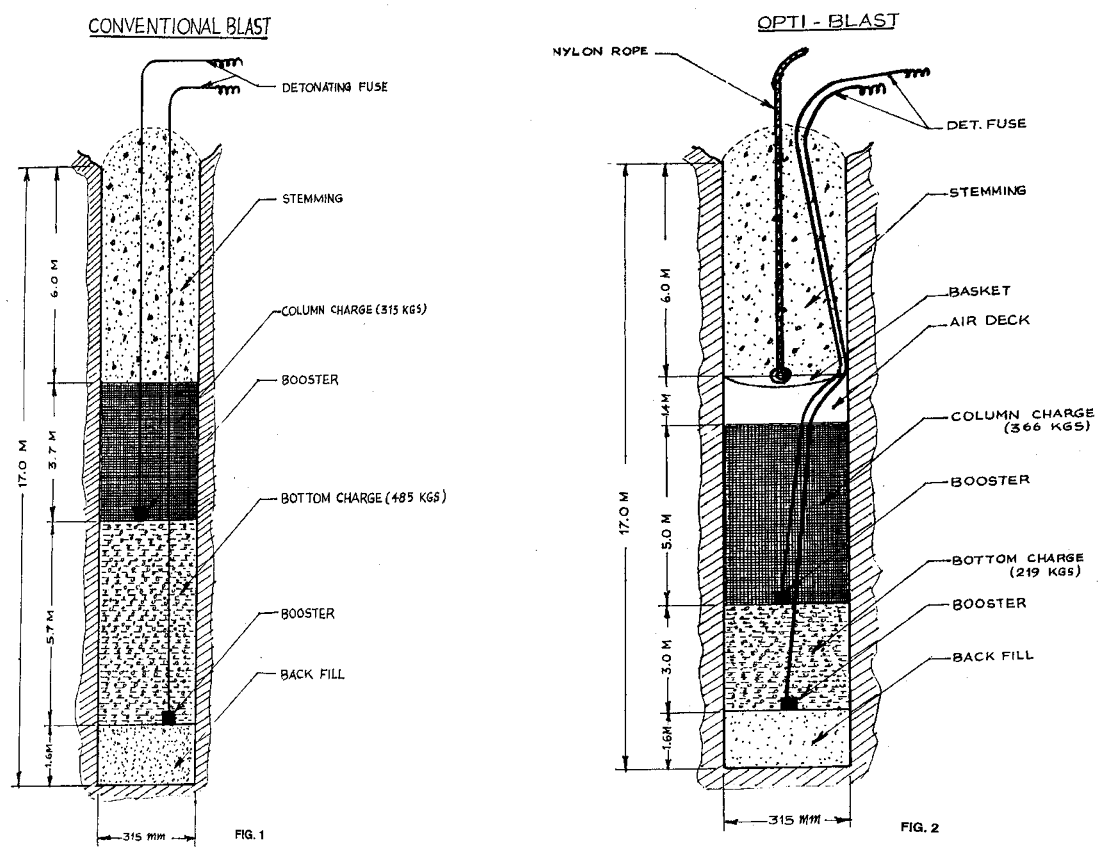


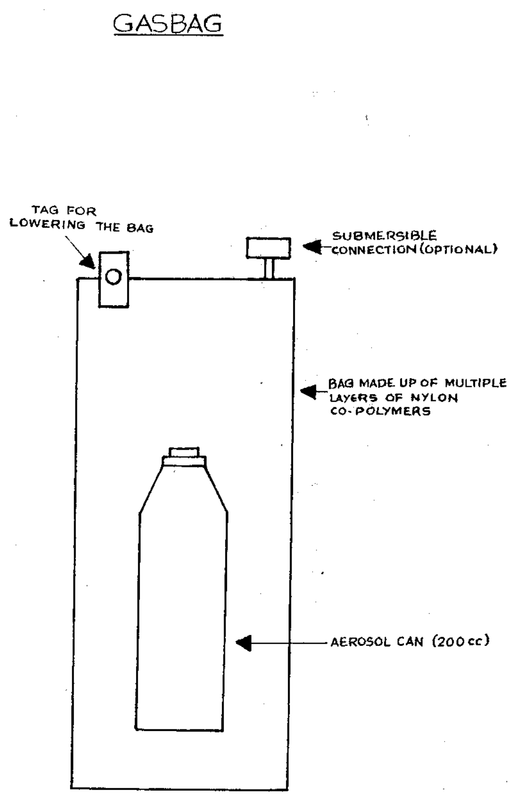
Fig. No. 5.1.4.1.1 Conventional Blast vs. Opti Blast

The advantages of opti blast technology are as follows;

1. Explosive consumption is less compared to conventional method of blasting.
2. Ground vibration, noise and fly rock generations are much less compared to conventional method of blasting.
3. Better utilisation of explosive energy compared to conventional blast.
4. Good fragmentation.

5.1.4.2 Split Charge Blasting techniques with Air Decking by Gas Bags

It differs from opti-blast in the sense that the Air Deck is created in the middle of explosive column (Fig B) and gas bags are used in place of cane baskets (Fig A). The gas bags are made up of multiple layers of NylonCo-polymers and contain an aerosol can with a plunger.



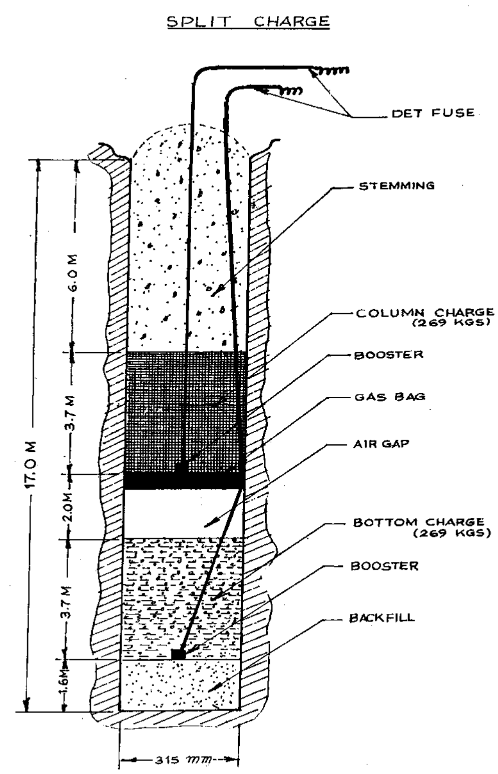


Fig- A

Fig - B

Fig. No. 5.1.4. 2.1 Split Charge Blasting with Air Decking by Gas Bags

The capacity of the can is 200 cc and it contains 100 gms of propane gas. One tag is provided on the top of the bag for lowering it down the hole, using a string. When the plunger is pressed, propane gas is released from the can and it inflates the bag within 45 seconds. After that, the bag becomes tight at the pre-determined depth, and the tag is pulled out.

In this method also two boosters (500 gms. each) are used – one in the bottom of the explosive charge, and the other on the top of the gas bag, in the column charge. Gas bag is a new introduction in KIOCL and helps in creating mid-column air decks. Experiments conducted by Melnikov and others have shown that by introducing air gaps in explosives columns, there is considerable increase in the utilisation of explosive energy.

5.1.4.3 Melinikov's Theory of Air Decking Blasting Techniques

The detonation of a confined explosive without any Air-Deck can be divided in to the following four stages. Shock and stress wave Propagation

Detonation stage :	Generates pressure front or shock front which acts on the Bore hole wall
Shock and stress wave propagation :	Occurs in conjunction with detonation producing crack network in the surrounding rock mass.
Gas pressure :	During or after stress wave propagation the high pressure gases impart stress field around the blast hole that can expand original hole, extending radial cracks.
Mass movement :	The fragmented material is moved out under the pressure of the explosive gases.

Although explosive/material interactions can be conveniently divided into four stages, in reality, these events can occur at the same time. Melinikov has suggested that air decks provide a mechanism by which a secondary stress wave can be readily and inexpensively generated. The theory postulates that shock wave reflections within the hole produce a secondary stress wave which extends micro fractures network prior to gas pressurisation. According to Melnikov, Air decks reduce the final hole pressure produced by the explosive products but increases the duration of their action on the rock (Air deck do not affect the detonation pressure of the explosives).

These after shocks arise from the different velocities or distances travelled within the air deck by three main pressure fronts:

- Shock front.
- Pressure front resulting from the formation of explosive products behind the detonation front.
- Reflected waves from the bottom of the blast hole or from the base of the stemming. As these shock fronts move within the air gap, they generate radial cracks from the discontinuities in the bore hole, provided the pressure is greater than the toughness of the material.

This method of Blasting is practiced in Australia and also has been successfully introduced in KIOCL resulting in reducing ground vibration, noise & air blasts due to reduction in explosive quantity.

Table No. 5.1.4.3.1 Comparison among Conventional, Opti-blast & Split-charge Blasting Techniques

Sl. No.	*Area*	*Conventional*	*Opti-Blast with Cane Baskets*	*Split-Charge with Gas-Bags*
1.	Decking	No Decking	Suitable for 'top' of column Air Deck only	Suitable for Mid-column, Top & Bottom Air Decks
2.	Air Gap	No Air Deck	Not very effective in maintaining the Air Gaps	Effective in maintaining Air Gaps
3.	Technology	General Method	Crude method	Advanced Technology
4.	Ease of Handling	-	Cumbersome to use	They are light and compact and quick and easy to apply
5.	Fragmentation	Fragmentation is not satisfactory	Produces satisfactory fragmentation	Fragmentation is better than Opti Blast
6.	Flyrock	Severe	Comparatively much less	Negligible
7.	Ground Vibrations	Ground vibrations are high	Ground vibrations are less compared to conventional and are within the statutory limits	Ground Vibrations are low and well within the statutory limits
8.	Watery Conditions	Can be applied in watery conditions	Not suitable for watery conditions	Suitable for watery holes
9.	Exp. Energy Utilisation	Wastage of explosive energy is highest	Lots of explosive energy get wasted	Better utilisation of explosive energy
10.	Cost	Expensive method	Comparatively cheaper	Most economical

5.1.5 Environment Friendly Blast Initiation Devices

The first phase of production cycle in the open cast iron ore the mining operations is rock breaking by drilling and blasting. Optimisation of this processes are very important because the fragmentation obtained in this operation affects the inter-related operations like loading, hauling, crushing and grinding.

Use of explosives for breaking the rock began in the year 1627. Black powder, the oldest low explosive used for rock fragmentation, couldn't prove to be an efficient blasting agent due to its' low strength. Therefore, it was gradually replaced by more powerful explosives such as Nitro - Glycerine (NG) based explosives, Ammonium Nitrate Fuel Oil (ANFO), slurry explosives, emulsion explosives and liquid oxygen explosives etc. Commercial explosives are designed to be relatively stable for safe usage, transport, storage and manufacture. A powerful localised shock or detonation is required to initiate commercial explosives this is achieved by use of an initiating device. The initiative device may be electric or non-electric. The initiation system will influence the blast results. While handling large size blasting, two important parameters to be considered are:

1. **Proper utilisation of explosive energy:** Means how much of energy is actually utilised for rock breakage i.e. the quality of fragmentation obtained. The remaining energy results in the form of ground vibration, noise and fly-rock. The cost factor is also dependent of effective & efficient use of explosive energy.
2. **Effect on environment:** It has become a major concern for mining industry. Therefore it is necessary to conduct environment friendly blast which will reduce the problems like flyrock, airblast, ground vibrations etc. Since, type of initiation system influences these parameters. It is necessary to select the appropriate initiation system.

5.1.5.1 Initiation Systems

An initiating system consists of three basic parts.

1. An initial energy source
2. An energy distribution network that conveys energy into the individual blast holes, and
3. An in hole component that used energy from the distribution network to initiate a cap sensitive explosive.

The initial energy source may be electrical such as a generator or a condenser discharge blasting machine or a power line used to energise an electric blasting cap, or a heat source such as a spark generator or a match. The energy conveyed to and into the individual blast holes may be electricity, a burning fuse, a high energy explosive detonation or a low energy dust or gas detonation.

There are basically two methods of initiation systems. Those are:

1. Electrical initiation system and
2. Non-electrical initiation system

1. Electric initiation systems utilise an electrical power source with associated circuit wiring to convey electrical energy to the detonator. Again in electrical initiating systems, there are different initiating devices like :
    - Electric detonators
    - High intensity detonators
    - Electronic detonators
    - Seismic detonators and
    - Submarine electric detonators

2. Non-electrical initiation system utilise various types of chemical reactions ranging from deflagration to detonation as a means of conveying the impulse to non-electric detonators. Different types of devices are available for surface initiation or for in the hole initiation. In non-electric initiating system, the different types of devices are :
   - Non-electric initiation using safety fuse and plain detonator and plastic ignite cord combination
   - Non-electric initiation using detonating cord
     - Detonating cord with delay element
     - Low energy detonating cord (LEDC) initiation
     - High energy detonating cord (HEDC) initiation
   - Non-Electric initiation systems (not utilising detonating cord) are :
     - NONEL
     - HERCUDET
     - EXEL
     - RAYDET

Although the detonating cord-based ignition system and also (safety fuse and plain detonator) ignition system is non-electric, usually in practice Non-electric refers to the "NONEL and NONEL type systems". NONEL refers to non-electric detonator initiation system. It is the common name of a series of blast accessories developed by Nitro Nobel of Sweden, which uses shock tube principle. It combines the advantages of electric detonator and detonating cord.

5.1.5.2 Electric Initiation

Electrical initiation system utilises an electrical power source with an associated circuit to convey the impulse to the electric detonator which in turn initiates the explosive charge. Basically there are two types of detonators.

1. Ordinary electric detonators (instantaneous type),
   - Low tension detonators
   - High tension detonators
2. Delay electric detonators
   - Half second or long delay detonators
   - Milli second or short delay detonators

Electric Detonators

In this type electric circuit to the detonator is supplied from the power source through the circuit wiring by means of two lead wires that are internally connected by a small length of high resistance bridge wire. The electrical energy is concerted into heat energy on passing the fire current through the bridge wire. The heat energy heats the pyrotechnic composition that surrounds the bridge wire on the bridge edge assembly. The resulting flame ignites initiating charge or delay element, these intern setoff the base charge.

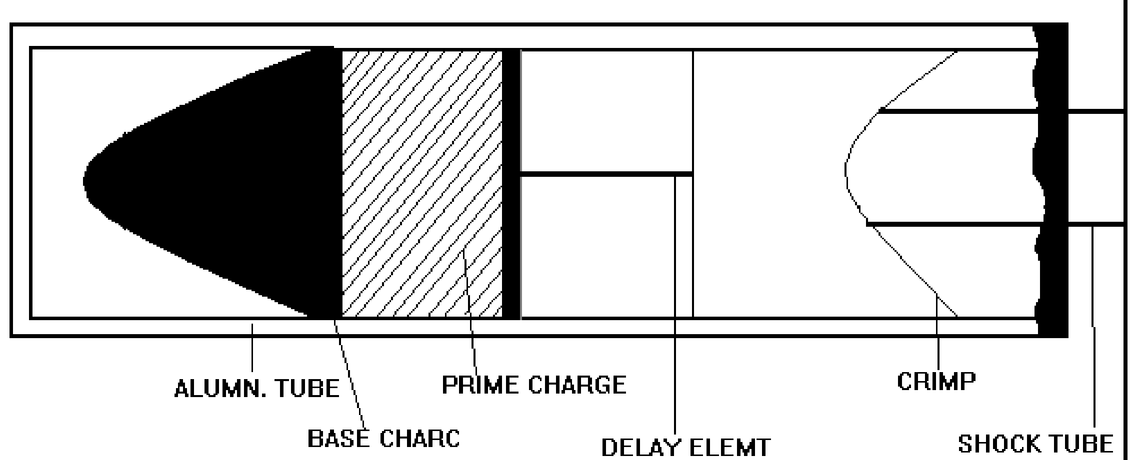
5.1.5.3 Non-electric Initiating Systems (Without Detonating cords)

Shock Tube Detonators: Shock tube as the name suggests, is a plastic tube of about 3-4 mm outer diameter and 1.5 mm internal diameter. It is coated inside with a explosive composition (reactive substance). The quantity of explosive is about 20 mg/m. It consists of a length of shock tube whose one end sealed and the other end is crimped with a delay detonator. Initiation is provided by using detonator or detonator cord to the sealed end. A mild shock wave in the form of dust explosion travels at a speed of 2000 m/s. The mild shock is very weak and hence it does not damage the shock tube. The shock wave intern detonates the high explosives primed with it.

It was invented in late 1960's and patented by the NOBLE in the trade name of NONEL. In many countries like Australia, USA they were manufactured by taking permission from NOBEL. In the last five years, after the expiry of the original patent, shock tube detonators of various types have come into the world market, some are in developing stage. Few developed ones are EXEL from ICI, RAYDET from IDL, HERCUDET from HERCULES.

NONEL: Nonel is the common trade name of a series of blast initiation accessories developed by Nitronobel of Sweden, which uses "shock tube principle". Nonel is a flexible plastic tube having outer dia of 3 mm and internal dia of 1.5 mm respectively. It is coated with a reactive substance internally. It maintains the propagation velocity of 2000 meter/sec. It consists of a delay detonator at one end and other end is sealed. The sealed end is initiated by either detonator or detonating cord. It sets a shock wave which travels through the shock tube. The Nonel detonator consists of following elements:

1. The visible part is an aluminium shell, the length of which may vary according to the length of delay element.
2. A base charge of high explosive is present at the bottom of the tube as shown in the figure below, which gives NO:8 strength.



NON - ELECTRIC DETONATOR

3. A prime charge made of flame sensitive explosives is present above the base charge as shown in the figure.
4. The desired delay interval is provided by an aluminium tube delay element filled with pyrotechnic composition, part of which is directly pressed into the shell.
5. The detonator is crimped against a rubber sealing plug which also protects a portion of Nonel tube against wear.
6. A specific length of Nonel tube with it's free end sealed is attached to the nonel detonator.

5.1.5.3.1 Special Variants of Nonel Detonators

NONEL GT/MS: It is an all round initiation system which is used in all applications where millisecond delay is required, e.g., blasting above or below the ground. It is made up in a conventional manner. The detonators have individual delay and the activation is simultaneous. The range of delay varies from 3 to 20 with 25 milliseconds between each period starting with 75 milliseconds.

AYDET: This product was developed by IDL industries Ltd. India. It is similar to NONEL and uses shock tube principle. RAYDET consists of a hollow polymer tube having an internal dia of 1.5 mm and external dia of 3 mm. The tube is thinly coated on the inner side with a reactive material 10 - 15 mg/m (PETN). The detonation velocity passing through the shock tube is of the order of 1800-2000 m/s (M.O. Sarathy, 1995). One end of the tube consists of a detonator and another end is sealed. It can be initiated by detonating card or detonator, or with special starter caps. Presently up to 20 delays is available starting with 50 ms and with an interval of (25 or 50 ms).

Raydet DTH (Down the hole) : Raydet DTH is essentially a Raydet milli second delay with an accurate firing time of 475 and 500 ms. Raydet DTH is used in-hole in conjunction with surface delay unit Raydet TLD. Other delay intervals are also available. Raydet DTH units are assembled with heavy-duty tube. The idea of using high delay interval of 475 ms is to ensure that the detonation of the surface hook-up would be at least several rows or drill holes ahead before the first hole gets initiated and ground movement starts subsequently.

Raydet TLD (Trunk Line Delay) : Raydet TLD is a surface delay initiation unit, which assists, in non-electric sequential blasting. Raydet TLD consists of a Raydet MS delay detonator assembly with delay intervals of 0,17,25,34,42,50,67 and 100 ms. A specially designed bunch block connector is fitted on the detonator shell. The bunch box connector has facility for hooking-up up to six shock tubes at a time. The bunch block connectors are coloured coded for easy identification. The colour codes are :

Delay Interval (ms)	***Colour***
0	Green
17	Yellow
42 / 50	White
67	Blue
100	Black

EXEL: In 1989 ICI patented a new method of producing the shocktube called EXEL (Bhushan & Srihari, 1995). This product was developed by ICI, in late 1970's. EXEL is a new type of shock tube which has good resistance to contamination by water and diesel fuel and has high strength, toughness. Therefore, it is able to withstand rough handling, low temperatures up to 3.5 degrees centigrade and high surface temperature of 65 degrees centigrade. It has four times the abrasion resistance & tensile strength compared to regular shock tube. EXEL shock tube is a plastic tube of 3 mm outer dia and 1.5 mm. inner dia. A fine dust of HMX and aluminium powder is sprayed during extrusion thus forming a fine coating of explosive in the inner walls of the tube. The quantity of explosive is between 14 to 16 mg/m. thus the tube remains intact after the passage of the shock wave.

Exel shock tubes cannot be normally be initiated by an electrical source, such as mains electricity, batteries, static electricity. They will not burn and cannot be initiated by an open flame.

EXEL MS detonator: Exel MS (milli second) detonators consist of a no-electric detonator with mill-second delay interval, a length of signal tube which has an inner coating of reactive powder, one of the ends of the tube being crimped into the detonator shell and a inert plastic cobra connector to provide a rapid mean of attaching the tube to a trunkline of detonating cord. EXEL MS detonator provide a series of delay times suitable for blasting in surface mining, tunnelling, quarrying and underground operation.

MS delays : 17 ms, 42 ms, 100 ms, 150 ms, 175 ms, 200 ms, 250 ms, 300 ms, 400 ms, 450ms.

Exel LP detonators: Exel LP (long period) detonators are similar to EXEL MS detonators with long period delay intervals. LP delays : 200 ms, 400 ms, 600 ms, 1000 ms, 1400 ms, 1800 ms, 2400 ms, 3000 ms, 3800 ms, 4600 ms.

Exel MS and Exel LP incorporates detonator with high strength base charge and can directly initiate detonator sensitive boosters and NG explosives. The detonators provide a high level of safety as the Exel detonators incorporate a isolation cup which allows any electrostatic charges which may prevent spark discharge in the detonator.

5.1.5.4 Advantages of NONEL

In conventional initiation method, detonation fuse (10 to12 gm PETN per m length) is used as trunk and down the hole lines and delays between rows or between the holes are provided by using cord relays (25 milli seconds or 50 milli second delay timing). The short comings of the conventional system of initiation are:

a) Detonating fuse generates a high degree of shock due to high grammage of PETN present in it and thereby generating high volume of noise of air over-pressure.

b) Loosening and ejection of stemming material in the stemming column takes place due to the gasses coming out during travelling of shock wave through detonation fuse.

c) Deflagration of desensitisation of non-cap sensitive column charge occur when shock wave travels through detonating fuse, which is in contact with the column charge in the blast tube.

d) True bottom initiation cannot be done with conventional system of initiation as prime / booster charge is distributed along the length of the blast hole.

e) In-hole delay system cannot be used with conventional system of initiation. Thus, deck charge cannot be separated in terms of delay time hence ground vibration is more in this case.

The above shortcomings of the conventional system of initiation with detonating fuse and cord relay can be to the great extent eliminated by using shock tube delay initiation (non-electric) system.

a) One of main plus point of shock tube initiation (non-electric) system is down-the-hole delay timings. As indicated earlier with multi-deck in-hole delay timing the ground vibration can be minimised as charge per delay can be kept minimum.

b) De-sensitisation of column charges non-cap sensitive in the blast holes is minimum or nil, as the shock wave travels through the inside of the shock tube and thereby enabling true bottom initiation of explosive column.

c) Loosening the compactness of stemming material and premature venting of explosion energy through stemming column is avoided by using non-electric system as the shock wave passes through inside the shock tube and the emanating of gases resulting in injection of stemming material is avoided.

d) Noise generated due to air-over pressure (air blast) is minimum as a low degree of shock wave travel through the inside of shock tube at surface trunk lines and the contact shock wave with the general air is minimum.

e) Reduced problem of fly rock.

Apart from the above advantages, it has better fragmentation and minimisation of toe problems. The technology of NONEL has been proved to be good for fragmentation and minimise the ill effects of blasting like ground vibration and noise which can improve the safety, production and productivity.

5.1.5.5 Stemming control during blasting operation

Recently several innovations have allowed improved utilisation of gas energy during blasting operation by stemming control. Stemming is used in order that a high explosive charge functions properly and release the maximum energy, the charge must be confined in the bore hole. The primary function of stemming is to confine the gases produced by the explosive until they have adequate time to fracture and move the ground. By reducing premature venting of high-pressure explosion gases to atmosphere, however, a stemming column of suitable length and consistency enhances fracture and displacement by gas energy.

Recently the value of effective stemming column design has been re-evaluated. It is confirmed that an inverse relationship between stemming ejection velocity and face velocity exists. Reduced stemming ejection has since been directly linked to improved fragmentation, improved safety, decreased dust emission and lower air blast.

In order to extract the maximum energy from the expanding gases the stemming plug should never blow out and allow the gases to escape prematurely. Three types of items have been introduced which are placed in the stemming part of the hole.

1. Stem plug

The stem plug is an injection moulded cone shaped device constructed of high-impact polystyrene with a 15,000PSI compressive strength. This is commonly known a funnel, placed within the stemming material at an optimal distance above the explosive column, the plug actively seals the borehole collar upon detonation to confine explosive energy at the typical path of least resistance.

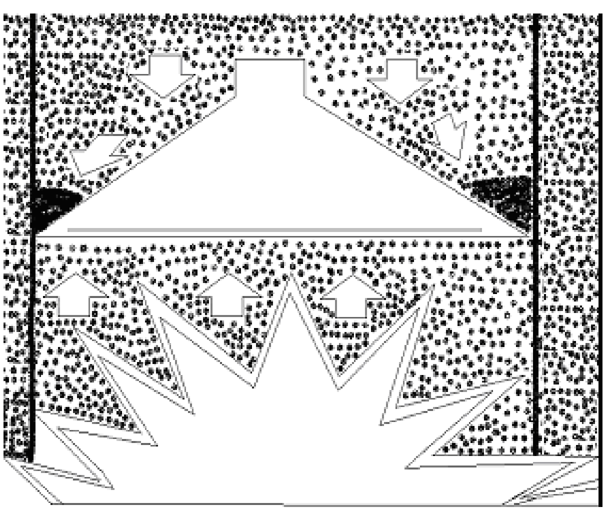
2. Maxplug is a flexible plastic moulded plug and used in similar manners stem plug.

Rock lock a stemming filled, high tensile, non-brittle, plastic sphere, functions by reducing and controlling the random variables leading to borehole venting and stemming ejection. For stemming to lock under explosive compression, resistance must be present in the stemming area for the frictional forces to over ride a tendency to vent or have stemming ejection.

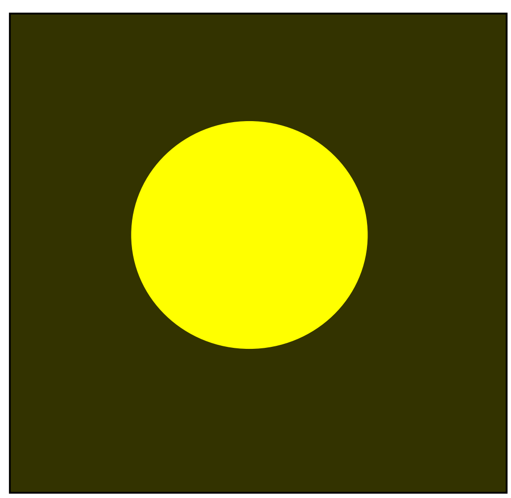
All these stemming control plugs have reduced stemming ejection and enabled the benefits of energy confinement. The blast control plug works with the blast energy to consistently replicate a "clogged gun barrel" effect. Essentially, the plug is self -driving wedge. When a blast control plug is introduced in the stemming column, it is subjected to explosive pressure. When the blast force hits the bottom of the control plug, the force pushes the bottom up causing the plug to expand and seal against the drill hole wall, where severe crushing of the stemming material in advance of the cone results in the lateral pressurisation of the bore hole walls. As the bottom moves upwards it forms a wedge forcing the stemming against the plug wall, locking the plug into place.

Water filled, high tensile, non - brittle plastic balls, have been used in stemming column. The ball works as a lock or obstruction to blow out of stemming material for a little time where as water inside it is acts as a dust. This avoids releasing of explosive energy from top, which in turn is used in productive work of rock breaking.

PVC ampules (water filled or gel filled) are used as safe stemming material. They significantly reduce dust and fumes from blasting. Water-filled plastic bags are permitted device for stemming. Water stemming bags have proven very effective in providing confinement and reducing dust.



Stem Plug



Rock Lock

Fig No. 5.1.5.5.1 Stemming Control by Stem Plug / Rock Lock

5.1.6 In-Pit Crushing and Conveyor Transport System

In the world 80 % of iron ores are extracted from open cast mines and rest only 20 % by underground mines. The conventional "All Dumper transport" system in the iron ore mines, represented a very flexible means of material transport, in the past few decades, when energy / fuel was abundant and cheap. However, the situation is different today.

Over the past few decades, a ten to twenty fold increase in oil prices and increased prices of tyres has made mine-operators aware of increasing transportation costs. Increasing mine depths, distances between mine face and the ore processing plants, increasing over burden to ore ratios, depletion of high grade iron ore reserves (at or near the surface iron ore deposits) and need to exploit even poorer laws for reclamation of mined out areas, all call for larger material volumes to be moved over longer distances and steeper gradients. On account of these factors, today, dumper haulage alone account for more than half of total mining costs. This trend is visible to look for alternative means of environment friendly transport.

This system has significant and cost effective application in mines having considerable lift, transport of material to transport over fairly long distance (more than 1.5 to 2 Km), having large quantity of material to transport and for minimising low grade and high stripping ratio deposit at greater depth. Although this system of transportation is applicable from starting of mining operations but it is much beneficial from 30m depth onwards and up to 200m or more.

The cost economics between shovel-dumper combination transport system are in-pit crushing-conveying system vary from mine to mine depending upon

- Depth of the mines
- Gradient in the mines
- Position of mine face
- Amount of material (tonne/hr) to be handled
- Basic characteristics of the materials, compressive strength of the rocks, maximum lump size, amount of fines, watery condition, roughness, abrasivity etc.
- Availability of electricity in the site, type (whether AC or DC), frequency, voltage etc.
- Climatic condition
- Cost economy
- Length in the dip direction
- Incubation period etc.

Today, mine operators abroad, aim at minimising dumper haulage and maximisation of belt conveying of materials. A comparison of dumper & conveyor transport is shown below :

Table No.5.1.6.1 Transportation through Dumper vs Conveyer

Sl. No.	Dumper Transport	Conveyor Transport
01.	Diesel oil operated.	Electrically powered.
02.	40 % of total energy is used to transport payload. 60 % is used to move self weight of the dumper.	80 % of total energy is used to transport payload. 20 % is used to move weight of the belt and overcome frictional resistance of the moving parts. Energy cost savings upto 70 % is obtained as compared to dumper transport.
03.	Can overcome maximum gradient of 6 – 8 % only.	Can safely overcome gradients upto 35 % and more by high-angle belt conveyor.
04.	Discontinuous system.	Continuous system.
05.	Dumper fleet requires large manpower for operation and maintenance.	Operation and maintenance is simple and requires less manpower.
06.	Dumper technology of only upto 85 T capacity is indigenously available in India, posing limitations to increase volume of mining activity.	No such limitations.
07.	Pollution of mine environment with exhaust fumes, dust and noise.	No such problems.
08.	Dumper operation is severely affected by bad weather e.g. fog, rains, heat, snow etc.	Insensitive to weather conditions, hence can be effectively used round the year.
09.	Dumper needs specially built and maintained haulage roads with heavy investment.	Trough careful mine planning costs of conveyor routing can be reduced or avoided.

Thus, we see from the above comparison that the conveyor transport has major economical, environmental friendly and operational advantages over dumper transport. These advantages can now be realised in the hard rock mines through introduction of the in-pit crushing system.

5.1.6.1 Elements of In-PIT crushing systems

There are three main elements of In-pit crushing and conveying system. These are In-pit Crushers, loading mechanisms to In-pit crushers, and conveying systems for crushed material.

5.1.6.1.1 In-pit Crushers

Depending upon the degree of mobility of crusher In-pit crushers can be grouped primarily into two categories e.g. mobile In-pit crushers & semi-mobile In-pit crushers.

5.1.6.1.2 Mobile In-pit Crushers

Mobile IPC are those which are self propelled and equipped with an integral transport mechanism. It has three main types of travelling mechanism walking pads, wheels and trucks and can be specified with either an electric, diesel or diesel/electric power source. Mobile IPCs are generally used at working face just near the excavators. These are directly fed by excavator and moved with excavator. The frequency relocation of these crushers from one place to another depends on the rate of face advance. Due to its excellent manoeuvrability and high speed, they provide the highest flexibility in comparison of all other In-pit crushing systems.

Because mobile In-pit crushing plants are designed to follow and be loaded directly from the working face, they usually have to be moved out of the danger area during blasting. It, therefore, follows the frequency of blasting and changes in working face will have a direct influence on the type of crushing plant that is selected for In-pit crushing.

A vast range of crushers of hammers, roll, jaw & gyratory types are used in mobile units. Generally for small capacity roll and hammer crushers are used for high capacity jaw & gyratory crushers are used. The crusher installed in a mobile plant depends on a number of parameters e.g., material strength, abrasiveness, feed size distribution, product size and required capacity. Apart from crusher, in general the main components of mobile IPC unit include feed hopper; apron feeder; discharge conveyor; and propelling device.

1. Feed Hopper
2. Apron Feeder
3. Discharge Conveyor
4. Propelling Device

Suitability of a propelling device under different conditions is given below:-

a) Rubber Tired Wheel Mechanism: Wheel-mounted crushers are more suited to in-pit crushing applications where long distances have to be covered in a short time. Enjoying growing market acceptance, particularly in Scandinavia, France and North America, they feature trailing or powdered axles and levelling jacks that raise the whole machine off the ground during operation. This design allows easy movement between sites, but makes wheel-mounted crushers less manoeuvrable on-site and more susceptible to poor ground conditions than track-mounted units. Operating experience in Europe indicates that the wheel-mounted mobile crusher is ideal for companies wishing to move between a number of smaller deposit, crushing upwards of 5000 tonnes per site.

b) Crawler or Track mechanism: The latest track-mounted crushers are versatile, highly manoeuvrable machines that can be easily loaded by a hydraulic excavator or wheel loader. Their heavy duty tracked under carriage allows them to operate in difficult ground conditions and travel across a site at speeds upto 2.0 Km/hr. Capacities range from 70 to 1600 T/hr. with the largest models having an operating weight of upto 250T. These features make track-mounted crushers ideal for applications where the working area of the face is frequently changed.

c) Walking Shoes or Pads mechanism: The walking mechanism is suitable for large mobile units. They are used in mobile crushers when crawler system becomes uneconomical. They are used upto weight 2000 to 3000T of crushers. This system requires level and stable ground condition and offers slow propelling speed and are not suitable for frequent relocation.

d) Rail: Carriage on rails has very limited application, as the crusher unit is restricted to movement only in the direction of the rails. It is unsuitable for frequent relocation.

5.1.6.1.3 Semi-mobile in-pit crusher

Semi-mobile IPCs do not have any integral mechanism. They are moved from one place to another with the help of a separate transporting device, called transporter. Most of the larger semi-mobile crusher units are of modular design in order to facilitate relocation. The relocation frequency of semi-mobile crushing plants ranges between three and five years, depending on mining plan and cost evaluations.

In a semi-mobile IPC unit, a crusher may be of any type i.e., Jaw, gyratory, impact or roll crusher. But generally gyratory or jaw crushers are used. The crusher has space or rooms, for variable speed crusher motor, hydraulic power pack for rock breaker etc. Semi-mobile crushing plants equipped with gyratory crushers can reach capacities of upto 10,000 T/hr. At such high capacities the design of the feed hopper allowing simultaneous dumping of two trucks is of importance. Another important design parameter for a direct fed crushing plant is a sufficiently large rock box below the crusher. Some operations have such an effective rock fragmentation that the major part of a truck load can pass the crusher in a very short time. Most crushers, except the gyratory crusher, require a regulated feed by an apron feeder. Some mining operations using a gyratory crusher and having favourable rock conditions and longer relocation cycles prefer direct fed semi-mobile crushing plants.

Like mobile IPC, a semi-mobile IPC also consists of feed hopper, apron feeder and a discharge conveyor. The details of these items are almost similar to the one discussed in mobile IPC units. In semi-mobile IPCs apron feeder is mounted on a sliding table with hydraulic rams which allows the discharge end of the feeder to be located at optimum location to feed the crusher. Further in these units, discharge conveyor is equipped with a fabric belt conveyor and a metal detector and discharges the material into conveying mechanism of transporting system. The inclination angle of conveyor can be changed with the help of supporting jacks.

In irregular or disturbed deposits many faces may be working simultaneously or in a given sequence. If belts were extended to each working face on each bench, then several mobile crushers would be needed and the utilisation will be low and investment will be high. In such cases, one or more crushing plants can be conveniently located so that each can serve two or more loading machines and having minimum distance of transportation. The crusher movement frequency would depend on the short term mining plan, ranges from once or twice a week up to several week or more. So a semi-mobile IPC system provides a best solution under such conditions. Out of 16 big installations of IPC systems in various mines of copper, gold, coal etc. during 1956 to 1987 are semi-mobile plants.

In some semi-mobile crushing systems dump-trucks are still used for a short and horizontal haul. These systems, therefore, utilise the flexibility of truck haulage for grade control, but avoid the truck haulage's low productivity at long uphill haul sections.

5.1.6.1.4 Loading Mechanism of In-pit Crushers

Loading mechanism of IPCs is an important element of In-pit crushing system as it affects the economy of the system. Excavators can directly load mobile crushers as they are placed at face just near the excavator and moved with excavators. In some mobile IPCs pay loaders are also used to load the crushers, placed 50 to 60 M away from the excavator. In all other cases, i.e. in semi-mobile, semi-stationary and in stationary crushers an intermediate transportation system between face and crusher is required. This intermediate haulage system is generally dumper system. These crushers are loaded either from upper bench or from a loading ramp made for dumping the material into the crusher. Mobile IPC can completely eliminate the dumper system of transportation from mine. Dumpers can directly feed semi-mobile crushing plant or feed apron feeder that can further feed crusher.

5.1.6.1.5 Conveying system for Crushed material

Conveying system for crushed material for various types of crushers is different as they have different amount of flexibility. A mobile IPC requires a highly mobile belt conveyor system. Semi-mobile IPC requires movable units but not so mobile as required in mobile crusher units. But in case of semi-stationary and stationary crushing units such movable belt conveyor units are not required. Conveying system for mobile and semi-mobile crushing units generally include crawler mounted or tyre mounted, belt wagons, movable high angle conveyors and fixed conveyors. Conveying system for stationary and semi-stationary crushers generally include fixed conveyors in different arrangement and high angle conveyors. For handling of wastes, tripper car, spreaders etc. are also required in all cases.

5.1.6.1.6 Application of In-Pit Crushing Systems

In-Pit crushing system was first introduced in 1922. The wide application of In-pit crushing started only in fifties but its significant application has been increased in only last decade. In initial year's application of stationary and semi stationary crushing system was prominent in mines. But it was experienced that when pit expands and deepens these systems become uneconomical and obstructs the mining of newly discovered deposits.

Initially application of In-pit crusher was popular in areas of world where diesel fuel was not available in plenty, primarily in Europe and in South Africa. Now application of In-pit crusher has become very wide throughout the world in most types of mines, i.e., copper, gold, coal, Iron etc. In India application of In-pit crushing system has started only a decade ago, but these applications are restricted to only limestone mines attached to cement industry and in some coal mines. Application of this system in Indian mines is now on rise. The Coal India has also decided mobile crushers with throughput capacity of 100 to 1000T/hr. have been used in hard rock mines. Only a few large units having output of 1000 to 1660 T/hr. have been predominantly used in limestone mines. In recent years some of the installations have throught capacity in excess of 3500 T/hr.

5.1.6.2 Advantages of In-Pit Crushing

In-pit crushing can be adaptable to nearly any production rate and set geological constraints. It can significantly reduce the cost of moving materials between the face and main processing plant. The main benefits of switching from off-highway trucks to an in-pit crushing system with conveyor haulage are:

- Smaller loading machines can be used;
- Less labour and maintenance cost;
- Less auxiliary equipment;
- Reduced fuel costs;
- Longer economic life of conveyor system and
- Environment friendly.

Cost and operational benefits are not the only advantages to be gained from using an in-pit crushing and conveyor system. But considerable reduction in vehicle movements also helps to reduce environmental problems such as dust and noise and makes a valuable contribution to site safety. Current estimates are that safety and environmental considerations can, depending on the location, add up to 30 percent to the overall cost of a new quarry or mine development. The benefits of In-pit crushing become even more apparent while extending the life of the quarry or open cast mine by increasing its depth. The ability of conveyors to work at angles of up to 18 degrees gives them an obvious advantage over off highway trucks that are usually limited to a maximum gradient of between 5 to 10 degrees. The new generation of "steeply inclined" or "high angle" conveyors reduce the amount of "sterilised" by the in-pit material transportation system still further. These elevating or paddle type conveyors can operate at a maximum incline of 70 degree or single lifts of upto 150 M, maximising the area of recoverable mineral reserves.

It is high time when we should examine the feasibility of In-Pit crushing conveying transport system in Indian Iron Ore Mines. The figures below depict the mobile in-pit crushing – conveying transport system:

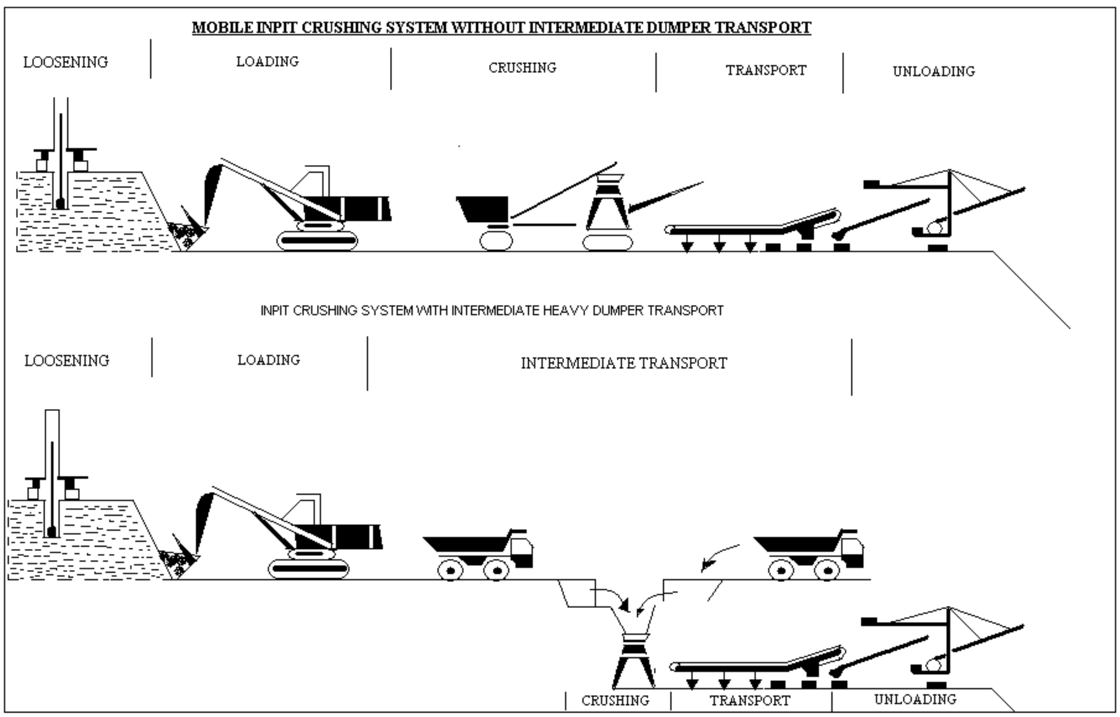


Fig No.5.1.6.2.1 In-pit Crushing & Conveying System

5.1.6.3 Transportation System by Trolley assisted dumpers

In advanced countries, trolley assisted dumpers of 120 T and up to 170 T are in use in view of the spiraling fuel costs, faster cycle and better productivity. Conventional electric drive dumpers can be converted after few years of operation into trolley assist with minor modifications which can finally result in fuel savings. The feasibility of trolley assisted truck haulage system in the future deep open pit in India should be studied and explored.

Advantages

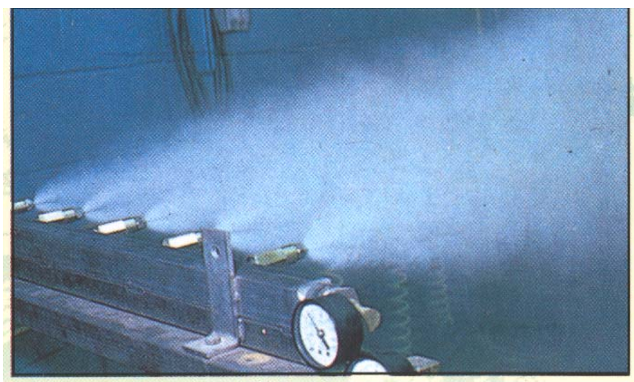
- Reduction of fuel consumption up to 35%, which results in reduced vehicle emission
- Increase productivity 14 to 15% due to increased truck speeds, shortened haulage cycle times etc., resulting overall reduction in emissions
- Increased engine life

This type of trolley assisted trucks is operating presently at USA, Canada, Australia and Brazil etc.

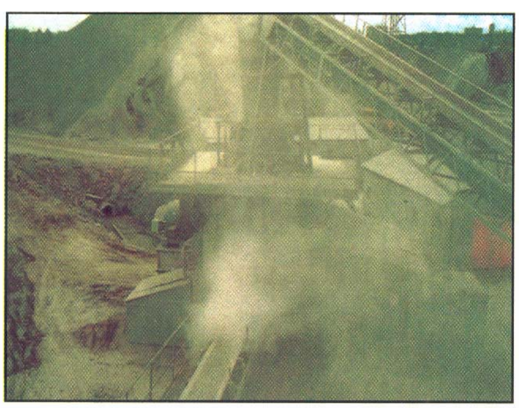
5.1.7 Dry Fog Dust Control System

Dry Fog Dust Control Systems have been in operation worldwide for over 30 years. The patented dual fluid (air & water) Sonicore atomizing nozzles control virtually all breathable and fugitive dust. This system is very well suited for suppression of dust in mineral processing plants. Dry fog is better suited for crushing and screening applications where the addition of large amount of water could cause problems. Dry fog would not be a first choice for outdoor areas as it is very sensitive to air currents. A cost effective alternative to de-dusting system with bag house

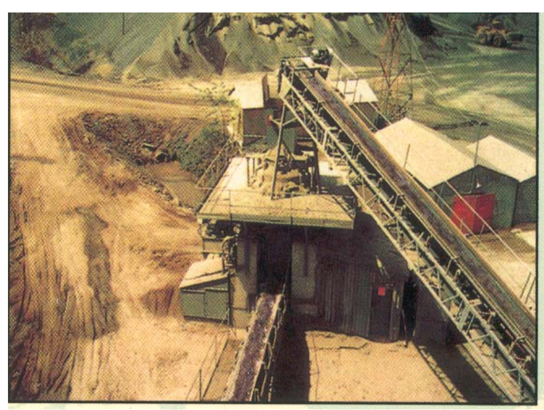
Theory and application: The 'dry fog' dust control system works on the principle of agglomeration. The dust particles released from a material handling/processing plant which became air borne, are made to pass through a blanket of extremely fine fog. The dust particles and the Micronics size fog droplets collide and adhere to each other, thus increasing their mass. After a series of such collisions, the mass becomes heavy enough to cause settlement of the agglomerates on the large mass of material being handled. The 'dry fog' system is capable of controlling all types of breathable and fugitive dust ranging from 1 to 800 microns.



Dry Fog Dust Control System



Without Dust Control



With Dry Fog Dust Control

Fig. No. 5.1.7.1 Dust Control through Dry Fog Control System

Advantages:

- Lower capital, operating and maintenance cost compared to de-dusting bag house system.
- There is no secondary dust disposal problem.
- Since particulate knock down is achieved in situ, there is no need for long duct runs to convey the dust to control collection point.
- Easy installation in existing plant.
- In most cases, the system can be installed while the plant operates at full capacity.
- The dry fog system takes less space and can be installed in the plants where there is no space for installation of bag house de-dusting system.
- Water addition to the process is as low as 0.1% of the weight of the material being handled.
- No requirement of chemical.

5.1.8 Utilisation of Tailings – Resource Recovery

After the beneficiation of iron ore, tailings, which are being disposed to tailings pond for contaminant, still contain iron concentration around 45% or more. Based on the present day techno-economic considerations it may not be worthwhile to extract the iron constituent from this lean source but in future when the present day resources will die down by huge extractions, it may become economically viable to extract iron content by applying futuristic technologies. However, due to huge land cost and also keeping in mind that forest land which normally are found around iron ore mines for which deforestation for construction of tailing's pond is statutorily not allowed, it is worthwhile to examine the feasibility to minimize the pondage volume (Sen and Ghosh 1997) on tailings management point of view reduction of tailing volume is feasible, if maximum iron content is extracted by suitable technology by adding additional units to the beneficiation plant (Down and Stocks 1977).

A scheme for further recovery of usable iron ore fines from tailings slime from conventional iron ore beneficiation plant extends the life of tailing pond. It also makes available the recovered fines for use as sinter feed. This scheme may be an ultimate strategy for environmental management for tailing disposal. Since it reduces pressure on utilization of land space. In this regard the available technologies are WHIMS (Wet High Intensity Magnetic Separation) and Slow Speed Classifiers (SSC). Brief description about these techniques is as follows.

5.1.8.1 Wet High Intensity Magnetic Separation Method (WHIMS)

WHIMS plants are used for the separation or concentration of weakly magnetic materials (Iron ore). Commercial models ranging in capacity from 1 to 120t/hour are available. Magnetic separation is achieved by the combination of a magnetic field and a field gradient.

On continuous type models, the high gradient high intensity magnetic fields needed to separate or concentrate feebly magnetic materials are generated by oil-cooled coils, each with expansion tank and relief valve. The cools are completely enclosed to protect them from moisture, chemicals or other elements. A background field from 7000 to 10000 gauses in the open air gap is produced by these coils in the separation zone to recover feebly magnetic minerals like haematite.

This saturates the matrix and results in the fields of 2 Tesla or more in the separation zone. The matrix is a select type of magnetics soft iron that files the moving part and produces the gradient to hold feebly magnetic particles, while allowing non-magnetic particles to pass through when the matrix is in the magnetic field.

Slurry feed is introduced into the magnetic matrix, which is contained in a stainless steel ring moving at controlled speed between the poles of powerful stationary electro magnets. The variable drive system is located under the ring to allow full visibility of the separation area. The feed pulp enters the matrix just ahead of each magnetic zone and as the magnetically susceptible particles flowed on through the highly induced expanded metal grid they are attracted and held. Most of the non-magnetic particles are passed right through to the discharge tray by the drag force of the slurry water. To further assist the flow of the non-magnetic particles, a low pressure water rinse spray is directed to the ring at the trailing edge (just beyond the feed point) of the magnetic field to dislodge additional physically entrapped non-magnetics.

As the rotating rings moves the metrical elements loaded with magnetic particles out of the field remaining in the material grid drops sharply and a high pressure water spray rinses the magnetic material in to the discharge tray. Adjustable dividers in the compartmented discharge tray separate the middling and magnetic fractions. A line diagram showing the details of proposed WHIMS scheme at Barsua Iron Ore Mines is given below.

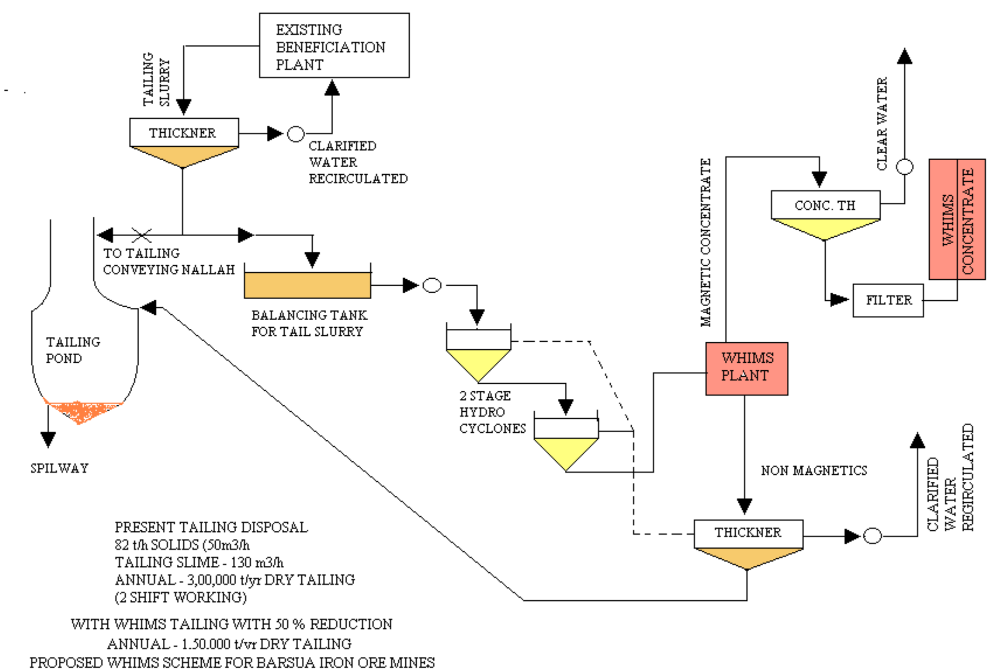


Fig No. 5.1.8.1.1 Proposed WHIMS Scheme for Barsua Iron Mine, SAIL

Thus installation of WHIMS plant will enable resource recovery of substantial quantity of fines from tailings, thereby reducing the quantity of tailings discharged of the environment by about 50%. As a result, the rate of inundation of the forestland and consequent damage to the trees may get reduced to the great extent. Besides, the life of existing pond may be extended and construction of a new pond as well as encroachment / invasion in fresh forest land may get deferred substantially. Moreover, the size of new pond will get reduced and thus the requirement of forest area for tailing disposal may come down considerably. In view of the foregoing, WHIMS process may be considered as a positive environment management strategy for its utilization to have land space for tailing pond and resource recovery from tailings. These types of magnetic separators are extensively used in Brazil, Canada, Norway, Finland and NMDC (India) successfully.

Installation of WHIMS plant will enable resource recovery of substantial quantity of fines from tailings, there by reducing the quantity of tailings discharged to the environment. As a result, the rate of inundation of the forest land and consequent damage to the trees may get reduced to a great extent. Besides, the life of existing pond may be extended and construction of a new pond as well as encroachment/ invasion in fresh forest land may get deferred substantially. Moreover, the size of the new pond will get reduced and thus the requirement of forest area for tailing disposal may come down considerably.

In view of the foregoing, WHIMS process may be considered as a positive environment management strategy for its utilisation to save and space for tailing pond and resource recovery from tailings.

5.1.8.2 Slow Speed Classifiers

Classifier is equipment for iron ore beneficiation for sinter grade fine ore. Recovery of iron ore fines can be maximised by installing Slow Speed Classifier (SSC) in the wet beneficiation circuit, wherever feasible. Because of this installation only a small amount of iron ore micro-fines along with shaly/poor quality material is let out to the tailings dam for quiescent settling. The use of slow speed classifiers will not only increase the recovery of fines/microfines, but also increase the life of the tailings pond.

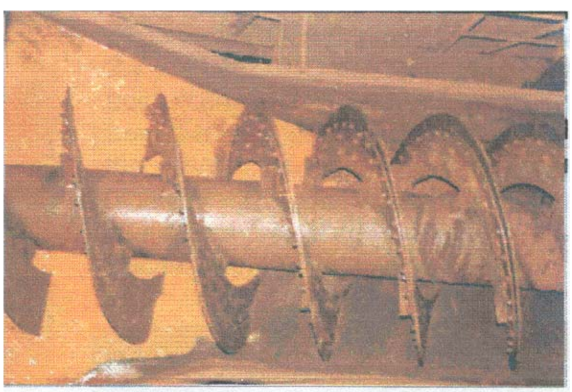


Fig. No. 5.1.8.2.1 Slow Speed Classifiers

5.1.9 Magnetic Elutriation Technology

A new patented magnetic elutriation process developed by US mining industries uses moving water to flush away impurities and deliver a highly refined product. The magnetic elutriation technology was specifically developed to allow US iron ore mines to meet DRI mills emerging market demand for DRI grade ore.

Magnetic elutriation improves the quality of low-grade iron ore by using an alternating current, pulsed magnetic field to clean iron a highly refined product. This innovative process differs from conventional element type magnetic separation systems by using permanent magnets that cause magnetic entrapment. Drum Separators use a less effective, static magnetic field middlings, which ultimately contaminate the iron product. The capacity of the magnetic elutriation device is 100 tons/hr and it is ready for commercialisation at US.

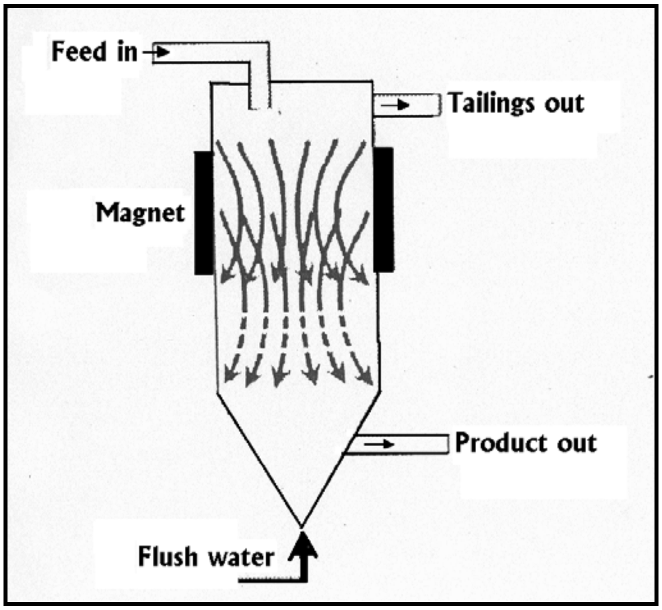


Fig. No. 5.1.9.1 Magnetic Elutriation Technology

Process: As crude iron ore enters the system (shown in Fig. No. 5.1.9.1) gravity pulls the magnetically gathered iron ore particle string downwards. Only rich iron ore particles move downwards, while tailings particles move upwards. The selective downward movement of the product is assisted by powerful electro magnets that agitate and hold the strongly magnetic iron ore preventing it from being flushed out of the system. Then water flushes the weakly magnetic middlings and sandy tailings out of the system. Highly refined iron ore is the final product.

5.1.10 Utilisation of Iron Ore Slimes for making Value-added Products

India ranks as the fourth largest producer of iron ore in the world with a total iron ore resources of more than 25 billion tonnes as on 01/04/2005 (Source IBM, Nagpur). The current practice of washing iron ore in India results in the generation of huge quantity of tailings. The generation of tailings is estimated to be around 14 million tonnes per year in India. These tailings are stored in massive ponds and pose severe environmental hazards. Safe disposal or utilisation of these materials thus remains a challenging task for the iron ore industry in India. One of the possible solutions is to convert the tailings into value added products for building industry. With the traditional building materials industry under pressure and unable to cope up with the demand, there is growing concern in many developing countries for updating production processes, as well as promotion of alternative building materials. Ceramic floor and wall tiles are one of such value-added products where industrial wastes can be used as raw material.

The tailings generated by iron ore industry may be used as one of the raw materials for making ceramic floor and wall tiles. Its high silica content favour formulation of tile body compositions. These tiles are superior with respect to scratch hardness and strength, maintaining most of the other properties comparable to EN specifications. Iron Ore tailings substitute some of the expensive minerals used in commercial tile compositions and lower the product cost. Further, these tailings are in powder form, thus requiring less grinding time, there is thus scope for energy saving. This new development may be cost-effective solution in managing tailings of iron ore and controlling environmental pollution.

Process flow sheet for manufacturing ceramic floor and wall tiles from iron ore tailings are as under.

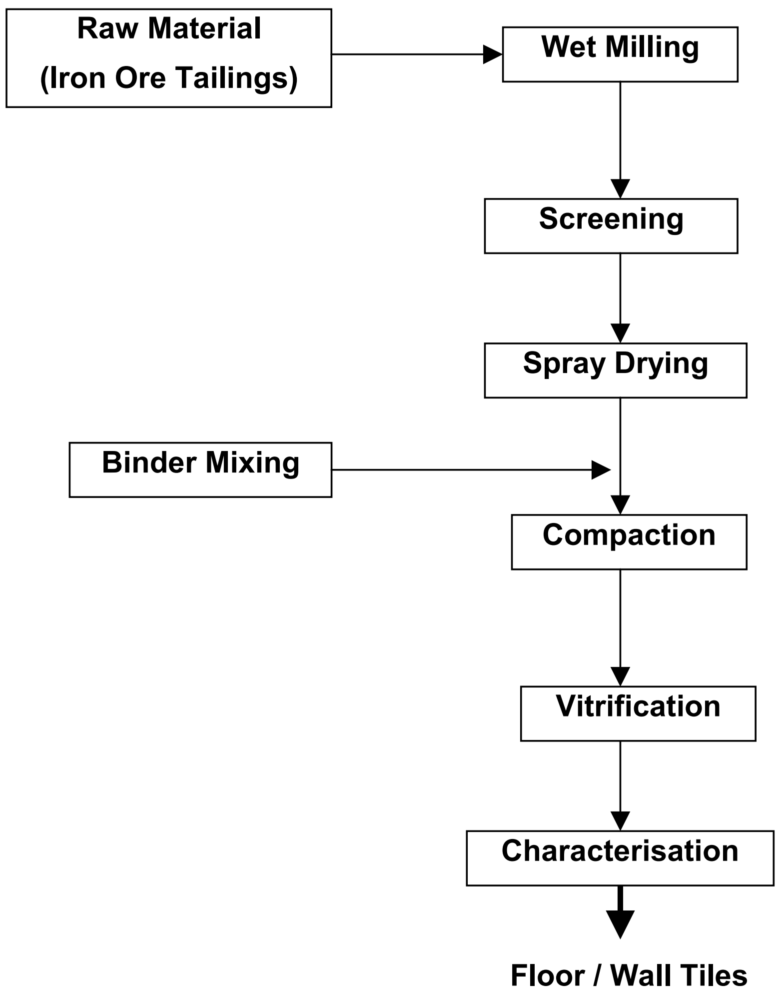


Fig. No. 5.1.10.1 Process Flow Sheet for Manufacturing Tiles from Tailings

5.2 ENVIRONMENT MANAGEMENT PRACTICES

Very few low capacity iron ore mines were operating during the pre-independence time. For the economic development of the country, new manufacturing industries came up during the post independence era, which resulted in the rapid growth of mineral exploration. During the period of development and rapid expansion of mining activities, environmental issues were not given major consideration by the industry for the society. However, now the society expects and demands the resource sector to apply high standards of environmental management to all projects. The Mining industry unfortunately has a legacy of environmental damage to live down and the public is now aware of it. Since last two decades, statutory bodies have taken stringent measures to tackle this problem, by adopting/imposing certain conditions during planning stage itself and monitoring continuously. Now, it has been realized by the mining authorities that careful planning and implementation of proper environment management practices are essential for sustainable development.

Some of the different aspects of the best environment management practices need to be followed in Indian Iron Ore Mining Industry with respect to the qualities of air, water and noise, vibration & air blast management, waste management practices, rehabilitation strategies and practices, etc. are discussed in the following sections.

5.2.1 Mine Planning for Environmental Protection

In the past (and to some extent now for the small mine owners), it was practiced that to see whether a iron ore deposit is feasible for mining or not without planning for or to keep provision for other aspects. Even in some areas, the land allotments/ mining leases are so small that the mine can not be properly planned for its development. However, the time has come to realise that the manner in which a mine is planned can have a major influence on the magnitude and duration of impacts over the life of the development, operation and following its closure. With the operational variations, nature of deposits and locations, mining techniques to minimise environmental impacts can not be standardised. Each deposit is unique in its combination of physical, social and resource opportunities and constraints. The use of consistently appropriate mine planning is the most effective way to harmonise mining with the environment. No single element of mining, by itself, minimise environmental impacts. The first step in planning is to recognise the environmental issues that need to be faced during designing a feasible mine layout. It may range from air quality, noise and vibration, water management, water quality, soil conservation, flora and fauna, transport, rehabilitation, visual impacts, hazard and risk assessment, waste management to socio-economic issues. All the environmental considerations are to be firmly integrated into the planning of each stage of a mining project. As well as the method and rate of mining, some of the issues to be considered during mine planning for environment protection include the location of the mine infrastructure such as:

- Haul roads
- Surface facilities, i.e. offices, workshops, garage, ware houses, power stations, etc.
- Tailings and waste disposal areas and methods
- Transport and service corridors, i.e. railway lines, roads, pipe lines, conveyors etc.
- Product stock piles
- Ore processing facilities
- Chemical and fuel storage
- Township and housing locations.

As the mining progress from the planning and concept design stages through to operation and possibly for decommissioning, proper planning can reduce environmental impacts, result in good environmental performance and enhance the public perception of the mining as able to operate in an ecologically sustainable way. Followings need to be considered and planned for over the life of the mine.

5.2.1.1 Mine Location

For developing a new mine, the general environmental constraints need to be considered and addressed by asking the typical questions, such as -

Location of the drainage basin – Will it flood? Is there a substantial upstream catchment that would need diverting around the mine? Who uses water downstream and what do they use for? What is the ecological need of aquatic and terrestrial flora and fauna? Will there be enough water to operate the mine?

Surrounding Land use - How is land surrounding the mine site is currently being used? Are there any sensitive users? Is the land is already zoned/earmarked for certain use?

Proximity to utility infrastructure - Where are the nearest main roads, railways, water supply, electricity, telecommunications, ports, etc.? Do they have sufficient capacity and will their intensified use cause environmental impacts? Can they be supplemented or modified to satisfy the needs of the mine?

Visual Exposure – Is the deposit in a visually prominent area? If it is, does this matter to the local community? What can be done by the facilities location to minimise future impacts?

Cumulative Impacts – Is there a potential for the impacts of the proposal to add to those from other mining or industrial operations? Will there be competition for water, transport services or employees? Will air quality, noise or water quality be cumulatively satisfactory?

5.2.1.2 Pre-Mining Investigations

Adequate baseline information is necessary before mining can be planned in an environmentally responsible way. An essential pre-requisite is proper identification and requirement of the deposit itself. The key requirement is an adequate understanding of the baseline environmental conditions. This would normally be obtained by an integrated monitoring programme that established pre-mining conditions in meteorology, flora and fauna, water quality, noise and air quality, transport and other characteristics of the site surrounding area. Conventionally, this would be collected over at least 12 months to account for seasonal variations. This baseline data is essential to enable the mine planners and environmentalists to understand the environmental issues that will be addressed.

5.2.1.3 Construction

Some of the more significant environmental impacts associated with projects can occur during their construction. Pollution control during construction are most of the times not designed for, and if any, they are of very low standards because they do not form part of the on going mine. However, there is little point in building elaborate controls for the operational phase of mining if the environment they are supposed to protect has been destroyed during the construction itself. It also undermines the environmental integrity of the mine owners and managers, who may have gone to considerable lengths to reassure local communities about the potential for impacts and their commitment to responsible environment performance.

5.2.1.4 Pollution Prevention and Control

Pollution prevention and controls are needed to be incorporated during the design phase of the mine operation. The underlying principle for effective pollution prevention and control is to contain contaminants on the site itself. This can include covering chemicals, avoiding unplanned equipment maintenance, etc. Air quality controls include the use of water tankers for dust suppression, water sprays on conveyors and ore stock piles, controls on blasting and limiting freefall distances while stockpiling the ores and overburdens. The design and maintenance of haul roads is also an important consideration in dust control. Similar control measures need to be integrated to each operation of the mine during the planning stage. One of the critical factors in successful pollution prevention and control is through proper training of the workforce. It is no matter how sound the plant design or committed the mine management, ultimately environment protection can only be achieved with the understanding and commitment of the every person working in the mine. An untrained or thoughtless dumper operator can cause significant harm and expose the company to serious legal liabilities.

5.2.1.5 Biophysical Impacts

Apart from identifying rare and endangered plants and animals, planners must consider the ecological sensitivity and integrity of an area and what role it plays as a part of a regional environment. Relevant questions include how well species and habitats are protected in the area and the role of the site as a part of a habitat corridor. Climate, soils and the rehabilitation strategy are important considerations in minimising impacts on native flora and fauna. Soil erosion can be minimised by a proper understanding of soil structure, conservative landform design, utilising complex drainage networks, incorporating runoff silt traps and dry detention ponds in the rehabilitated landform. A dry detention pond is designed to hold water over a short period and allow its later controlled release. Careful use of topsoil can promote vegetation cover if the topsoil material is structurally appropriate and contains propagules of native vegetation. Selection of native floral species can be desirable in promoting a stable and robust vegetation cover. Where possible, species endemic to the area should be used, preferably those from the site itself.

5.2.1.6 Socio-economic Issues

Mining of iron ore affect the local and national economics in a variety of ways. Mines are built to exploit the mineral resources of the country to provide economic benefit to the community and the government, while earning profit for the share holders of the mining company. Some people will get direct benefit via the creation of employment and business opportunities, while other people may feel aggrieved by the project proceeding. Where communities exist at a potential mine site, mining impacts on the host environment can significantly influence community attitude to the operation. Measures are available to promote positive aspects of mining while recognising and addressing potentially adverse side effects. This applies to community infrastructure, employment and land use planning.

5.2.1.7 Environmental Monitoring

Ongoing operational environmental monitoring provides factual information to test environmental performance, demonstrate compliance with environmental legislation, refine operational practices and safeguard the interests of both the mining company and the surrounding community. A well conceived monitoring programme must give attention to what is being measured and the ultimate use of the data. Monitoring within the minesite can be useful in checking source emissions, but it gives little information on the environmental effects on surrounding communities and the region. Environmental monitoring, including physical, chemical and biological elements, needs to be extended to areas that may be affected around the mine site.

5.2.1.8 Decommissioning

Ideally mine decommissioning should be planned at the commencement of operations. Where this is not possible because the mine is already long established, there is a greater potential for proper decommissioning if it is integrated with the final year of mine operation. Final rehabilitation should be influenced by the long term post-mining land use and environmental condition of the site determined in partnership with the local community. Mine sites often have established transport links, heavy workshops and other infrastructure that can be put to a range of post-mining uses. Whether this is not the case or where restoration of pre-mining condition is required, hauls roads and buildings should be removed and the site rehabilitated and revegetated. One of the longer-term challenges is to ensure the safety and environmental appropriateness of final mining voids. It is, sometimes, possible to use these voids for disposal of surplus rejects and overburden from an adjoining mine, or to provide make up water and additional sedimentation capacity to other operations. A coordinated and planned approach to the issue of final voids for adjacent mines can significantly reduce environmental impacts.

It is essential that the mine planner and developer has an excellent understanding of all the environmental issues and constraints so that they can be considered at the start of the projects planning in order to produce the best outcome in terms of economic feasibility, resource utilisation, community acceptance and minimal environment impact.

5.2.2 Rehabilitation and Revegetation

Rehabilitation is the process used to repair the impacts of mining on environment. The long term objectives of rehabilitation can vary simply converting an area to a safe and stable condition to restoring the pre-mining conditions as closely as possible with all the area's environmental values intact. Planning is the key to successful rehabilitation. A clear objective for the rehabilitation must be defined including final land use planned for the area. Rehabilitation plan should be prepared to meet the objective and shall be an integral part of the mine plan. It should take into account an appropriate and agreed final land use for the area and the level of management that will be required to maintain the land use. The post mining land use for the area should be defined in consultation with relevant interest groups including government departments.

The long-term objectives of rehabilitation vary but can be categorised as:

- Restoration of the area so that the pre-mining conditions are replicated as closely as possible with all the area's environmental values intact. This term generally applies to the restoration of native ecosystems.
- Reclamation of the area so that the pre-mining land use can be re-established under similar conditions. Reclamation can refer to returning to low maintenance native vegetation or restoring a land use such as agriculture or forestry.
- Developing the area for a land use significantly different to that which existed before mining. This type of rehabilitation aims to achieve new landforms and land uses which bring about a greater overall community benefit than would occur if the former

land use was restored. For example mined land could be developed for wetlands, recreational areas, urban development, forestry, agriculture of numerous other uses.

- Converting low conservation value areas in regions with intrinsically low productivity to a safe and stable condition.

Rehabilitation normally comprises two stages:

- Landform design and the reconstruction of a stable land surface; and
- Re-vegetation or development of an alternative land use on the reconstructed landform.

5.2.2.1 Principles of Rehabilitation

In the iron ore mining, removal of overburden and waste rock and its replacement in waste dumps or the mined-out pit can significantly change the topography and stability of the landscape. These materials can sometimes be selectively placed so that they don't cause problems, or they may require special rehabilitation treatments. Followings are the basic principles of rehabilitation, which needs to be always followed.

- Prepare a rehabilitation plan prior to the commencement of mining.
- Agree on the long-term post-mining land use objective for the area with the relevant government departments, community and other stake holders. The land use must be compatible with the climate, soils, topography of the final landform and the degree of management available after rehabilitation.
- Progressively rehabilitate the site, where possible, so that the rate of rehabilitation is similar to the rate of mining.
- Prevent the introduction of noxious weeds and pests
- Minimise the area cleared for mining and associated facilities to that absolutely necessary for the safe operation of the mine.
- Reshape the land disturbed by mining so that it is stable, adequately drained and suitable for the desired long-term land use.
- Minimise the long-term visual impacts by creating landforms which are compatible with the surrounding landscape.
- Reinstate natural drainage patterns disrupted by mining wherever possible.
- Minimise the potential for erosion by wind and water both during and following the mining.
- Remove or control residual hazardous materials. Identify any potentially toxic overburden or exposed strata and manage them so as to prevent environmental damage.
- Characterise the top soil and retain it for use in rehabilitation. It is preferable to reuse the topsoil immediately rather than storing it in stockpiles. Only discard if it is physically or chemically undesirable, or if it contains high levels of weed seeds or plant pathogens.
- Consider spreading the cleared vegetation on disturbed areas.

- Deep rip compacted surfaces to encourage infiltration, allow plant root growth and put the topsoil to the subsoil, unless sub- surface conditions dictate otherwise.
- Ensure that one or two meters of soil is capable of supporting plant growth.
- If topsoil is unsuitable or absent, identify and test alternative substrates, eg overburden that may be a suitable substitute after addition of soil improving substances
- Revegetate the area with plant species consistent with the post-mining land use.
- Make the area safe.
- Remove all facilities and equipment from the site.
- Monitor and manage rehabilitated areas until the vegetation is self-sustaining and meets the requirements as envisaged, or until their management can be integrated into the management of the surrounding area.

5.2.2.2 Rehabilitation Procedure

Despite the wide range of climate and soil-conditions, and different methods of mining operations the basic rehabilitation procedures which, with appropriate modification for local conditions, may be applicable to most situations are as follows:

Objective: A clear objective for rehabilitation must be defined. It should include a statement of the final land use planned for the area. This land use should take into account of the land capability of the rehabilitated area and the level of management that will be required to maintain this land use. Rehabilitation plans should be drawn up as early as possible in the development of a project. Sufficient resources must be allocated to enable the rehabilitation aims to be met. Comprehensive and accurate records should be kept of all rehabilitation activities.

Clearing: The area cleared should always be the least necessary for safe operation of the mine. Where possible, a use should be found for the cleared vegetation. It can often be used during rehabilitation as a source of seed, as a much to protect soil from erosion or as habitat for fauna. When the rehabilitation objective is to restore the original ecosystem, the optimum time for clearing may be determined by the time when the important plant species set seed.

Soil Handling: Topsoil is often the most important factor in successful rehabilitation, particularly where the objective is to restore a native ecosystem. If the topsoil contains large numbers of seeds of undesirable species then it may be better to use the sub-soil as a substrate for rehabilitation. However, in most situations, the topsoil from all areas being cleared should be retained for subsequent rehabilitation. The topsoil contains the majority of the seeds and other plant prop gules (such as rhizomes, lignotubers, roots etc.), soil micro-organisms, organic matter and much of the more labile (more readily cycled) plant nutrients.

The timing of topsoil stripping can be important for subsequent rehabilitation. Soils should not be stripped or replaced when they are too wet or too dry, as this can lead to compaction, loss of structure, and a loss of viability of seeds and mycorrhizal inoculum (a natural eco-system component that increases uptake of plant nutrients from the soil). The ideal moisture content to handle soil to resist damage will vary with different soils. Local knowledge and experience will be required to determine when soils can be handled without damage. In most areas there is a distinct period when many native species flower and set seed. Clearing and soil stripping should take place after seed set, where possible, to maximize the stores of seed in the soil.

Topsoil should be replaced along the contour where possible. This will help in erosion control by reducing water flow down slope and increasing water storage. Wherever possible, the topsoil should be immediately replaced on an area where the land form reconstructions are complete.
Direct returns have several advantages compared with placing the topsoil in stockpiles and storing it for later rehabilitation. First, it avoids double handling. Second, the need to create stockpiles may mean that extra land must be cleared. Thirds, and most importantly, stockpiling reduces the quality of the soil resource. Stockpiles become anaerobic, soil structure deteriorates, organic matter and nutrients may be lost, seeds deteriorate, other plant propagules die and populations of beneficial soil micro-organisms are reduced significantly. For example, fresh, soil contained around five to ten times as many seeds as soil stockpiled for three years. Researches have shown that both the density and numbers of species of native plants are significantly decreased when an area is rehabilitated with stockpiled rather than direct-returned topsoil.

If the topsoil must be stockpiled then it should be for as short a time as possible and:

- the stockpiles should be as low as possible with a large surface area (2m height or less);
- the stockpiles should be re-vegetated to protect the soil from erosion, discourage weeds and maintain active populations of beneficial soil microbes and
- the stockpiles should be located where they will not be disturbed by future mining as excessive handling will adversely affect soil structure.

Alternatives to topsoil: If topsoil is not available, the cost of transporting is prohibitive, or the topsoil contains such high levels of week seed or plant pathogens that it is unsuitable for rehabilitation, then subsoil, overburden, waste rock or similar materials must be used as a substrate for re-vegetation. These materials will generally require techniques to increase their organic matter content and nutrient status. Their physical characteristics may require ameliorations and their pH may need to be adjusted. The physical and chemical properties of the proposed substrates should be thoroughly investigated prior to their use in rehabilitation. The following are techniques which can be considered to improve the ability to support plant growth in the long term.

- Application of organic matter such as animal manures, sewage sludge or other wastes
- Chemical amendments such as
    - Gypsum to improve the structure and reduce the pH of highly alkaline substances
    - Lime to raise the pH of acid substrates and
    - Inorganic fertilizers.
- Solid conditioners. Many proprietary soil conditioners, such as polyvinyl alcohol polymers are available which may have application in certain situations. Trial areas should be treated to assess their value before large areas are treated.
- Growing green manure crops which can be incorporated into the substrate.

- Establishing nitrogen fixing species to increase the organic matter and nitrogen content of the substrate.
- Applying mulch.

Seeding rates will probably have to be increased compared to those on topsoils to establish a satisfactory cover of plants on these alternative substrates.

5.2.2.3 Rehabilitation Earthworks

Landform design and reconstruction

The re-shaping and grading of a site is an essential aspect of rehabilitation. The need for extensive re-shaping of soils piles can sometimes be minimized by good mine planning and management. The final landform must be hydrologically compatible with the surroundings area. Slopes must be stable and will be less obtrusive if they have a similar gradient to natural slopes in the area. The following factors should be considered during landform design.

Stability: The maximum angle and lengths of slope that will be stable at a specific site depends on site specific variables such as spoil and top soil characteristics and rainfall intensity. The erosion potential of the different materials on site needs to be assessed and a geo-technical investigation may be required. Terraced landforms with short, steep (angle of repose) slopes and gently sloping terraces (<5%) may be as stable and have a higher land capability than a conventional landform of around 15-18% slope.

Drainage Density: The drainage density of surroundings areas will provide a guide. An increase in drainage density may be required if there have been an increase in the gradient of slopes and changes in the nature of the surface materials.

Erosion Control: Control of erosion is important both during mining and the rehabilitation program. A major objective of rehabilitation should be to establish an adequate cover of vegetation to stabilize the site and prevent or control erosion. Until an adequate cover of vegetation has been established, it is imperative that provision be made to control erosion from disturbed areas. Soil particles can be lost in three ways - they can be blown away; washed away; or the whole surface may slip away or slump.

Before a vegetation cover is established, wind erosion can be controlled by the following three basic methods:-

- Protecting the soil surface with a mulch of natural or manufactured materials
- Maintaining the soil in an erosion resistant condition (i.e. moist, or with a compact surface crust); and
- Reducing wind velocity across the disturbed areas by establishing wind breaks.

Measures to protect the soil from water erosion should be carried out on a catchment basis. Drainage from external catchments must be controlled by diversion channels or holding structures such as banks, drains or dams. Water leaving the site or diverted around the site must also be controlled. It is necessary to discharge this water so that it does not cause erosion or carry sediment downstream. Sediments dams are the most common means of controlling sediments levels in runoff. On disturbed areas control of water erosion is achieved by:

- Slowing the water flow across the soil surface;
- Reducing the impact of raindrops on the soil surface; and
- Maintaining the soil in an erosion resistant condition.

Water flow across the soil surface can be reduced by encouraging infiltration and building drainage control structures to channel water off the site. Slopes of the dumps should be designed to reduce the velocity of runoff (See Figure No. 5.2.2.3.1). Infiltration can be encouraged by ripping and cultivating on contour and constructing contour banks. Water can be channelled off-site by drains, graded banks and stabilized waterways. Ripping encourages infiltration, relieves soil compaction, increases the volume of soil readily accessible to plant roots and binds the topsoil to the subsoil. Ripping should always be along the contour. Areas can ripped after the topsoil has been returned or before top soiling, in which case the area will normally need to be cultivated before revegetating. When ripping after topsoil return, care must be taken to avoid burying significant quantities of the topsoil and therefore losing its benefits. Ripping should not continue when conditions are too wet to allow the soil to shatter or when it brings large amounts of rock to the surface.

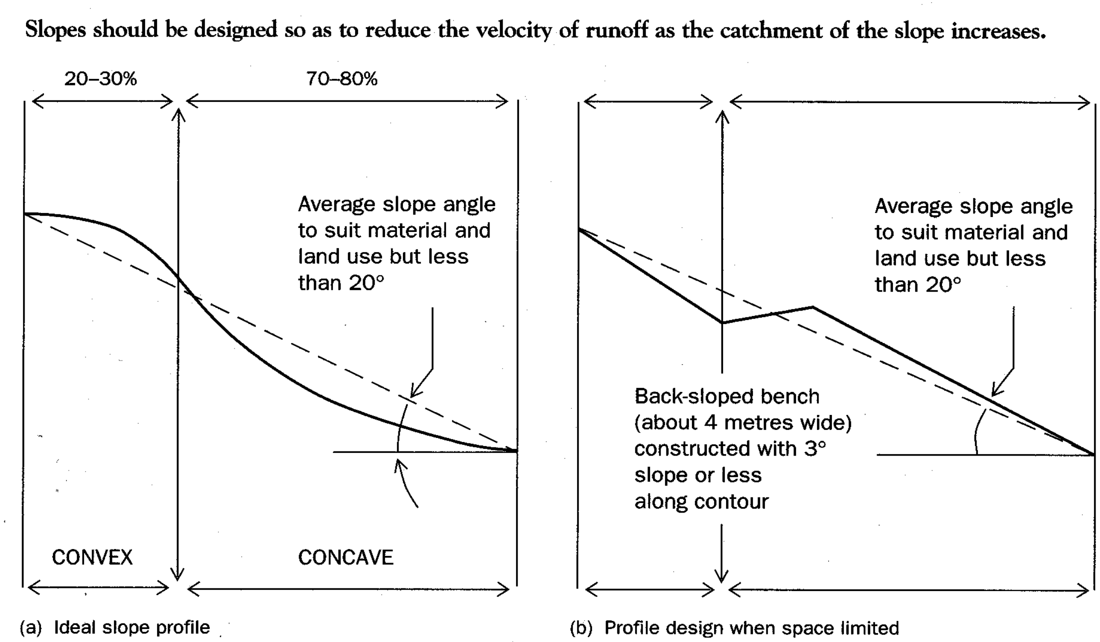
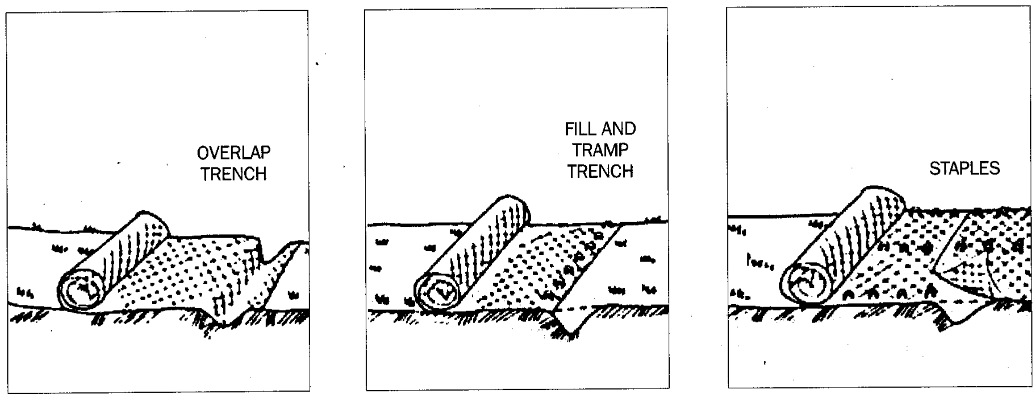


Fig. No. 5.2.2.3.1 Dump Slopes for Controlling Velocity of Runoff

Mulches can be used to protect the soil from raindrop impact. Most suitable materials are brush matting, stubble mulch; lazy mulch, sawmill wastes, bitumen, and other chemical stabilizers. These materials may also aid, or in some cases inhibit, germination of seeds in the revegetation program. One technique for soil erosion control in drainage lines by use of jute mesh is shown in Figure below.

One technique for soil erosion control in drainage lines is through the use of jute mesh.



Place mesh over seeded and fertilised topsoil. Bury the top end of the jute mesh strip in a trench 150mm in depth.

Lay mesh and ensure contact with soil at all times.

Secure mesh with U-shaped wire staples.

Fig. No. 5.2.2.3.2 Techniques for Soil Erosion Control

5.2.2.4 Revegetation

When attempting to restore a native ecosystem, the initial revegetation effort is unlikely to produce vegetation identical to the original. This does not mean that the final canopy species cannot be established in the first instance, merely that other species may dominate the vegetation in the early stages of rehabilitation. The initial revegetation effort must establish the building blocks for a self-sustaining system, so that successional processes lead to the desired vegetation complex. The best time to establish vegetation is determined by the seasonal distribution and reliability of rainfall. All the preparatory works must be completed before the time when seeds are most likely to experience the conditions they need to germinate and survive, i.e. reliable rainfall and suitable temperatures.

Species Selection: The species selected for establishment will depend on the future landuse of the area, soil conditions and climate. If the objective is to restore the native vegetation and fauna then the species are pre-determined.

Some indigenous species may not thrive in areas where soil conditions are substantially different after mining. If this is the case, and the objective is to re-establish vegetation which fulfils the functions of the original native vegetation, then some species from outside the mining area will have to be introduced. Species which have similar growth forms to the original vegetation, and thrive in areas with comparable soil types, drainage status, aspect and climate of the rehabilitated area, are the most appropriate. Care must be taken to avoid introducing a species which could become an unacceptable fire hazard, invade surrounding areas of native vegetation or become a weed for the local agriculture.

Establishment: Plant species can be established on rehabilitated areas from:

- Propagules (seeds, lignotubers, corns, bulbs, rhizomes and roots) stored in the topsoil
- Sowing seeds
- Spreading harvested plants with bradysporous seed (seed retained on the plant in persistent woody capsules) onto areas being rehabilitated;
- Planting nursery-raised seedlings;
- Transplants of individuals from natural areas;
- Habitual transfer – the transfer of substantial amounts (around 1 m^2 or more in area and 200-300 mm depth) of relatively undisturbed soil with its vegetation intact from natural areas;
- Invasion from surrounding areas through vectors including birds, animals and wind.

Topsoil: The topsoil has an important role, particularly in the establishment of native species. Maximising the return of species from the seed resource in the topsoil is one of the most important aspects of restoring the full suite of pre-mining species to rehabilitated areas. The members and diversity of seeds in the topsoil could not be duplicated economically by collecting and sowing seed.

Seeding: Sowing seed is an economical and reliable method for establishing some species. Seeding results in a more random distribution of plants than planting seedlings, and leads to more natural looking vegetation. The species best established from sown seed are those which produce large numbers of easily collected, viable seeds which have high germination and survival rates in the field. These species are easy to establish and quickly provide cover, erosion control and other benefits. However, they can also have significant and long-lasting effect on the numbers and cover of small shrub and herb species. Care must be taken when re-establishing the original landuse in areas of native vegetation, that these easy to establish species do not dominate the rehabilitation at the expense of botanical diversity.

Transplanting and habitat transfer: Direct transplanting of species (which cannot be established by other means) is possible by transferring slices or front end loader buckets of soil with the vegetation intact. However, it is an expensive option. Success of transplanting is influenced by the climatic conditions. In general, transplanting is best carried out in cool, wet conditions.

Seed collection: A consistent supply for quality seed is essential for the success of revegetation. There are many difficulties inherent in collecting native seeds. Some of the points which should be considered when collecting seed are:

- Consider establishing a seed orchard of species which are rare, produce limited seed or have seed which is difficult to collect.
- Identify collection areas before the seed matures
- Collect seed only when it is mature.
- Avoid seed or fruits that have been attacked by insects or show signs of fungal infestation.
- When operating in forest areas seed can often be collected from trees that have been felled for saw-milling.

Seed processing, Storage and Treatments: Seed should be cleaned before storage to remove as much debris and chaff as possible. Techniques include: drying the capsules or pods in the sun or in an oven; threshing, using commercially available threshers; burning seed cones to release the seed; soaking fleshy fruits in water before recovering the seed, etc. Seed of some species requires pre-sowing treatments. Germination of most native legumes and a number of other species is enhanced by heat treatment. These species are commonly immersed in boiling water for 30 seconds to five minutes before sowing.

Seed bed preparation: The preparation of a suitable seedbed is an important factor in the successful establishment of plants from seed. The objective in creating a seedbed is to place the seed in a suitable place for germination. The seed must be in good contact with the soil to ensure it can take up water easily and the soil must be well aerated. The soil around the seed must be loose enough for the seedling to grow up through the soil and allow root growth. The seedbed should be free of weeds. Care should be taken not to over prepare the soil as a rough surface provides more niches for the seeds and encourages infiltration of rain. A variety of conventional agricultural equipment can be used to prepare seed beds. Soils should be cultivated when moisture levels are adequate, to avoid powdering, but not so wet that compaction and loss of structure become a problem.

Seedling methods: Seed can either be broadcasted onto the surface of the soil or drilled into the soil using some form of mechanical seeder. Target densities for each of the seeded species, and an estimate of how much seed is required to obtain these densities, needs to be established. The seeding technique chosen will depend on local factors such as topography, the size of the area being rehabilitated and the type of seed. Hydro seeders are a convenient way of seeding steep areas. Aerial seeding is used to seed large areas, especially when the soil is too wet or the slope too steep to use tractor mounted seeders.

Timing of seeding can also be important for successful revegetation. In most cases seed should be sown immediately prior to the expected consent of reliable rains or after the break of the season. Native seeds may require specific moisture and temperature conditions to germinate, so that they establish at the optimum time of the year for survival. Seed theft by ants, birds and small mammals is a potential problem when seed is sown early, although less likely than in areas of native vegetation, because of the impact of disturbances of fauna populations.

5.2.2.5 Fertilisers and Soil Amendments

Most rehabilitation programs will include an application of fertilizer in the establishment phase. Initial applications of fertilizer can result in increase species numbers, plant cover and density, and growth rates. The type of fertilizer and the application rate will vary according to the site, soil type and post mining landuse. Application rates of up to 80 kg/ha. Nitrogen, 5-80 kg/ha of phosphorus and varying rates of potassium and micro-nutrients can be used.

The pH of acid soils can be increased by application of lime (calcium carbonate). Low pH (below about 5.5. when measured in water) can cause aluminium or manganese toxicity and reduce the availability of some nutrients. Application rates of lime are usually in the range of 2.5 tonnes / ha but will vary according to soil type, initial pH and the source of the lime.

Gypsum can be used to improve the structure of poorly-structured soils. An exchangeable sodium proportion of greater than 6% can indicate unstable soil structure. Gypsum is normally incorporated into the soil at around 5-10 tonnes/ha. The application of gypsum results in the replacement of sodium with calcium on the soil exchange surfaces, which can improve soil structure, reduce surface crusting and increase water infiltration. It may also reduce the pH of sodic soils (i.e. soils with pH>8.5).

Various organic wastes (e.g. animal manures, sewage sludge, and blood and bone) can have value as both fertilizers and soil amendments. However, supply may be unreliable and they are often too expensive, variable in composition and too hard to spread to be used for large-scale rehabilitation.

5.2.2.6 Fauna

Encouraging the native fauna to return to areas cleared for mining is a fundamental part of any rehabilitation program that aims to restore a natural ecosystem. Some invertebrate species will be introduced if fresh topsoil is placed on the areas, but most fauna species will need to recolonise from surrounding areas. The rate of recolonisation by fauna is influenced by a range of factors including the size of the rehabilitated area, the fauna populations in surrounding areas and the success of the revegetation programme.

Many fauna groups will quickly colonise in areas which contain the resources they require such as food, shelter and breeding sites. In many cases the main aim in a fauna return strategy should be the re-establishment of the native vegetation. If this is successful, then the fauna should colonise from surrounding areas.

Fauna may be slow to return where species require resources which are not available in young rehabilitation. The return of these species can be expedited by creating fauna habitats and corridors during rehabilitation using logs, stumps and other natural materials. Fauna corridors running from the surrounding areas to the center of the rehabilitated areas encourage smaller species of mammals and reptiles, which are reluctant to traverse large distances of open ground, to colonise. Tree hollows can be substituted by providing nest boxes of appropriate size for the target species in developing rehabilitated areas.

Animals, particularly invertebrate species, are important in many ecological processes such as nutrient cycling, litter decomposition, soil aeration, seed dispersal, seed predation and pollination. Invertebrates also form part of the diet of a wide range of species from other fauna groups. The abundance and diversity of invertebrates has been used to evaluate the success of restoration programs. Ants are the dominant functional group throughout the arid zone. Because of their abundance, diversity and functional importance in natural ecosystems, it has been suggested that ants are the ideal faunal group to use as bio-indicators to evaluate restoration programs.

5.2.2.7 Maintenance

Rehabilitated areas need to be monitored and managed after rehabilitation. Rehabilitation success is often compromised by the invasion of feral and stock animals, weeds and human activities. Self-sustaining conditions may take many years to reach. Maintenance may include;

- Replanting failed or unsatisfactory areas;
- Repairing any erosion problems;
- Fire management;

- Pest and weed control;
- Control of floral and native animal populations, including fencing;
- Fertilizer applications;
- Watering plants in drier areas, especially in the establishment phase;
- Application of lime or gypsum to control pH and improve soil structure

5.2.2.8 Success criteria and monitoring

It is essential to monitor the success of any rehabilitation program and to be prepared to rework any areas of rehabilitation not developing adequately. Components of the success criteria could include;

- Physical (stability, resistance to erosion, re-establishment of drainage).
- Biological (species richness, plant density, canopy cover, seed production, fauna return, weed control, productivity, establishment or nutrient cycles)
- Water quality standards for drainage water; and
- Public safety issues.

Rehabilitation can be considered successful when the site can be managed for its designated landuse without any greater management inputs than other land in the area being used for a similar purpose. Restored native ecosystem may be different in structure to the surrounding native ecosystems, but there should be confidence that they will change with time along with or towards the make up of the surrounding area. The rehabilitated land should be capable of withstanding normal disturbance such as fire or flood.

5.2.3 Dust Control

The impacts of mining and mineral processing operations on the air quality depends on the nature and concentrations of the emissions, the meteorology and the nature of the receptors – humans, flora, fauna or materials. The major air pollutants from mining include:

- Particulate matter of various sizes and chemical constituents (Dusts)
- Gases, such as, sulfur dioxide and oxides of nitrogen from combustion activities.

Dust is the main air pollutant produced by the iron ore mining. Diesel power stations and vehicles produce some NOx and SO2 emission, usually at low levels. The major sources of dust are haul roads, followed by drilling and then blasting. For many material handling facilities, the main sources of fugitive dust are stock-piles. Dust control can be done by appropriate planning in case of new or expanding mining operations, and by identifying and controlling dust sources during the active phases of all mining operations. The steps to be followed are:

Planning:

- A systematic identification of the potential sources of dust
- Prediction of the duct levels likely to occur near the mine site

- Evaluating the potential for dust particles to effect human health and environment, and
- Incorporating dust predictions and control measures into mine planning and design.

Identifying:

- ***Observation:*** Existing dust sources, particularly point sources, can be readily identified by visual observation. In many cases this is all that is required to confirm the existence of problems that require attention. Around a process plant, visual inspection by an experienced operator is often the most effective means to identify and rank dust sources.
- ***Dust Emission Rates***: The identification of diffuse dust sources, and the task of assessing the relative contributions of all sources to total dust levels.
- ***Models***: Models that predict ambient dust concentrations or deposition rates are commonly used in mine planning. The models use source dust emission rates in conjunction with meteorological data to produce contour maps of dust concentrations.

Controlling:

- Workforce awareness
- Integrating dust control provisions into operations planning e.g. construction, top soil stripping, blasting etc.
- Integrating dust control provisions into work practices
- Monitoring and feed back mechanisms
- Using observational and quantitative assessments to guide control efforts
- Awareness of current methods and technology.

A long term view of dust control has proven consistently cost effective. Mine planning has a particularly important role to play in dust control. The application of dust controls after problems arise is often difficult, impractical or costly. The location of items such as process plants or haul roads may be flexible at the planning stage. Once established in the "wrong" place in terms of prevailing winds and neighbours, a dust problem may be very difficult to rectify and be an irritating factor with surrounding residents. In general, control of dust emission can be achieved by taking a number of considerations into account, including:

- Appropriate use of water to dampen dust-generating areas such as stockpiles, haul roads or exposed soil.
- Enclosure of the dust emitter, eg. covering conveyors and enclosing crushers and conveyor belts (this may have other benefits in noise control);
- Vegetating exposed spoil heaps and cleared areas;
- Minimization of exposed areas through careful planning
- Collection of the dust at the emission point through the use of dust extractors and subsequent capture using electrostatic precipitators, bag house or wet scrubbing.

- Good housekeeping to minimize the accumulation of loose dust piles.
- Removing odors emitted by the process plant by passing the off-gas through a burner to combust the offending chemical.
- Incorporating the effects of the meteorology in the mine or processing plant design, eg. Alignment of stockpiles at right angles to the prevailing wind pattern.
- Carefully controlling blasting procedures to avoid high wind periods, and restricting blast sizes to those actually necessary.
- Minimizing the height that material will freefall on dumping.
- Using hard, unfriable materials for haul roads.
- Adding certain chemicals to water sprays to enhance their effectiveness through forming crusts (though the potential pollution effects of these additives must also then be addressed.).
- Limiting the speed of vehicles on haul roads as increased speed increases dust emissions.

5.2.3.1 Source wise Dust Control Measures

5.2.3.1.1 Land Clearing & Top Soil Removal

In the surface mining process, overburden and top soil will be stripped and relocated. Mining, loading, transport and dumping can all produce dust. The options for control are limited to a certain extent. Clearly the location of the ore body is fixed, but the siting of transport routes and waste dumps and stockpiles may offer opportunities to limit the impact of dust on sensitive adjacent areas. Locating such activities from sensitive areas is desirable.

Control options during mining, loading and dumping of topsoil and overburden are generally limited to dust suppression by watering. Scheduling these activities to coincide with favourable winds and weather conditions may be option. There may be advantages in scheduling this activity to occur during periods when soil moisture can be expected to be optimal. Application of water during topsoil stripping may be necessary.

5.2.3.1.2 Drilling and Blasting

The initial removal of ore and surrounding waste rock involves drilling and blasting. Blasting is usually a relatively minor contributor to total dust emissions. However, blasting dust is produced as a concentrated cloud that is highly visible and potentially may effect near neighbours downwind of the blast. The blasting of near-surface weathered materials that contain a high proportion of fines creates large dust emissions.

The options for controlling dust from blasting are somewhat limited. Watering of the blast area following the charging of blast holes with explosives may assist. Another method that can be effective in protecting areas adjacent to the mine from dust pollution is to avoid blasting under unfavourable wind and atmospheric conditions. This requires some flexibility in blasting schedules, but can be highly effective. Planning mining so that adequate buffer stocks of ore are available is required to accommodate delays in blasting. Knowledge of seasonal and daily wind patterns will give some degree of predictability to the likelihood and frequency of blast postponement.

Blast-hole drilling also contributes to the dust generated from open pit mining. To some extent this is mitigated by dust retention of the pit and use of modern drilling machines fitted with dust collection apparatus. Wet drilling may also mitigate dust emissions.

5.2.3.1.3 Transportation

Loading material into haul trucks usually occurs within the pit, trucks then transport the waste rock and ore to its next destination along designated haul routes. Fugitive dust emissions are produced by the contact of the tyres with the unsealed road surface and are affected by the total distance travelled. Each stage of material transfer involves loading, transport and unloading, also generate fugitive dust. Control measures for fugitive dust control are as follows:

- Applying water, or a mixture of water and chemical for dust suppression on mine haul roads,
- Compaction & gradation and drainage on both sides of haul roads
- Chemical treatment of permanent road
- Proper maintenance of transport vehicles

The following photograph shows the high pressure water sprinkler, while it is in operation indicating effective dust suppression on haul roads.

Fig. No.5.2.3.1 Haul Road Water Sprinkling System

In case of public road is being used for transport of materials, the following additional measures need to be taken:

- Strengthen, reinforce and widen the roads wherever feasible.
- Green belt on both sides of the road of adequate width (10m)
- Prevent spillage by changing design of chassis; all trucks to have a free board of 9" on the chassis.
- Overloading to be controlled by installing weigh bridges in the mines
- Loaded trucks to be covered with tarpaulin or any other suitable material while transporting dry ore. Use of high capacity dumpers with automated hooding arrangements should be encouraged.
- Enforcing speed limit
- Introduce wheel wash system of trucks at the mine
- Spraying loaded trucks with water
- Regular checks by government and mine officials to enforce these measures.

5.2.3.1.4 Processing, Crushing and Screening

Dust generated when processing mined materials, primarily occurs as a result of the mechanical handling of ore. The main points which produce dust are hopper, primary crusher, transfer points, discharge points, stockpiles, dry screens and conveyer belts. Centralized dust collection systems are very effective to capture, transport and separate dust emitted around the processing and handling areas. General dust control measures in ore processing are given in table below:

Table No. 5.2.3.1.4.1 Dust Control Methods for Ore Processing Units

Source	***Dust Control***	***Dust Suppression***
Whole Plant	Enclosures/ barriers	-
Plant Equipment	Dust Proofing	-
Enclosure structures	Regular maintenance	-
Dump Hopper	-	Three sided, roofed sheds for truck dumping, with low volume high pressure adjustable water atomising sprays actuated at the time of dumping. If hoppers are open, fogger sprays at a higher level coupled with atomisers at dumping level will increase fall out rates and prevent dust surges due to the up flow of displaced air. Wind breaks are also effective.
Conveyers	Side wind guards, covers on high and steep conveyors, belt cleaning, dust collection systems, clean up	Sprays at transfer points to wet dust and particles and prevent liberation, mist/fog systems to increase fall out rates. Belt cleaning sprays in opposite direction to

Source	*Dust Control*	*Dust Suppression*
	program, maintenance of enclosures.	travel.
Stockpiles - discharge	-	Minimising discharge heights and conveyor speeds, use of rill tower, enclosure of stockpiles, atomising water sprays to wet failing stream. Drainage often required at stockpile base and foundations.
Stockpiles - Storage	-	Fixed water cannons, or vehicular based sprays for small stock piles. Drainage often required at stockpile base and foundations.

5.2.3.1.5 *Material Handling*

Ore surge piles and stockpiles used to transfer ore to processing facilities are frequently disturbed and may be considered as active disturbance areas. Run-of-mine ore stockpiles contain fewer fines, but can be very large in size. Regular watering of these stockpiles is necessary to control the dust emissions. Stockpile dust suppression can be expensive to install and operate due to the volumes of water required to cover large areas and the associated plumbing and pumping costs. The following figure shows the stationary water sprinkling system on ore stockpile.

Fig. No. 5.2.3.1.5.1 Stockpile Water Sprinkling System

Conditioning of the ore with water (7.5 – 9.5 %) can also be practiced as a primary method to minimize the dust emissions without affecting flow of ore in the ore processing and handling areas. The conditioning is being used in the iron ore industry to control particulate matter from material handling, where the optimum moisture from a particulate matter emission and material handling viewpoint is maintained. This is illustrated in the following figure using the rotating drum test and a

Durham flow test to determine the optimum moisture range for lessening particulate matter emissions and material handling problems such as blocked chutes.

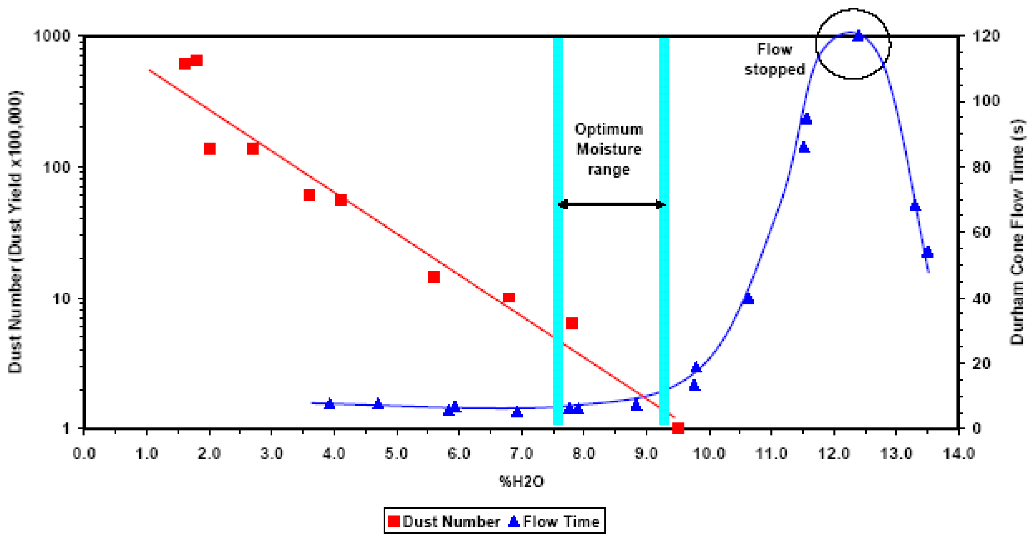


Fig. No. 5.2.3.1.5.2 Particulate matter number and Durham cone flow time as a function of moisture content for an iron ore

5.2.3.1.6 Waste Rock Dumps

Waste rock dumps and dry tailings present in exposed surfaces may be prone to wind erosion during non-monsoon period. It is desirable to plan the waste dump rehabilitation to occur as early as possible in the life of the mine. Establishing the final faces of waste dumps early and revegetating these surfaces will significantly reduce wind erosion. The same principle applies to open areas, i.e. areas cleared of vegetation in advance of mining, waste dumps etc. Mine planning should aim to minimize open areas and clear vegetation only when necessary for the upcoming mining program.

Tailings are distinct in silt and moisture content from both ore and waste rock, and differ in their potential for particulate emissions from wind erosion. Tailings contain a high proportion of fines, but usually deposited as wet slurry. While tailings remain dry, there is likelihood of dust problems occurring. However, the exposed surfaces of tailings dried out, wind erosion is likely to become a significant problem. Dry exposed tailings can be a problem in climates with strong seasonal rainfall. It needs appropriate planning and design of the impoundment and the associated water circuit in order to accommodate both seasonal events and the decommission phase.

In order to mitigate this problem, tailing surface treatment at decommissioning is to be undertaken with the aim of stabilizing them. Revegetating tailing surfaces may be possible, depending on the ability of the tailings material to support vegetation. The tailing surfaces shall be covered with rock and / or soil for better and successful stabilization and vegetation. As this approach can cause very high costs, appropriate provision must be built into financial planning for the mine. Alternative methods which still offer long term dust mitigation include the in situ inducement of permanent crusts that are resistant to erosion.

5.2.4 Noise, Vibration and Airblast Control

Noise, vibration and air blast are unavoidable by-products of mining operations, which involve using large mobile equipment, fixed plant and blasting. Noise, vibration and airblast are among the most significant issues for communities located near mining projects. The growth in public awareness and expectations of environmental performance has led mining companies to focus their attention on the potential impacts arising from noise, vibration and airblast generated by mining activities. The initial planning phase of a mining project should recognise the potential for adverse impacts due to noise, vibration and air blast emissions and preferably follow the following three stage approach for its management:

1. Noise, vibration and air blast impact assessment.
2. Developing and implementing a noise, vibration and air blast management plan.
3. A monitoring and audit program.

5.2.4.1 Noise Control

Noise, vibration and air blast are unavoidable by-products of mining operations, which involve using large mobile equipment, fixed plant and blasting. The basic task in determining whether or not the noise of mining activity is causing an undesirable impact is done by comparing the background sound levels (the average of the minimum sound levels without the mining) with the average of the maximum sound levels of mining at the affected residences. If the background sound level is exceeded by more than 5 dB(A), then the mining noise is considered excessive and should be controlled. The noise control management strategies should include the followings:

- Maintaining adequate separation distances (buffer zones) between mining operations and residential development.
- Ensuring that the actual noise emissions of the equipment are as low as possible. Manufacturers' stated external noise levels should be in accordance with the applicable standards.
- Locating haul roads at sufficient distance from residences and in such a way that there is as much screening (eg by hills and ridges) from residences as possible.
- Locating processing plant (eg crushers, screens, washing plant) at sufficient distance from residences.
- Lining noise-impacting components of processing plants (eg bins, hoppers, chutes) with resilient material to dampen vibrating surfaces.
- Enclosing high noise sources (eg vibratory screens, crushers) with high-mass acoustic enclosures.
- Establishing high-mass acoustic barriers or screens between residences and noise sources. Such barriers or screens should be located as close to the source as possible.
- Forming earth mounding along or around high noise sources. Earth mounds should be at least as high as the noise source and preferably higher (generally, the higher the mound with respect to the source the greater the noise reduction; use natural contours to best effect).
- Fitting effective mufflers to all items of equipment.

- Maintaining all roads in good conditions to reduce vehicle noise. Vehicle noise is exacerbated by high speed and by deceleration and acceleration, and these should be avoided where nuisance can be caused (corrugations, bumps and cattle grids all contribute significant noise).
- Limiting hours of operation. Noise impacts are less significant during the day- time and this is when the noisiest operations should be scheduled to occur.

5.2.4.2 Vibration Control

Vibration is the term used to describe the reciprocating motion in a mechanical system and can be defined by the frequency and amplitude of the oscillations. In the mining, vibration is experienced and /or generated by many items of plant and equipment. The major source of vibration emission, which can be of sufficient strength to cause community concern, is blasting. When an explosive charge detonates in the blast hole, intense strain waves are transmitted to the surrounding rock. The energy carried by there strain waves, known as strain energy fragments the rock medium due to different breakage mechanisms such as crushing, radial cracking and reflection breakage in the presence of a free face when the strain wave intensity diminishes to the level where no permanent deformation occurs in the rock mass (i.e. beyond the fragmentation zone), strain wave propagate through the medium in the form of elastic waves, oscillating the particles through which they travel. These waves in the elastic zone are known as ground vibration. Basically ground vibrations at a point near blast site depends on the distance from blast site, maximum charge/delay type and amount of explosives, stemming length, initiation sequence of pattern, time delay between holes and rows, priming sequence, geo - mechanical characteristics of the strata and sequence of blast hole detonation.

Damage caused by ground vibration is dependent on the frequency of ground motion. All the vibration standards till date are based on the resultant peak particles velocity (PPV) of ground vibration because this is accepted as the best criterion for assessing levels of damage due to vibration. The recent trend is to refer to frequency of the ground motion. Low frequency waves (<6HZ) causes more damage to structure particularly in case of multi-storeyed buildings.

In India, DGMS prescribed 10 mm/sec as the safe limit of ground vibration at the foundation level of the structures within a distance of 300m, depending on dominant excitation frequency and nature/construction of the building/structure. Permissible Peak Particle Velocity (PPV) at the foundation level of structures in mining area in mm/sec [(DGMS) (Tech) (S&T) Circular No.7 of 1997)] is given below:

Table No. 5.2.4.2.1 Permissible Peak Particle Velocity & Dominant Excitation Frequency

Type of structure	**Dominant Excitation Frequency**		
	<8 Hz	8 - 25 Hz	> 25 Hz
A) Buildings/structures not belonging to the owner	***PPV in mm/sec***		
i) Domestic houses/structures (Kuchha, Brick & cement)	5	10	15
ii) Industrial Buildings (RCC & Framed structures)	10	20	25
iii) Objects of historical importance & sensitive structures	2	5	10
B) Building belonging to owner with limited span of life	***PPV in mm/sec***		
i) Domestic houses/structures (Kuchha, Brick & Cement)	10	15	25
ii) Industrial Buildings (RCC & Framed structures	15	25	50

The ground level vibration can be altered or reduced by optimum blast design. Some of them are:

- Reducing the maximum instantaneous charge (MIC) by using delays, reduced hole diameter and/or deck loading. Blast vibration research shows the level of ground vibration is proportional to the Scaled Distance (vibration), which is defined as the distance to the blast divided by the square root of the MIC. So, at a given distance, reducing the MIC will generally result in lower levels of vibration.
- Changing the burden and spacing by altering the drilling pattern, and/or delay layout, or altering the hole inclination. The optimum use of explosives in blasting occurs when the available energy is efficiently used in fragmenting and moving the rock. When the hole inclination (relative to the force angle) is decreased or the burden and/ or opening are increased, the explosive energy cannot fully fracture the rock and the energy instead dissipates through the ground in the form of vibration.
- Exercise strict control over spacing and orienting all blast drill holes.
- Use the minimum practicable sub- drilling which gives satisfactory toe conditions. Less than optimum sub-drill in blast holes results in "toe" being left after the blast, i.e. rock remains intact above the level of the previous bench floor. Too great a sub-drill will result in higher levels of ground vibration due to confinement of the explosives.
- Investigate alternative rock breaking techniques. Hydraulic rock breakers and digging and ripping of product and overburden can (where feasible) ameliorate excessive levels of vibration caused by blasting.
- Establish times of blasting to suit local conditions. Least disruption and concern is caused by blasting when firing times are scheduled to coincide with periods of high activity rather than when people are sitting and relaxing in their homes.

5.2.4.3 Air Blast Control

When blasting is carried out, it is accompanied by a loud noise called airblast. It is an atmospheric pressure wave consisting of high frequency sound that is audible (from 20 Hz to 20 Khz) and low frequency sound or concussion (< 20 Hz) that is sub-audible and cannot be heard, but is capable of causing objects to vibrate such as the rattling of loose windows and crockery. Although air blast seldom causes structural damage but sudden great noise causes psychological fear in the nearby inhabitants.

Air blast may be produced by one or more of the following mechanism:

1. Premature release of the high pressure gaseous products from a confined or partially confined detonation known as stemming release pulse. This is the result of an improper and inadequate stemming.
2. The escape of explosion gases through the fractured rock which is identified as gas venting pulse. This release may also occur if mud pockets are present in the rock strata surrounding the borehole.
3. The sudden movement of the earths surface when displaced by the blast. This is very common in mines where faces are high and long. This is known as Air Pressure Pulse.
4. The detonation of an unconfined explosive, such as an exposed detonating fuse trunk-line or down-line.

However, the main cause of noise is the energy released in open air by the initiation system and inadequate stemming column, burden etc.

To reduce airblast the following measures can be investigated and incorporated where found to be effective:

- Reduce the MIC- Blast emissions research has shown that the level of airblast at a point is proportional to the Scaled Distance (airblast) which is defined as the distance to the blast divided by the cube root of the MIC. Hence, at a given distance, reducing the MIC will generally result in lower levels of airblast.

- Ensure stemming depth and type is adequate. Excessive levels of air blast are often associated with stemming ejection, which commonly occurs when drill cuttings are substituted for stemming aggregates. Optimising the depth of stemming should also maximise energy into the overburden or ore body.

- Eliminate exposed detonating cord and secondary blasting. In the event that an explosive detonating cord is used to detonate the blast holes, it should be covered with suitable aggregate material. However, the potential for initiation related airblast emissions can be minimized with the use of NONEL (non electric) initiation system.

- Restrict blasts to favourable weather conditions. The propagation of airblast emissions is subject to meteorological conditions including refractions by wind and temperature gradients. Wherever possible blasting should be confined to between 0900 hours to 1700 hours to minimize the noise-enhancing effects of temperature inversions.

- Orient quarry faces away from potentially sensitive receivers. Subsonic airblast noise levels are often associated with face heave which generally propagates noise emissions from the blast face. Orientating the blast face away from receiver locations can therefore reduce airblast levels.

- Use a hole spacing and burden which will ensure that the explosive force is just sufficient to break the ore to the required size. Excessive use or explosives may result in the release of energy into the atmosphere in the form of acoustic emissions.

- Take particular care where the face is already broken and consider deck loading where appropriate to avoid broken ground or cavities in the face. High airblast levels may arise from face "blowout" which commonly results from existing fractures or uneven face burden.

- Bore Tracking - in mining industry, recent initiatives to survey blast holes (orientation) have significantly reduced airblast. Uncontrolled drilling of blastholes can result in wide divergence of the hole from the intended position, thus causing blast problems, including "Blowout" airblast.

- Conduct blasting at a set time, or implement a pre-warning signal for nearby receivers.

In addition to reducing airblast, many of these control techniques will maximize rockbreaking efficiency, which in turn results in the use of less explosives and an associated cost savings.

5.2.5 Water Quality Management

Water is integral to virtually all mining activities and typically the prime medium, besides air, that can carry pollutants into the wider environment. Consequently, sound water management and practice are fundamental for most mining operations to achieve sustainable development.

Mining operations can substantially alter the hydrological and topographic characteristics of lease areas. Typically, massive volumes of spoil are shifted, major road and rail infrastructure built and an ore processing plant with associated water supply requirements constructed. Finally, a major open cut pit may remain. These activities affect the surface runoff, soil moisture, evapo transpiration and groundwater behaviour of lease areas. Potentially adverse effects of inadequate minesite water management and design include:

- the rehabilitation process not having enough water;
- the risk of flooding;
- unacceptably high levels of suspended solids and dissolved solids in surface runoff;
- bed and bank erosion in waterways;
- ineffective rehabilitation and revegetation operations; and
- the excessive build-up of 'dirty water' in mine site storages, possibly curtailing mining operations and complicating the rehabilitation process.

At most mine sites, ore extraction and processing, workforce health and safety, and rehabilitation, all require water. Developing water management systems for a mine must account for site-specific physical, chemical and climatic characteristics as well as mine process factors.

5.2.5.1 Minesite Water Management System

A minesite water management system consists of a number of *physical* elements to control the movement of clean and 'dirty' water onto, across and off the minesite, together with a number of *process elements* to control potential water problems at source, while maintaining and verifying the appropriate functioning of the water management system. It is essential that every effort should be made to avoid uncontrolled releases. By definition, uncontrolled releases are events beyond the capacity of the system (or due to a system failure). While it is important to include design features that mitigate their effects, an uncontrolled release almost automatically represents a failure of the water management system and, consequently, is not best practice.

5.2.5.1.1 Physical Elements

A minesite water management system has several inter-connected physical elements that:

- supply water required for the mine to operate;
- convey water;
- store water and liquid-based wastes (eg tailings);
- dispose of water by evaporation or discharge elsewhere; and
- improve water quality.

Conveyance: The use of pumps, pipelines and open channels to convey water around a minesite is self-evident. Water management issues associated with these elements include:

- Pumps - capacity and reliability.
- Pipelines - capacity and integrity (potential for rupture).
- Open channels - channel capacity (overtopping), bank and bed erosion.

Storage: The usual ways of storing raw water, dirty water and liquid-based process wastes on minesites are water storages and tailings dams. Mine pits can sometimes provide suitable alternative storage for clean or contaminated water or tailings. Water management issues associated with each of these include:

- ***Water Storages*** Storage capacity; spillway capacity (ability to safely pass the design flood); likelihood and frequency of spills; impact of spills on downstream receiving waters.

- ***Tailings Dams*** Capacity; ability to contain the design rainfall event; likelihood and frequency of spills; impact of spills on downstream receiving waters; seepage and impact on groundwater quality. (see *Tailings Containment* in this series.)

- ***Open Cut Pits*** Treatment at mine closure; seepage and impact on groundwater quality when used as a tailings dam.

Treatment: Water flows on minesites can undergo various types of treatment before ultimate disposal. Three types of treatment are commonly being used on minesites, namely sediment basins, oil catch pits and wetlands.

- Sediment basins provide a simple form of physical treatment to reduce the level of suspended solids (filterable residue) in surface runoff. Ideally, sediment basins should be used in conjunction with a soil erosion management plan to limit soil erosion at source. The sediment basins are an effective way to remove coarse sized particles from sediment laden runoff i.e. sand-sized particles or greater (0.1 mm diameter or grater). The sediment basins are not effective at removing clay-sized particles (0.005 mm diameter or less) unless supplemented by chemical dosing.
- Oil catch pits / Air Flotation units can treat the effluent generated from the workshops and garages for removal oil & grease and suspended solids.
- Wetlands treat waters passing through them physically and biologically and can improve water quality in various ways, including raising pH and removing nutrients and heavy metals. Wetlands act as sediment basins and commonly 'polish' effluent from other processes, eg treated mine water from mines. Wetlands are being increasingly used as cost effective and aesthetically attractive components of minesite water management and treatment systems.

Disposal: There are only three ways to dispose of excess water on a minesite:

- By evaporation (from water storages, evaporation basins, tailings dams, open cut pits and application).
- By release to surface waters as a 'controlled release' from a storage (via a pump or valve-controlled outlet) or as an 'uncontrolled release' (such as a spill from a storage).
- By recharge to groundwater.

5.2.5.1.2 Process Elements

'Process elements', as well as physical elements, need to be included in a minesite water management system to control problems at source, and maintain and verify the functioning of individual physical elements and the whole system. Process elements typically incorporated in a minesite water management system include:

- an erosion/sediment control plan;
- a hazardous Materials Management Plan;
- an inspection and maintenance plan for the physical elements of the system;
- monitoring water volumes, water flows and water quality; and
- reporting.

Erosion and Sediment Control Plan: Developing and implementing a comprehensive erosion and sediment control plan is a fundamental approach for responsible minesite water management. The plan must define a coordinated approach to sediment and erosion control throughout the life of the mine, and include standard techniques to control the risk of sediment loss from disturbed areas, eg silt fencing and the construction of sediment dams. The plan also needs to address rehabilitation and revegetation options.

One of the most effective ways to reduce erosion risk from spoil piles and other disturbed areas is to rehabilitate and revegetate these areas as quickly as practicable.

Managing Hazardous Materials : All mining operations use hazardous materials of some type, or materials potentially hazardous to human health or the environment when improperly managed, treated, stored or disposed of. This includes grease, oils and petroleum products, as well as other more toxic processing materials. Many of these materials are liquids, water-based or water soluble, able to cause water pollution, health risks and environmental damage if they escape. Consequently, another key element of a minesite water management system is a hazardous materials management plan.

Inspection and Maintenance: It is one thing to appropriately design and construct the physical elements of a minesite water management system. It is another to ensure these elements are adequately maintained at full operational readiness and function. An inspection and maintenance plan is another important component of a minesite water management system.
Note that inspection and maintenance planning applies to both physical and process elements of a minesite water management system.

- for physical elements, only simple visual inspections of key elements is generally needed eg bed and bank erosion in open channels, damage to above ground pipelines, silt build-up in sediment basins. Sometimes, more refined procedures may be required, for example, calibrating monitoring equipment such as water level recorders and water quality sensors.
- for process elements, the importance of inspecting the operation of sediment and control plans and managing geochemically aggressive wastes and hazardous materials is self-evident. Note that 'maintenance' activities for process elements may include modifying processes to achieve outcomes.

Monitoring: Monitoring hydro-meteorological, water quality and biological parameters at key points throughout a minesite water management system is essential to acquire:

- reliable pre-mining baseline data to use as an objective yardstick when assessing the impact of mining operations on hydrological processes ('baseline monitoring').
- data to design physical and process elements of the water management system ('design monitoring').
- regular data to verify the water management system's adequate operation ('operational monitoring').
- data documenting the consequences of any incident affecting minesite water eg an uncontrolled spill from a dirty water dam, a spill of hazardous material, etc. ('incident monitoring').

The monitoring program must be well designed and regularly reviewed. Otherwise, additional monitoring will need to be paid for and the program will be unable to provide objective and appropriate data at critical times, for example when water quality incidents occur, thereby negating a key objective of the program.

5.2.5.2 Principles for Minesite Water Management Plan

A comprehensive Minesite Water Management Plan (MWMP) is the most appropriate way to identify effective management measures and integrate these into a minesite water management system. Erosion control and water quality management plans are essential components of the MWMP.

A comprehensive planning process is the best way to realize the multiple objectives of a minesite water management plan. The planning process should include:

- in the first instance, adopting a catchment-based approach to minesite water management. This will identify current and potential water management issues in the catchment containing the mine leases, and will assess how mining may exacerbate or ameliorate problems. This approach will ensure minesite water management takes account of catchment issues as well as lease-area ones.
- incorporating public consultation (with regulators and stakeholders) to ensure all issues are identified and addressed.
- planning to address the three phases of mining: development, operation and decommissioning.
- recognizing the cost-effectiveness of jointly formulating minesite water management and mine plans. This optimizes coordination of minesite infrastructure and minesite water management measures.
- recognizing the most cost-effective solutions to minesite water management issues come from an integrated 'whole of mine' investigation, rather than investigating specific issues in isolation and on an ad hoc basis.
- a risk management approach to how changing levels of flood, drought and water quality risks should be addressed.
- a risk management approach to identify and deal with operational risks that generate potentially adverse water management consequences.

- undertake appropriate technical studies to adequate standards.
- identify and assess a full range of management measures and options.
- identify and implement appropriate performance indicators.

A water management plan must consider and/or develop site-specific standards, targets, operational or contingency plans and procedures (as appropriate) for all of the following:

- Community expectations,
- Statutory requirements,
- Risk management,
- Minesite Water Balance,
- Monitoring of Hydrological Process,
- Operational Monitoring,
- Emergency Monitoring,
- Flood Risk and Hazard,
- Water Supply,
- Soil Erosion,
- Water Quality,
- Computer Models,
- Performance Indicators, and
- Training and Research.

Managing water used on, and leaving, a mine site is a key aspect of minimizing environmental impacts. The water environment is the mechanism which can most easily and quickly carry and disperse pollutants from the site. To be most effective, the water management system needs to be incorporated in the initial planning stages and adapted as conditions and mine layout develop during operations, right through to decommissioning and beyond.

5.2.6 Tailings Management

The iron ore extracted from the mines are beneficiated to separate out the valuable mineral content. The prime function of beneficiation of iron ore is to improve the Fe content and to decrease the Alumina / Silica ratio for smooth Blast Furnace operations. The nature of iron minerals and associated gangue minerals decides the method of beneficiation to be adopted. The left over residue of the iron ore after the beneficiation in the state of fine particles mixed in water in a slurry form, known as tailings and are needed to be disposed of in the tailings pond for containment. The tailings vary considerably in their physical, chemical and mineralogical properties. These properties influence the behaviour of the material, storage facilities, resistance to erosion and reuse of tailings if any. Along with the physical properties, chemical properties of the tailings contribute significantly towards environmental contamination. During 2006-07 India has produced 172.296 (P) MT of iron ore (including lumps, fines & concentrate) and generated more than 14 MT tailings per annum.

The disposal of tailings is a major environmental problem, which is becoming more serious with increasing extraction of lower grade deposits. The tailings are usually transported and deposited as slurry of high water content into a pond for containment, which are generally called as tailing ponds / tailing dams. The major short term and long term environmental problems associated with the tailing dams are:

- Water pollution (including ground water)
- Dam safety and stability
- Air pollution
- Visual impact
- Reclamation an restoration

Management of the tailings dam at iron ore mines is an important issue from pollution point of view and conservation of resources. Tailings contain more than 45% of iron. In future when the present day rich source will be used up, it may become economically viable to extract iron from tailings. But, due to huge land cost and also for the safety of the dam, it is worth examining the feasibility to evaluate the appropriate tailings pond size to a minimum level.
The objective of tailings dam is safe storage of tailings material and separation of water and solids. The tailings dam should be so designed as to permit retention of the tailings indefinitely and minimize long-term impact on the environment. Reclamation objectives, inter-alia, include,

- Achieving long term stability of the 'dam'
- Reducing long term erosion
- Abating long term effects on ground water and surface water
- Retaining the area to productive use

The design, construction an operation of the tailings dams is rapidly becoming a major consideration for most new mining developments as well as existing operations. The tailings dam can be built as conventional water dams and then filled, or built progressively using the tailings in their construction. There are three main following approaches when considering the progressive construction of a dam. These methods allow for staged construction of the embankments which minimise start-up capital costs, and have the potential to improve the overall mining economics. They are

- Up stream method
- Downstream method
- Centre line method

5.2.6.1 Tailings Dam – Upstream Method

In this method, a small starter dam is placed at the extreme downstream points and subsequently dam wall is raised progressively on upstream side. The various methods used in raising the dam may be by using hydraulic techniques when, the initial pond is nearly filled, the dyke is raised and the cycle is repeated. The diagram of upstream tailing dam is given in figure below. The upstream method is generally suited for hard rock mining products, which produces silt and classify into sandy beach.

The main advantages of the upstream construction are the low cost and the speed with which the dam can be raised by each successive dyke increment. However, the method suffers from the disadvantage that the dam wall is built on the top of previously deposited unconsolidated slimes retained behind the wall, which limits the height of the dam. The limiting height of the dam to which this type of dam can be built before failure occurs and tailings flow out, and because of this, the upstream method is now less commonly used.

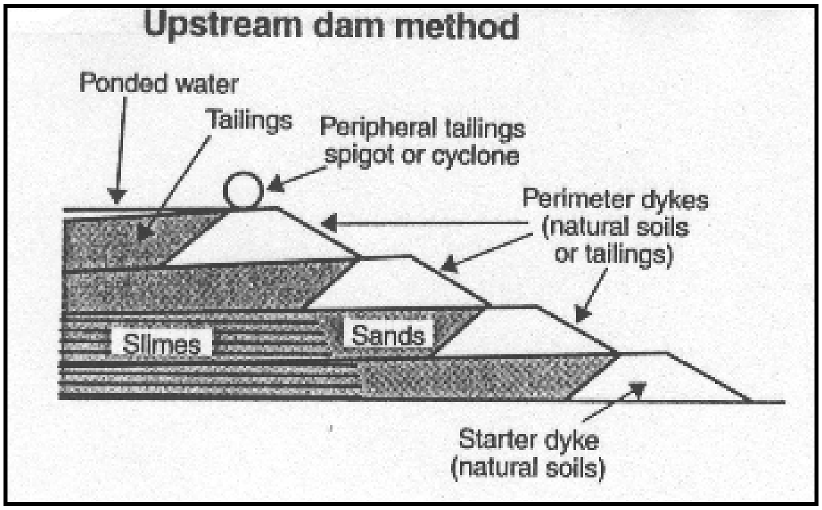


Fig. No. 5.2.6.1.1 Upstream Dam Method

5.2.6.2 Tailings Dam – Downstream Method

The downstream method is a relatively new development which has evolved as a result of efforts to devise methods for constructing larger and safer dams. This type of dam is usually constructed by reverse of the upstream method. In this, the dam wall is raised and the centreline shifts downstream and the dam remain founded on coarse tailings. The common procedure involves the use of cyclones to produce sand for dam construction. Construction of downstream tailing dam is given in figure below.

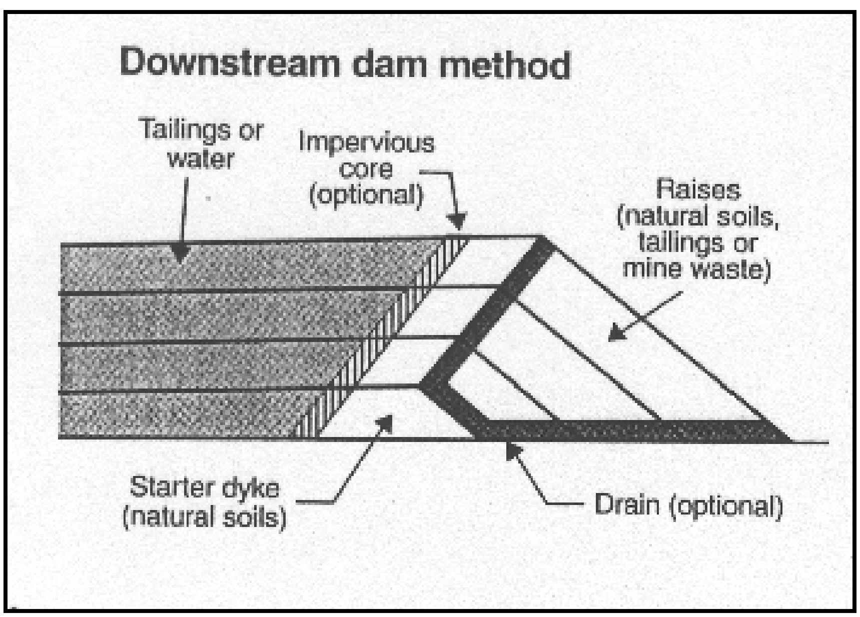


Fig. No. 5.2.6.2.1 Downstream Dam Method

Downstream dam building is the only method that permits design an construction of tailings dams to acceptable engineering standards. All tailings dam in seismic areas, and all major dams, regardless of their location, should be constructed using some form of the downstream method. The major disadvantage of the technique is the large amount of sand required to raise the dam wall.

5.2.6.3 Tailings Dam - Centreline method

Centreline method is a variation of the method used to construct downstream dam. Here the crest remains in the same horizontal position as the dam wall is raised. For this purpose, smaller volumes of and fills may be used to raise the crest at any given height. Construction of centreline tailing dam is given in figure below.

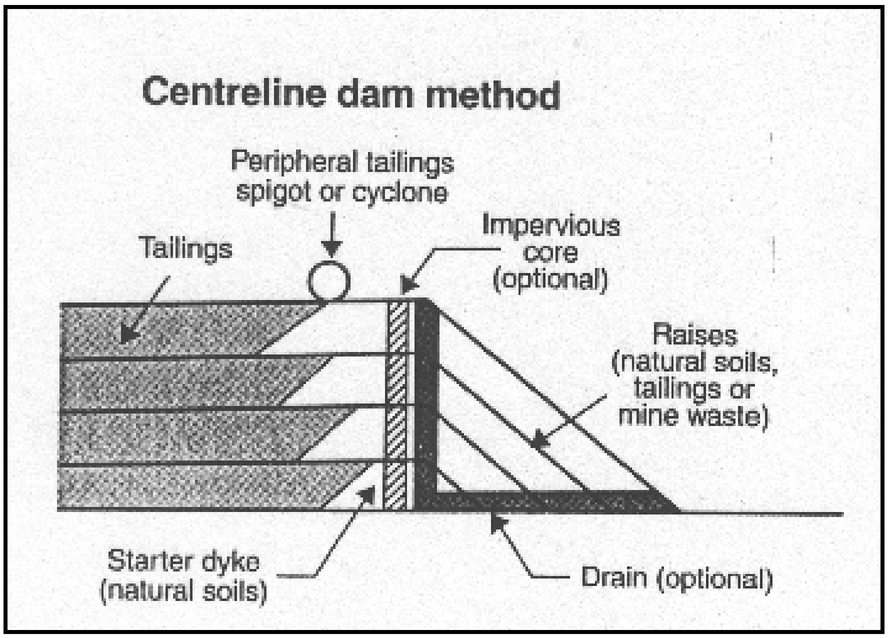


Fig. No. 5.2.6.3.1 Centreline Dam Method

This method has the advantage of requiring the smaller volumes of sand fill to raise the crest to a given height. The dam can thus be raised more quickly and there is less trouble keeping it ahead of the tailings pond during the early stages of construction. Care, however, must be exercised in raising the upstream face of the dam to ensure that unstable slopes do not develop temporarily.

5.2.6.4 Guidelines for Tailings Management

Important factors need to be considered in tailing management are as follows:

- Selection of an appropriate site
- Delineation of the most appropriate method of storage and management of tailings deposition.
- Monitoring of the operation
- Developing an appropriate rehabilitation and closure strategy.

The following general principles should be followed while designing the disposal methods for the tailings:

- Mine / mill waste water should be recycled to the maximum practicable extent.
- Re-vegetation of tailing disposal areas should be phased to synchronise with the disposal schedule.
- Tailing area decant ponds must be adequately deep to provide a quiescent settling zone for the particles. Wind and wave action would prevent settling if pond is too shallow.
- The water in a decant pond should not come into direct contact with the tailing dam. In such eventuality, the water depth should be minimal with protection against wave action provided.
- Tailing dams should be redesigned to provide for storm water run-off.
- Decant tunnels (within a tailing mass) should be kept as short as possible.
- Whenever practicable, tailing should be used for filling in the mine workings after proper testing to ward off ground water contamination.

Site Selection: It is economically advantageous to site the impoundment close to the mine, but this imposes limits on site selection. The ground underlaying the dam must be structurally sound and able to bear the weight of the impoundment. If such a site can not be found close to the mine, it may be necessary to pump the tailings to a desirable location. The following factors need to be considered for selecting the dam site:

- A site underlain by maximum available thickness of unsaturated material (deep water table) should be selected.
- A site underlain by material with lowest permeability should be chosen.
- The site should not be underlain by shallow unconfined aquifers.
- Sites adjacent to streams, where the contaminated seepage or leachate and ground water may discharge into them are not acceptable. If such locations are not available, the designs should provide for minimum seepage. Cut off zones beneath dams, impermeable lines and segregation of mill tailings are important design parameters to ensure this.

Tailing Storage Facility: While considering the tailings storage area, it is important to consider the various types of impoundments and select the most appropriate one depending on topography, drainage pattern & geology/hydro-geology of the area. Tailings storage structures fall into three main categories viz. dumps, impoundment dams and storage in exhausted mine pits. Impoundment dams / tailing dams are generally used in India for tailing storage. The following are the some of the new environmental friendly technologies related to tailing disposal methods;

- Thickened Tailing Disposal
- Sub Marine Tailing Disposal

Thickened Tailings Disposal: Compared to conventional wet disposal, thickened tailings disposal technology for surface disposal of tailings has potentially wide application in some countries, which eliminate environmentally undesirable, high perimeter dams retaining a wet settling pond on top of saturated tailings. In this method, the under flow slurry from the thickener need to be dewatered for thickening to paste consistency, which can be achieved through Deep Thickener, Paste Thickeners or pressure filters. New generation thickeners can more economically produce paste at the limit permeability and of consistency just below that of vacuum filters. Addition of flocculants (25 - 45 grams/ton.) may be necessary to get the desired concentration. Then the thickened paste tailings may be transported by pipeline, trucks or conveyer and discharged as stack configuration, which requires less storage space. The thickened tailings disposal therefore reduces the footprint of land occupied by waste, thereby maximizing storage capacity and minimizing the surface runoff water potentially requiring treatment. Stabilization and revegetation of the dried tailings can be done faster and easier than the conventional tailing ponds.

Although the technology was introduced more than 25 years ago, its application was limited in few mines due to lack of facilities for dewatering of slurry to adequately consistent solids. More recently interest in stacking of tailings has been received, because of significant advances in design, availability and performance of compact automated deep thickeners able to produce stackable paste solids without need for the use of filters or centrifuges.

Marine Disposal of Tailings: Disposal of tailings slurry in a marine as a submerged granular solid at the sea bottom is being practiced in some of the countries. Near-shore marine tailings disposal may be the best for the following conditions, provided that the physical, chemical and biological conditions are met:

- Restricted terrain availability or unfavourable contour
- Engineering or environmental restrictions on replacing the tailings in the mine or
- Unfavourable weather or seismic conditions

Water Management (collecting and recycling of seepage water from tailings dam)

In spite of all efforts it is sometimes not possible to make tailings dam completely seepage free. The common way to control water pollution from such seepage is to prepare a small toe dam on the downstream side and collect the seepage water which can be pumped back to the main reservoir. In this manner zero discharge can be achieved from the tailings pond. Minimising the quantity of water escaping from the tailings dam will be necessary to avoid water pollution, and is good environmental practice. This can be achieved by recirculation of process water and control of seepage. Measures used to control seepage from a tailing's dam might include:

- Use of clay liners and synthetic liners
- Foundation grouting and the use of cut-off trenches
- Controlled placement of tailings and
- Inclusion of toe drains and under drains to collect and treat or recycle seepage.

Many major dam failures are due to inadequate decant design of the tailing dams. Many older dams used decant towers with discharge lines running through the base of the dam to downstream pump-house. Failures of such structures were common due to the high pressure exerted on the pipelines, leading to uncontrolled losses of fluids and tailings downstream. Floating, or movable, pump houses situated close to the tailings pond are now in common use.

Recycling of water from decant is becoming more important due to pressures from governments as well as water scarcity. As much water as possible must be reclaimed from the tailings pond for reuse in the beneficiation and the volume of fresh water make-up water used must be kept to a minimum. The clarified water from the tailing pond can be reclaimed by using floating or movable pump for reuse in the beneficiation plant or other purposes. In order to collect the seepage from the dams, a seepage pond shall be constructed in downstream of the dam. The seepage from the downstream can then be pumped back to the tailing pond. A typical water reclamation system for tailing ponds is shown in figure below:

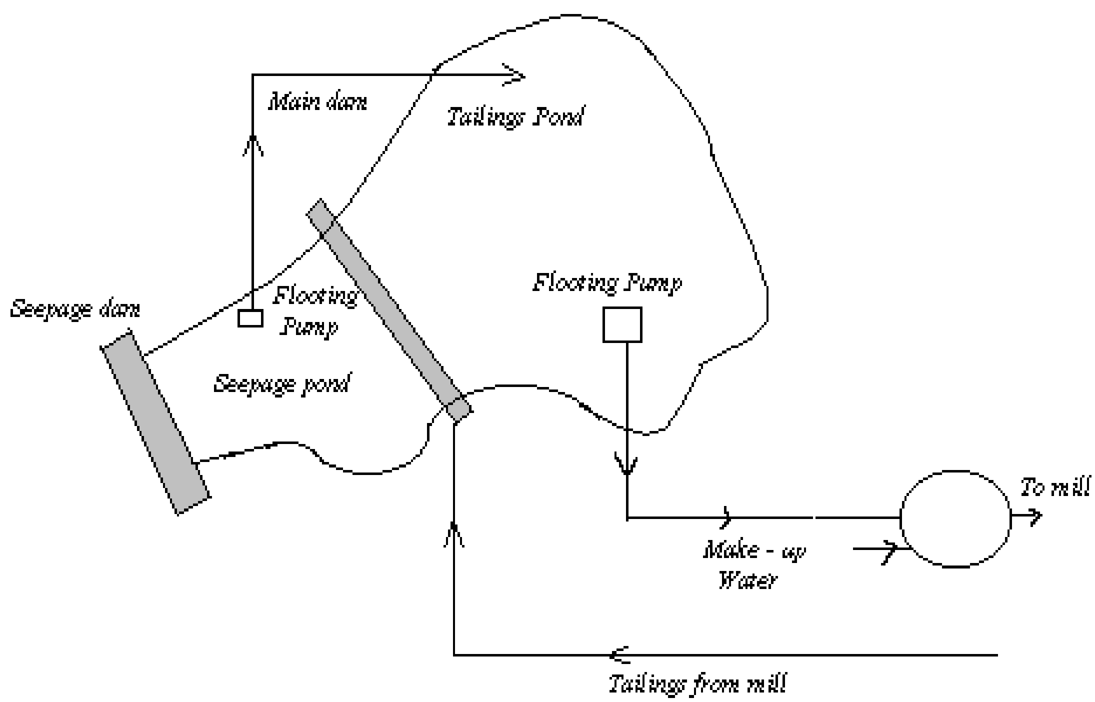


Fig. No. 5.2.6.4.1 Water Recirculation System at Tailings Pond

Rehabilitation and Closure Systems:

There are number of objectives that need to be considered when planning the closure of a tailing storage area. They include:

- Containing / encapsulating tailings to prevent leaching into ground and surface waters
- Providing surface drainage and erosion protection to prevent surface water transporting tailings from the storage area;
- Providing a stabilized surface cover to prevent wind erosion; and
- Designing the closure to minimize post closure maintenance.

The physical characteristics of the tailings generally determine the type of erosion protection required, while the chemical characteristics and the amount of rainfall will determine the need for and requirements of a surface cover.

By adopting all the above principles of best practice environmental management during the planning, design and operational stages of a facility, and using effective environmental monitoring and auditing, relatively inexpensive tailings storage methods can be practiced, while avoiding the many pitfalls that can lead to short and long term environmental problems.

5.2.7 Mine Closure Plan

5.2.7.1 Introduction

While mining is often a short-term landuse, an important aspect of mine planning is the rehabilitation of disturbed lands to a stable and productive post-mining landform, which is suitable or acceptable to the community. Normally it is being observed that the iron ore mining or for that matter any mining operation leaves scar mark or voids at the mining site after the mining is being completed. The existence, ultimate shape and size of final void at the end of an open cut mine's life depends on a range of factors. These include mining method, the resource size and extend, physical constrains (such as roads, railway lines, rivers, lease boundaries, etc.) government regulatory requirements and economics, both in terms of resource amounts that can be viably extracted and the cost of backfilling voids. Determining the end use for final voids is undoubtedly the most difficult aspect of rehabilitation planning, especially during the early phases of mine planning and development. Not only is the creation of the residual void many years or perhaps even decades into the future, but variations in mining methods, technology and economics during a mine's life can mean that the ultimate location, size and configuration of the voids can only be an educated guess.

The concepts and standards underlying mine rehabilitation and closure today are much more demanding than they were just a few years ago and reflect changing public priorities and environmental imperatives, worldwide. Mine rehabilitation is an ongoing programme designed to restore the physical, chemical and biological quality or potential of air, land and water regimes disturbed by mining to a state acceptable to the regulators and to post-mining land users. The objective of mine closure is to prevent or minimize adverse long-term environmental impacts, and to create a self-sustaining natural ecosystem or alternate land use based on an agreed set of objectives.

More recently, the emphasis for management of the environmental aspects of mine closure and decommissioning has shifted towards the idea of "planning for closure" (Sassoon, 1996). Mine closure is a continuous series of activities that begins with pre-planning prior to the project's design and construction and ends with the achievement of long-term site stability and the establishment of a self-sustaining ecosystem. Not only will the implementation of this concept result in a more satisfactory environmental conclusion, but it can also reduce the financial burden of mine closure and rehabilitation.

Now, there is a need to lay down procedures and guidelines on how mine owners should act in the post-mining scenario. Before exhausted mine is abandoned, all reclamation activities including safety, environmental mitigation and required social impact mitigation's have to be completed.

So now the issue is the development of an effective and efficient approach for the development of comprehensive Closure Plans that return all mine sites to viable, and wherever practicable, self-sustaining ecosystems, and that these plans are adequately financed, implemented and monitored within all jurisdictions. Mine closure should be made mandatory for all types of mines irrespective of their size and location. Decommissioning process calls for proper closing down the mine by closing its operations and reducing steep slopes of surface excavations and removing buildings and other structures from the site. For this purpose necessary guidelines are discussed in the following sections.

5.2.7.2 Regulatory Frameworks

5.2.7.2.1 Indian Regulations

Thousands of abandoned mines, after working, have been left over and now form a historical legacy. But, there in no single law, which regulates mining and environmental aspects of mining. An extensive regulatory system is now needed to be developed to cover current mining operations as well as to guide cleanup of these abandoned mine sites. The framework primarily exists but requires new regulations for mine closure. Recently, draft notification has been circulated among FIMI members with a proposal to make mine closure mandatory and consequent upon suitable amendments in MCDR, 1988 and MCR,1960.

5.2.7.2.2 Australian Regulations

Regulation to meet growing community expectations of environmental management is increasing in all Australian jurisdictions. The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, which came into effect in July 2000, has established a new and nationally consistent framework for environmental assessment of new projects and variations to existing projects, based on consultative agreements between the Commonwealth and State and Territory Governments. Issues related to mine closure are an important consideration in the assessment process for mining proposals. Appropriate planning and adequate provision for mine closure are issues now being addressed by both the regulators and the minerals industry across Australia. Australian State and Territory Governments (and in some cases local government) are responsible for the regulation and management of mine closure and rehabilitation requirements on industry. All States and Territories have mine closure policies requiring site-specific post-mining rehabilitation plans developed by companies for approval by the respective mining agencies in each jurisdiction. State and Territory Governments also require some form of security bond, usually in the form of a bank guarantee or a cash payment for smaller operations, but the calculation process for bonds varies between jurisdictions.

5.2.7.2.3 USA

Mining and mine closure is covered by a variety of legislation both at Federal and State level. The Bureau of Land Management regulates mining activity of Federal lands, while most States have a Mines Lands Reclamation Act or similar. Overall, there is a requirement for every mine to develop a closure plan, which is then submitted to the applicable regulatory agencies for approval prior to implementation of the plan. The focus of most agencies is to prevent unnecessary and undue degradation of land and to ensure the long-term chemical stability of process components, specifically spent heap leach areas, pit lakes and tailing impoundments. A general feature of the US regulatory environment is the multiplicity of permits which have to be obtained, and the strict regulatory approach taken to mine closure.

For abandoned mine sites, the two key pieces of legislation are the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or "Superfund") and the SMCRA. CERCLA was intended to deal with abandoned unregulated waste sites where no ongoing regulatory scheme was in place to monitor environmental impacts. It provides that those responsible for releases of hazardous substances (i.e. incidents) were responsible for cleaning up or remediating the problems created. Remediation would return the natural resource to a condition such that it would not pose a substantial danger to public health or welfare or the environment. CERCLA also provided for the collection of monetary damages to society for the resource lost as a result of an Incident. In practice, however, the Superfund scheme has become enmeshed in legal argument and investigatory studies, to the detriment of many actual successful remediation exercises.

SMCRA also established a fee on coal produced from both surface and underground mines for the purpose of reclaiming coalmines abandoned without adequate reclamation prior to the effective date of the Act. This money is paid into an Abandoned Mine Fund. Priorities for reclamation of abandoned mines are set by the States and the reclamation is paid for out of the Fund. There is also provision for reclamation of non-coal mines, which are posing a significant pollution threat.

5.2.7.2.4 South Africa

Under the Minerals Act, 1991, the South African Government requires the owner of every mine to submit and obtain approval for an Environmental Management Programme before mining operations may commence. The Environmental Management Programme Report (EMPR) must include assessment of the environmental impact of the decommissioning phase of a mine, and any residual impacts after closure. The Environmental Management Programme must incorporate a section on the decommissioning phase and closure. Every effort should be made during the life of the project to minimise the cost and amount of the work required for this phase. The EMPR should cover:

- Closure objective
- Infrastructure areas- demolition or disposal of structures and buildings, removal of foundations and debris and rehabilitation of the surface
- Management of mine residue deposits, including ongoing seepage, control of rainwater, long-term stability and final rehabilitation in respect of erosion and dust control.
- Sealing of underground workings and rehabilitation of dangerous excavations
- Final rehabilitation of open cast mine haul ramps and roads and final voids
- Maintenance of the decommissioned site until closure is approved.

Mine closure should ensure that:

- The safety and health of humans and animals are safeguarded from hazards resulting form mining operations;
- Environmental damage or residual environmental impacts are minimised to such an extent that it is acceptable to all involved parties;

- The land is rehabilitated, as far as practicable, its natural state, or to a predetermined and agreed standard or land use which conforms with the concept of sustainable development;
- The physical and chemical stability of the remaining structures should be such that risk to the environment is not increased by naturally occurring forces to the extent that such increased risk cannot be contended with by the installed measures;
- The optimal exploitation and utilisation of South Africa's mineral resources are not adversely affected.
- Mines are closed efficiently and cost effectively; and
- Mines are not abandoned but closed in accordance with the Mine Closure Policy.

The Department of Minerals and Energy Affairs requires that adequate financial provision be made by mining companies in order to meet their obligations under the EMPR, including final closure of the mine.

The State accepts responsibility for rehabilitation of derelict and/or defunct mine for which no owner exists or can be traced. There is provision for a proportional payment towards this cost by anyone who will benefit from the rehabilitation, such as the landowner or a regional authority. There is also provision for the State to fund rehabilitation of derelict and/or defunct mines for which an owner can be identified but where it would be impracticable or inequitable to require this person to be responsible for the rehabilitation.

5.2.7.3 Components for the Development of Mine Closure Plan

5.2.7.3.1 Stakeholder Involvement

Consultation with relevant internal and external stakeholders is a necessary step in ultimately receiving employee, regulatory and community endorsement for the Closure Plan. Stakeholders are those parties with the potential to be affected by the mine closure process. They are distinct from interested parties, who have an interest in the process or outcomes of mine closure. Identifying key stakeholders and interested parties, and developing a good relationship with them, is fundamental to a successful closure process. Consultation should commence during the development of a Closure Plan to ensure issues are adequately considered. Consultation with relevant stakeholders will assist with:

- Developing realistic employee, community and regulatory expectations
- Establishing a satisfactory post-closure land use
- Understanding internal and external stakeholder issues
- Enabling stakeholders to participate in the process
- Enabling stakeholders to prepare for closure
- Minimising dependency on the company
- Avoiding costly surprises

Annual reporting against completion criteria (which need to be established early in the process), commitments and proposed and/or actual closure planning activities is an effective means of communicating the Company's closure strategy and assists in providing a consistency to the planning process.

5.2.7.3.2 Financial Provisioning

Determining the costs associated with closure and accruing these costs during the life of the operation is a fundamental part of closure planning. A provision is a mechanism to ensure that there are sufficient funds to close the operation and that closure costs do not become a burden in later years of a mine life when revenues are typically diminishing. Closure provisions should reflect the real cost of closure.

Determining a closure provision during the feasibility stage of a project is an important element in determining if a project is economically feasible. If a provision is not determined at this stage in the project life it is recommended that it be developed as soon as possible and reviewed at regular intervals in the mine life to ensure that the closure cost is considered as part of the ongoing evaluation of mine economics.

Developing a provision will assist in determining the real costs associated with:

- Decommissioning
- Rehabilitation (Reclamation)
- Impacts on the surrounding environment
- Impacts on community
- Post-closure environmental monitoring
- Site maintenance
- Long term treatment facilities
- Relinquishment

Provisioning may also assist in the establishment of economic completion criteria for closure.

5.2.7.3.3 Resources

Closure planning should consider both physical and human resource aspects of closure to minimise risk and maximise outcomes. Communication with, and involvement of, employees is fundamental to successful implementation of strategies. Issues relating to retention, retrenchment and retraining of employees require careful consideration. Closure planning for human resources should consider:

- Mechanisms to retain key employees during closure
- Retraining and relocation requirements
- Mechanisms for reducing employees near or at the time of decommissioning
- Inclusion of suitable skills within the closure team

5.2.7.3.4 Research

Contributing to focussed and relevant research on strategic mine closure issues is an important part of closure planning as it contributes to site specific, regional and industry knowledge. Research also provides the information required to make informed decisions in relation to closure design options, financial provisioning as well as assisting in developing improved mine closure outcomes through mechanisms such as completion criteria.

5.2.7.4 Closure Plans

At least two types of closure plan will be required through the life of a mine; a Conceptual Closure Plan (project phase) and the main Closure Plan (operations phase):

- A Conceptual Closure Plan for use during feasibility, development and detailed design; and
- A Closure Plan for use during construction, operation and post-operation

5.2.7.4.1 Conceptual Closure Plan

A Conceptual Closure Plan identifies the key objectives for mine closure to guide project development and design. It should include broad land use objectives and indicative closure costs. (This does not preclude land use objectives being varied during the mine life to reflect changes in both knowledge and technology.)

5.2.7.4.2 Closure Plan

Closure planning includes a commitment to progressive rehabilitation and detailed plan development and implementation. A number of subsidiary plans need to be developed as the Closure Plan evolves. These typically include: a rehabilitation plan, a decommissioning plan and maintenance and monitoring plan.

- *Rehabilitation plan:* A key component of the Closure Plan is a commitment to progressive rehabilitation. In conjunction with an active research and trials programme, this may assist in minimising ongoing contamination and reduce final costs by confirming or modifying completion criteria and demonstrating that they can be met. Progressive rehabilitation allows best use of available personnel and equipment and should assist in minimising required security deposits.
- *Decommissioning plan:* As a detailed component of the Closure Plan, a decommissioning plan should be developed towards the final stages of an operation. (As the exact date for ceasing production is rarely known, it is suggested that the decommissioning plan be developed 2 to 4 years prior to estimated cessation.) Once established it should be updated annually. The decommissioning plan include such things as: details of the demolition and removal or burial of all structures not required for other uses; removal, remediation or encapsulation of contaminated materials; and the procedures for making safe and sealing, openings to underground workings.
- *Maintenance and monitoring plan:* The last aspect of the Closure Plan is performance monitoring, which should be designed to demonstrate that the completion criteria have been met. This period should also plan for remedial action where monitoring demonstrates completion criteria are unlikely to be met. If progressive rehabilitation has been successful, with stabilisation and revegetation meeting completion criteria this last phase of closure may be shortened. It is, however, unlikely to be less than 5 years in duration.

5.2.7.4.3 Typical Contents of a Closure Plan

The development of a Closure Plan needs to take into account both the legal requirements and the unique environmental, economic and social properties of the operation. Outlined below are the typical contents of a Closure Plan, which will vary depending on individual circumstances. In developing the Closure Plan, the following four key objectives should be kept in mind:

- to protect the environment and public health and safety by using safe and responsible closure practices;
- to reduce or eliminate environmental effects once the mine ceases operations;
- to establish conditions which are consistent with the pre-determined end land use objectives; and
- to reduce the need for long-term monitoring and maintenance by establishing effective physical and chemical stability of disturbed areas.

The typical contents of a Closure Plan should have the followings:

- Introduction & Project Description
- Objectives of Closure
- Baseline Environmental Data
- Legal & Other Obligations
  - Key statutes & regulations
  - Responsible Authority
  - Regulatory instruments
- Stakeholder Involvement
  - Stakeholder identification
  - Community consultation
- Risk Assessment
  - Existing legacies
  - Future risks
  - Cost/benefit analysis
- Closure Criteria
- Closure Costs
  - Provisions
  - Securities
- Closure Action Plan
  - Human resources/responsibilities
  - Progressive rehabilitation
  - Decommissioning
  - Remediation
  - Geotechnical assessment
  - Landform establishment
  - Revegetation
  - Aesthetics
  - Health & safety
  - Post-closure maintenance & monitoring
  - Survey (remaining structures & areas of contamination)
  - Documentation/reporting/records
- Tenement Relinquishment

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6.1 INTRODUCTION

It is recognised that minerals and metals are the mainstay of the economic development and welfare of the society. However, their exploration, excavation and mineral processing directly infringe upon and affect the other natural resources like land, air, water, flora and fauna, which are to be conserved and optimally utilised in a sustainable manner. The Mineral Sector in our country is on the threshold of expansion, with more and more mines being opened up. Among the metalliferous minerals, iron ore is one of the economically most important mineral for our country. Production of iron ore in our country is through a combination of large mechanised mines in both public and private sector and several small mines operate in manual or semi manual in the private sector. Major environmental damages resulting from iron mining are as follows;

- Alternation of the land form
- Air pollution with dust and gases due to drilling, blasting; crushing & screening, loading, unloading, waste dumps, exhausted tailings pond, mine haulage and transportation etc.
- Water pollution due to discharge of mine effluent
- Modifying water regime such as surface flow water availability and lowering down of water table.
- Soil erosion, soil modification with dust and salt
- Noise and vibration problem in the mine and adjoining areas
- Deforestation affecting flora & fauna
- Spoiling aesthetics with unstabilised waste dumps

It is therefore necessary that environmental concerns must be integrated with the mining operations at the planning stage itself to minimise all these adverse affects. To protect the environment, mining sector in general, is regulated by the Environment (Protection) Act, 1986, the Forest Conservation Act, 1980, the MMRD Act 1957, Wild life Act, 1972, Water (Prevention & Control of Pollution) Act, 1974 and Air (Prevention & Control of Pollution) Act, 1981, etc.

In order to protect the environment, environmental standards specific for Indian Iron Ore Mines are being proposed under Environment (Protection) Act, 1986. The details of proposed standards for air, water & noise quality, and guide lines for solid waste management and code of practices for pollution prevention & control for achieving the proposed standards, are described in this section.

6.2 EMISSION STANDARDS

6.2.1 Sources of Emissions & Parameters of Concern

The air quality of mining and mineral processing operations on the environment is depend on the nature and concentrations of the emissions, and meteorology of the environment. The major air pollutants from the iron ore mining are particulate matter of various sizes & its chemical constituents and gaseous emissions such as sulphur dioxide and oxides of nitrogen.

In mining operations dust is the single largest air pollutant and can be a significant nuisance to surrounding land users as well as a potential health risk in some circumstances. As the mining and mineral processing activities do not involve any chemical processes, the emission of gaseous pollutants such as Sulphur Dioxide, Oxides of Nitrogen and Carbon Monoxide, is only from the vehicle exhaust and diesel operating machines. Levels of these gaseous pollutants are also observed very low in the iron ore mining areas. Major sources of dust emissions from the iron ore mining are as follows:

- Land clearing and removal of topsoil and overburden
- Drilling and Blasting
- Operation of crushing and screening equipment
- Loading and unloading of material on site and subsequent transport off site
- Transport by vehicles on access roads and haul roads
- Wind action on stockpiles, dry tailings impoundment's and exposed areas of the site

6.2.2 Existing Air Quality

Field monitoring was conducted at the iron ore mines in the Eastern Zone i.e. Kiriburu Iron Ore Mines and Meghahatuburu Iron Ore Mines for four seasons through out the year. Air quality at both the ambient and work zone was monitored for RPM, total dust, SO_2 and NO_x. Chemical analysis of work zone dust was done for parameters of concern i.e. lead, silica and Fe, etc. Total chemical analysis of the work zone dust samples was also analysed. The presence of crystalline silica was also checked in the RPM and total dust. Besides the air quality data of the major iron ore mining operating all over India in the four identified zones were collected. The existing air quality for all the four zones are discussed in Section Four of the Report, while discussing the impact on air quality of the respective mining zones. The detail data are compiled and presented in a separate booklet.

Observations from the statistical analysis of available ambient and work zone air quality monitoring data for the annual average and 98 percentile values of SPM, RPM, SO_2 and NOx in the four different zones are given in the table below:

Table. No. 6.2.2.1 Ambient Air Quality at Iron Ore Mines in India

(Unit: $\mu g/m^3$)

Zone	*Eastern*		*Western*		*Southern*		*Central*	
Parameter	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*
SPM,	534	191	992	323	410	177	193	114
RPM,	314	93	381	117	141	72	53	27
$SO_{2,}$	36	13	64	14	15	8	34	17
$NO_{x,}$	37	13	30	9	23	11	27	17

Lead in dust & CO in AAQ are very insignificant. Maximum of the observed Lead value was 0.77 $\mu g/m^3$ and most of the values are in the range of 0.01 to 0.02 $\mu g/m^3$. The CO values were reported as less than 1ppm.

Table. No. 6.2.2.2 Workzone Air quality at Iron Ore Mines in India

(Unit : $\mu g/m^3$)

Zone	*Eastern*		*Western*		*Southern*		*Central*	
Parameter	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*	*98 Percentile*	*Avg.*
SPM,	1321	305	1862	508	2175	490	387	217
RPM,	560	215	811	196	515	179	94	66
$SO_{2,}$	44	14	82	22	25	15	28	21
$NO_{x,}$	29	13	40	12	28	17	35	25

Detailed analysis of work zone dust, which include analysis of parameters of concern i.e. lead, silica & Fe, and crystalline silica, was conducted. Size distribution of respirable dust was also analysed and found that 0 -5 µm and 5 – 10 µm were in the range of 20 – 45 % and 55 – 80 %, respectively. Chemical analysis of dust is given below;

Table. No. 6.2.2.3 Chemical Analysis of Workzone Dust

Parameter	*Respirable Dust*	*Coarse Dust*
Lead as Pb	0 – 0.04 %	0 – 0.12 %
Silica as SiO2	14 – 56 %	2 – 8 %
Iron as Fe	0.28 – 3.3 %	4 – 4.4 %

Crystalline silica in coarse dust was found to contain approximately 2%, whereas in the respirable dust it was only in traces. Total chemical analysis of the dust samples indicates that, the major constituents were Silica, Alumina, Iron and Lime.

6.2.3 Existing Emission & Air Quality Standards

Emission standards in many countries are determined by the policy of promotion of best available technology or state-of-the-technology or best practicable means, apart from ensuring protection of environment and human health. There are no air emission standards specific to the iron ore mines in any country. However, work zone and or ambient air quality standards were notified by most of the countries, which need to be complied by all the industries in order to protect environment and humans. The factors that determine the formulation of the ambient air quality standards are the protection of human health, vegetation, property, sensitive areas / locations and overall development. The existing air quality standards in India and other countries are given below.

6.2.3.1 Existing Air Quality Standards in India

6.2.3.1.1 National Ambient Air Quality Standards (NAAQS)

During April, 1994, Central Pollution Control Board (CPCB), has notified the National Ambient air Quality Standards (NAAQS) for Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM -PM_{10}), Sulphur Dioxide (SO_2), Oxides of Nitrogen (NO_X), Lead in RPM, Carbon Monoxide (CO) and Ammonia (NH_3) for industrial, residential and sensitive areas under the Air (Prevention & Control of Pollution) Act, 1981. Later on in April, 1996, the NAAQS were also notified under Environment (Protection) Act, 1984 by Ministry of Environment & Forests (MoEF). The ambient air quality shall be monitored twice in a week for 24 hourly at uniform intervals so that minimum 104 measurements can be taken in a year. The 24 hourly values should be met 98 % of the time in a year. However, 2 % of the time, it may exceed but not on two consecutive days. National Ambient Air Quality Standards notified under the Environment (Protection) Rules, 1986 are given in the following table.

Table No. 6.2.3.1.1.1 Indian National Ambient Air Quality Standards

Pollutant	*Time Weighted Average*	*Concentration in Ambient Air*		
		Industrial Areas	*Residential, Rural & other areas*	*Sensitive Area*
Sulphur Dioxide	Annual Average *	80	60	15
SO_2 ($\mu g/m^3$)	24 Hours **	120	80	30
Oxides of Nitrogen	Annual Average *	80	60	15
As NO_2 ($\mu g/m^3$)	24 Hours **	120	80	30
Suspended Particulate Matter – SPM ($\mu g/m^3$)	Annual Average *	360	140	70
	24 Hours **	500	200	100
Respirable Particulate Matter – RPM ($\mu g/m^3$)	Annual Average *	120	60	50
	24 Hours **	150	100	75
Lead(Pb) ($\mu g/m^3$)	Annual Average *	1.0	0.75	0.50
	24 Hours **	1.5	1.0	0.75
Carbon Monoxide (CO) (mg/m^3)	8 hours **	5.0	2.0	1.0
	1 Hours	10.0	4.0	2.0

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice in a week 24 hourly at uniform interval.

** 24 hourly / 8 hourly values should meet 98 % of time in a year. However, 2 % of the time, it may exceed but not on two consecutive days.

In addition to the above, during October, 1998, CPCB has notified Ambient Air Standard for Ammonia (NH_3) as 0.4 mg/m3 and 0.1 mg/m3 for daily average and annual average respectively, under the Air Act.

6.2.3.2 World Bank Guidelines

World Bank has developed guidelines on standards for ambient air, liquid effluents and ambient noise, which are used in making decisions regarding provision of World Bank Group assistance. The emission levels must be consistently achieved by well designed, well operated and well maintained pollution control systems. Ambient air quality standards under the World Bank Group for mining are as follows:

Table No. 6.2.3.2.1 Ambient Air Quality Standards - World Bank Guidelines

S. No	*Parameter*	*Annual Arithmetic Mean*	*Maximum 24 hrs. Average*
1	Respirable Particulate Matter (RPM)	100 μg/m^3	500 μg/m^3
2	Oxides of Nitrogen (NO_x) as NO_2	100 μg/m^3	200 μg/m^3
3	Sulphur Dioxide (SO_2)	100 μg/m^3	500 μg/m^3

The concentration of above mentioned contaminants, measured outside the project property boundary, should be achieved for at least 95 % of the time that the mine is operating.

6.2.3.3 United States of America

There are no air quality standards specific to the Iron Ore Mining in USA. However, occupational health and safety regulations are set in the US at the federal level under the Department of Labour by the two following organisations:

- ***Occupational Safety and Health Administration (OSHA)***: is responsible for general occupational environment
- ***Mine Safety and Health Administration (MSHA)***: is responsible for mining.

The OSHA and MSHA have recommended a set of limits for DPM (Diesel Particulate Matter), CO, CO_2, NO, NO_2, HCHO & SO_2, which generally found in diesel exhaust. Under the Clean Air Act, two types of National Air quality Standards i.e. primary and secondary Standards were notified. The primary Standards set limits to protect public health, including the health of sensitive populations such as asthmatics, children and the elderly people. The secondary standards set limits to protect public welfare including protection against decreased visibility, damage to animals, crops, vegetation, and building. The EPA Office of Air Quality Planning and Standards (OAQPS) has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" pollutants. They are listed below. Units of measure for the standards are parts per million (ppm) by volume, milligrams per cubic meter of air (mg/m^3), and micrograms per cubic meter of air (μg/m^3).The National Ambient air Quality Standards under the Clean Air Act are as follows:

Table No. 6.2.3.3.1 US National Ambient Air quality Standards

Pollutant	**Standard Value ***		**Standard Type**
Carbon Monoxide (CO)			
8-hour Average	9 ppm	(10 mg/m^3)	Primary
1-hour Average	35 ppm	(40 mg/m^3)	Primary

Nitrogen Dioxide (NO_2)			
Annual Arithmetic Mean	0.053 ppm	(100 µg/m^3)	Primary & Secondary
Ozone (O_3)			
1-hour Average	0.12 ppm	(235 µg/m^3)	Primary & Secondary
8-hour Average **	0.08 ppm	(157 µg/m^3)	Primary & Secondary
Lead (Pb)			
Quarterly Average	1.5 µg/m^3		Primary & Secondary
Particulate (PM 10) *Particles with diameters of 10 micrometers or less*			
Annual Arithmetic Mean	50 µg/m^3		Primary & Secondary
24-hour Average	150 µg/m^3		Primary & Secondary
Particulate (PM 2.5) *Particles with diameters of 2.5 micrometers or less*			
Annual Arithmetic Mean **	15 µg/m^3		Primary & Secondary
24-hour Average **	65 µg/m^3		Primary & Secondary
Sulphur Dioxide (SO_2)			
Annual Arithmetic Mean	0.03 ppm	(80 µg/m^3)	Primary
24-hour Average	0.14 ppm	(365 µg/m^3)	Primary
3-hour Average	0.50 ppm	(1300 µg/m^3)	Secondary

Note:
* Parenthetical value is an approximately equivalent concentration.
** The ozone 8-hour standard and the PM 2.5 standards are included for information only. A 1999 federal court ruling blocked implementation of these standards, which EPA proposed in 1997. EPA has asked the U.S. Supreme Court to reconsider that decision.

6.2.3.4 South Africa

Mining in South Africa is primarily regulated by "National Environment Management Act (NEMA) and the Water Act. In most of the cases, the requirements are the same for all mining operations, regardless of the commodity.

The Minerals Act, 1991 requires that an EMP must be submitted to the Director, Mineral Development of the Department of Minerals and Energy (DME) for approval and the approved EMP must be implemented during the life of the mine until closure is granted. No operation shall be commenced before obtaining approval. Thus the EMP can be seen as an environmental management and regulatory tool through the requirement of the Minerals Act, 1991, for the purpose of environmental management in the mining industry. The EMP represents the basis of the legally binding contract between the mining company and the Department of Minerals and Energy. The main purpose of an EMP is, to ensure that a binding commitment is gained regarding the environmental measures that are to be implemented during the construction, operational and decommissioning phases and at closure. Regulations promulgated under the

Minerals Act 50 of 1991 requires that no dust, fumes or smoke from any extraction system may be discharged in to the atmosphere unless adequate provisions has been made to ensure that such discharge is harmless and inoffensive.

6.2.3.5 Canada

There are no standards specific to the iron Ore Mines in the Canada. However, the desirable Ambient Air Quality Criteria are defined in Regulation 337 under the Environment Protection Act. Standards for selected parameters, which are relevant to Mining Industry, are as follows:

Table No. 6.2.3.5.1 Air quality Standards for Mining Industry in Canada

Parameter	***Point of Impingement Standard Half hour point of impingement standard (μg/m³)***	***Ambient Air Quality Criteria - 24 hourly average(μg/m³)***
SPM (PM_{44})	100	120
SO_2	830	275
NO_x	500	200
Silica in RPM, Crisitabolite, quartz & tridymite (each)	15	5
Lead	6	2

6.2.3.6 European Union

The European Commission, on 8th September 1997 adopted a proposal for a Directive setting new ambient air quality limit values for Sulphur Dioxide (SO_2), Oxides of Nitrogen (NOx), Particulate matter and Lead (Pb). The new limit values are based on the revised Air Quality Guidelines for Europe adopted by the World Health Organisation (WHO) in 1996 (since then the WHO's air quality guidelines have been revised and updated twice during 1998 and 1999). The major goals of this directive are to provide a high level of protection for public health through out the European Union, and to set for the first time ambient air quality limit values designed to protect the environment. The limiting values for these pollutants are given in the table below:

Table No. 6.2.3.6.1 Limit Values for Air Pollutant adopted by European Commission

Parameters	**Averaging time**	**Limit Value (μg/m³)**
Respirable Particulate Matter (PM_{10})	24 hourly	50 (not to exceed 25 time a year)
	Annual	30
Sulphur Dioxide (SO_2)	One Hour	350 (not to exceed 24 times a year)
	24 Hourly	125 (not to exceed 3 times a year)
	Annual	20
Oxides of Nitrogen (NOx)	One Hour	200 (not to exceed 3 times a year)
	Annual	40
Lead	Annual	0.5

6.2.3.7 People's Republic of China

No standards specific to the iron ore mining exists in China. Similar to the India, Ambient Air quality Standards are notified for Class # 1, 2 & 3 areas, which need to be complied. The areas and AAQ standards are as follows:

Class 1 ☞ State designated nature, conservation beauty spots, historic sites and places of convalescence.
Class 2 ☞ Residential areas, mixed commercial traffic and residential zones, cultural areas, historic sites, villages and other zones as designated in municipal plans.
Class 3 ☞ Cities, towns and industrial zones with relatively high atmospheric pollution, city traffic, intersections, major arteries and other zones.

Ambient Air Quality Standards in China

Pollutant	***Sampling time***	***Concentration (μg/m³)***		
		Class 1	***Class 2***	***Class 3***
All atmospheric particles (TSP)	Average over one year Maximum at any time	150 300	300 1000	500 1500
Dust (PM_{10}) / RPM	One day average Maximum	50 150	150 500	250 700
SO_2	Average over one year One day average Maximum	20 50 150	60 150 500	100 250 700
NO_x	One day average Maximum	50 100	100 150	150 300
CO	One day average Maximum	4,000 10,000	4,000 10,000	6,000 20,000
Ozone	One hour Average	120	160	200

6.2.4 Proposed Emission Standards for Iron Ore Mines

In mining and mineral processing operations, dust is the single largest air pollutant and can be a significant nuisance to surrounding land users, deteriorates the ambient air quality as well as a potential health risk in some circumstances. Dust is being produced from a number of sources and through number of unit operations such as land clearing, removal of top soil (during opening up of new areas), overburden removal, drilling, blasting, crushing & screening, processing of ore, loading & unloading of material on site & subsequent transport off the site etc. In addition to this, wind action affecting stockpiles, dry tailings and exposed mining areas also contribute generation of dust.

Various types of dust control measures have been adopted by the Indian Iron Ore Mines. Dust extraction systems have been installed in some of the big mechanised mines mainly to cover dust prone areas like crushing & screening areas and transfer points. Dust suppression through application of water or in some cases mixed with chemical additives is being practiced at the other sources such as haul roads, loading & unloading points, stock piles, transfer points etc. Use of cleaner technologies like Wet Drilling, NONEL initiation, air decking using gas bags, use of ripper dozer, etc. are also in practice to prevent the dust emissions.

In order to maintain the air quality in and around the mines, all the high dust prone areas need to be equipped with dust extraction and / or dust suppression facilities. The dust levels in the mines mainly depend on the type of dust control measures adopted & its effectiveness. The dust levels also depend on the nature of the ore feed, method of mining & ore processing, topography & climatic conditions of the area etc. Keeping in view of all these factors, environmental standards specific to Indian Iron Ore Mines have been proposed for both point and area sources.

6.2.4.1 Stack Emission Standard

Dust collection, extraction and emission for proper dispersion through stack have been installed (or need to be installed) in the mechanised mines to control the pollution generated from the units, such as crushing, screening and material transfer points etc. To assess the effectiveness of the dust collection and extraction system, the stack emission standard has been proposed as given in the following table:

Table No. 6.2.4.1.1 Proposed Stack Emissions Standards

S. No	Parameter	Standard
1.	Particulate Matter (PM)	100 mg/Nm^3

Height of the stack attached to the de-dusting system should be calculated for proper dispersion of particulate matter using the formula $H = 74 Q^{0.27}$ m (where H = Stack height in metre and Q = PM emission in tonnes/hr). Height of the stack should be at least 2.5 m above the nearest building height. But in any case, stack height should not be less than 15 m. Sampling portholes and platforms shall be provided as per the CPCB guidelines.

Stack height for various particulate matter emission rates (kg/hr) are given below for reference;

S. No.	PM Emission Q (kg/hr)	Stack Height H (m)
1.	2.71 kg/hr	15
2.	7.86 kg/hr	20
3.	17.96 kg/hr	25
4.	35.29 kg/hr	30

Stacks attached with power generating units / DG Sets shall follow the existing stack emission standards and guidelines for the Power Plants/ DG Sets.

6.2.4.2 Fugitive Dust Emission Standards

In order to develop the fugitive dust emission standards for Iron Ore Mines, a detailed study on fugitive dust emissions from various mining unit operation has been conducted at Kiriburu and Meghahatuburu Iron Ore Mines during November, 2005. The Kiriburu Iron Ore Mine (KIOM) and Meghahatuburu Iron Ore Mine (MIOM) are fully mechanised open-cast mines equipped with state-of-art facilities and each has a capacity of 5.0 MTPA ROM each. These mines are located in West Singhbhum Dist., in Jharkhand.

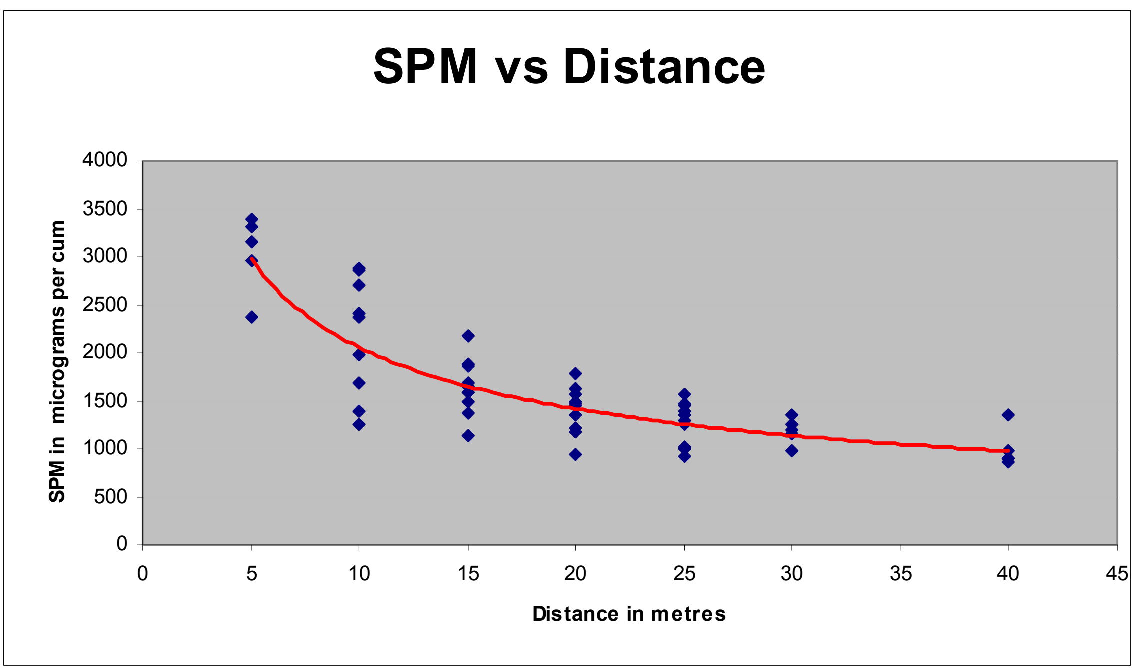
In order to assess the dust settling characteristics, the dust levels (SPM & RPM) at various distances i.e. 5m, 10m, 15m, 20m, 25 m, 30m m and 40m have been measured from various sources in downwind direction. The measured dust levels at various distances for the selected locations are given in the following table.

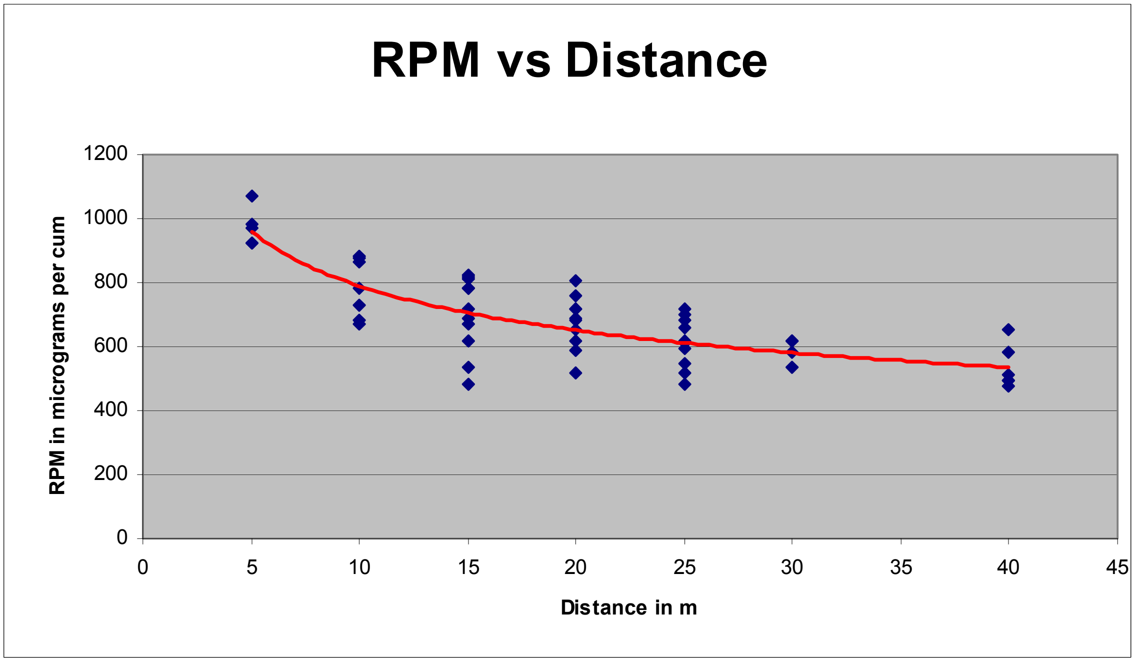
Table No. 6.2.4.2.1 Dust Levels at Various Distances from the Source

Location	Dis. form Source in m	Dust Levels in $\mu g/m^3$		RPM/SPM ratio
		RPM	SPM	
Transfer Point	5	1068	3314	0.32
Transfer Point	5	925	2967	0.31
Primary Crusher/ Hopper	5	972	3148	0.31
Primary Crusher / Hopper	5	926	3383	0.27
Double Deck Screen	5	980	2368	0.41
Transfer Point	10	874	2890	0.3
Transfer Point	10	866	2704	0.32
Primary Crusher/ Hopper	10	728	2413	0.3
Primary Crusher/ Hopper	10	670	2378	0.28
Double Deck Screen	10	784	1982	0.4
Double Deck Screen	10	684	1682	0.41
Stock Pile at Screening Plant	10	884	2860	0.31
Stock Pile at Screening Plant	15	816	2173	0.38
Stock Pile at Screening Plant	15	720	1868	0.39
Ore Stock Pile	15	782	1650	0.47
Ore Stock Pile	15	824	1874	0.44
Double Deck Screen	15	615	1487	0.41
Double Deck Screen	15	480	1138	0.42
Primary Crusher/ Hopper	15	538	1248	0.43
Primary Crusher/ Hopper	15	673	1386	0.49
Excavation at Mine Face	15	687	1378	0.5
Excavation at Mine Face	15	784	1579	0.5
Excavation at Mine Face	15	812	1684	0.48
Double Deck Screen	20	518	937	0.55
Double Deck Screen	20	586	1216	0.48
Double Deck Screen	20	615	1186	0.52
Stock Pile at Screening Plant	20	682	1486	0.46
Stock Pile at Screening Plant	20	718	1793	0.4
Ore Stock Pile	20	761	1459	0.52
Ore Stock Pile	20	805	1632	0.49
Excavation at Mine Face	20	652	1348	0.48
Excavation at Mine Face	20	718	1476	0.49
Excavation at Mine Face	20	687	1562	0.44

Location	Dis. form Source in m	Dust Levels in $\mu g/m^3$		RPM/SPM ratio
		RPM	SPM	
Double Deck Screen	25	480	916	0.52
Double Deck Screen	25	546	1024	0.53
Double Deck Screen	25	515	991	0.52
Excavation at Mine Face	25	612	1286	0.48
Excavation at Mine Face	25	658	1352	0.49
Excavation at Mine Face	25	593	1246	0.48
Ore Stock Pile	25	716	1562	0.46
Ore Stock Pile	25	685	1456	0.47
Stock Pile at Screening Plant	25	616	1384	0.45
Stock Pile at Screening Plant	25	702	1463	0.48
Stock Pile at Screening Plant	30	618	1346	0.46
Double Deck Screen	30	538	984	0.55
Excavation at Mine Face	30	584	1197	0.49
Ore Stock Pile	30	616	1259	0.49
Stock Pile at Screening Plant	40	584	1162	0.5
Stock Pile at Screening Plant	40	652	1357	0.48
Double Deck Screen	40	476	856	0.56
Excavation at Mine Face	40	496	911	0.54
Ore Stock Pile	40	492	894	0.55
Stock Pile at Screening Plant	40	512	987	0.52

The graphs showing distance vs dust levels are as follows;





It can be observed from the above graphs that the both the SPM and RPM, mostly settle within the 25 m distance from the source of generation. After 25 m, the rate of settlement of dust is comparatively less and uniform. Keeping this in view, fixing of fugitive dust level standards at a distance of 25 m away from the source of generation has been considered.

The measured dust levels at 25 m distance from the various sources with dust control measures are given in the following tables.

Table No 6.2.4.2.2 Dust Levels at 25 m Distance from the Source with Dust Control Measures

Area/ location	***RPM ($\mu g/m^3$)***	***SPM ($\mu g/m^3$)***	***Dust Control measures***
Drilling	372 - 414	683 - 879	Wet drilling.
Excavation & Loading	593 - 658	1246 - 1352	Pre-wetting of ore (Moisture content in ore: 7 - 8 %)
Haul Road	359 - 432	734 - 876	Water sprinkling on haul roads.
Hopper & Primary Crushing	314 - 508	785 – 1098	Dust suppression through water (spray nozzles)
Stock Piles	616 - 702	1384 - 1463	Moisture content in ore: 7 -8 %)
Screen	480 - 515	916 – 1024	Dry screening and dust suppression through water (spray nozzles)
Ore Stock Piles & loading	685 - 716	1456 - 1562	Moisture content in ore: 7 -8 %

It can be observed from the above tables and graphs, that the SPM levels were in the range of 683 – 1562 µg/m3 and RPM in the range of 314 – 716 µg/m3, with dust control measures. The dust levels can be further brought down to lower levels by improving the performance of the dust control measures. *Keeping in view of the existing dust levels and best management practices, it is proposed that the Fugitive dust emission levels of Suspended Particulate Matter (SPM) and Respirable Particulate Matter (RPM) from the dust generation sources identified and mentioned below in the table, should not exceed 1200 µg/m3 and 500 µg/m3 respectively at a distance of 25 m (± 5 m) from the source of generation in downwind direction considering the predominant wind direction.*

***Table No.* 6.2.4.2.3 Sources of Fugitive Dust Emissions**

Area	**Sources of Dust Generation / Monitoring Location**
Mine face / benches	Drilling, Excavation & Loading (Not required for benches operating below water tables. However applicable for operating benches above water table)
Haul Roads / Service Roads	Haul roads leading to Ore Processing Plant, Waste dumps & Loading areas and Service Roads.
Crushing Plant	Run-off-mine unloading at Hopper, Crushing Areas, Screens, Transfer Points
Screening Plant	Screens, Transfer Points
Ore Storage & Loading	Intermediate Stock Bin / Pile areas, Ore stock bin / pile areas, wagon / truck loading areas
Waste Dump Areas	Active waste / reject dumps

The measurement shall be done for a period of 8 hours in any working shift. However, depending upon the prevalent conditions at site, the period of measurement can be reduced.

6.2.4.3 Guidelines / Code of Practices for Pollution Prevention & Control at Source for Fugitive Dust emissions in Iron Ore Mines

Dust is the main air pollutant generated from the iron ore mining. The major source of dust emissions in mines are haul roads, followed by drilling, blasting, excavation & loading, ore processing and handling operations.The nature of mining operations are such that complete elimination of dust from mining process would not be possible. However, some preventive measures i.e. control at source like provision of dust collectors, wet drilling etc. and control at receptor level like dust suppression during the course of various mining operations, can minimise fugitive dust emission. In iron ore mining industry, conditioning of the ore with water (7.5 – 9.5 %) is being practiced as a primary method to minimize the dust emissions with out affecting flow of ore in the ore processing and handling areas.

Source wise dust control measures have been discussed in the Section # 5 under the best environmental management practices. The following prevention & control measures shall be practiced in order to reduce the fugitive dust emissions in iron ore mines;

1. To control fugitive dust at source, wet drilling shall be practiced. Where there is a scarcity of water, suitably designed dust extractor shall be provided for dry drilling along with the dust hood at the mouth of the drill hole collar.
2. Pre-wetting of blasting site shall be practiced or need to be done as far as possible.
3. Establish time of blasting to suit the local conditions. Avoiding blasting i.e., when temperature inversion is likely to occur and strong wind blows towards residential areas.
4. Conditioning of the ore with water (moisture content: 7.5 – 9.5 %) shall be practiced as a primary method to minimize the fugitive dust emissions without affecting flow of ore in the ore processing and handling areas.
5. All the long life permanent haul roads shall be black- topped metal roads to the extent feasible.
6. Water sprinklers of fixed type shall also be provided at the mine HEMM maintenance shop, other service centers and approach roads from mine face / benches to crusher hopper to prevent the generation of dust to be air borne.
7. Dust consolidation on mine haul roads, active OB dumps and mine working benches shall be done by spraying water through water sprinklers along with chemical binders/wetting agents at frequent interval in order to reduce water consumption, to improve retention & re-absorption capacity of water & effective dust consolidation.
8. The speed of dumpers/trucks on haul roads shall be controlled as increased speed increases dust emissions. Overloading of transport vehicles shall be avoided.
9. Planting of trees all along main mine haul road and regular grading of haul roads shall be practiced to prevent the generation of dust due to movement of dumpers/trucks.
10. During transportation of ore by trucks/tippers through public roads, the truck shall be properly covered with tarpaulin sheets/leak proof and shall ply in safe speed. The trucks/tippers shall have sufficient free board. Spillage of ore on public roads shall be cleared immediately on occurrence.
11. Use of wheel wash facilities to minimize mud and dust track-out from unpaved approach roads to main paved and/or public roads.
12. Dust suppression and/or dust extraction systems shall be provided at crusher-hopper, crushing, screening, ore bunkers, transfer points, loading points & other strategic dust generating areas. Proper enclosures of crushing & screening areas, conveyors, transfer points etc. shall be provided in order to reduce spread of air borne dust to possible extent.
13. The ore, right from primary crusher to screening plant for further processing shall be done through a system of closed conveyor belts in order to control the dust generation during transportation of ore at strategic transfer points.
14. At the iron ore stockpiles areas, atomized stationery mist spray of water or conditioning of ore with water shall be practiced to prevent the dust to be air borne.

15. Green belt of adequate width shall be developed all around the perimeter of crushing and screening plant, ore stockpile & loading areas, boundaries of mine pits etc., when these are located close proximity to the villages and residential areas.
16. Appropriate transfer chutes shall be provided at ore discharge points at ore stock piles, loading points etc., to minimize the discharge height and spread of air borne dust.
17. The operator's cabin in the drills, shovels, dumpers and other HEMMs shall be provided with dust proof enclosure and the persons working at high dust prone areas shall be provided with dust mask. In case of bigger capacity HEMMs, operators cabin shall be air- conditioned based with dust & noise proof enclosures as far as possible.
18. Re-vegetation of exposed surfaces shall be done as far as possible in mines. Techniques such as hydro-seedling & use of geo-textiles shall be used on steep slopes and other difficult areas as a measure of soil erosion control and slope stabilization.
19. Proper house keeping at the mining, ore crushing & screening areas, loading & dispatch areas, service facilities, etc., shall be practiced.

6.3 EFFLUENT DISCHARGE STANDARDS

6.3.1 Necessity of Effluent Discharge Standards

Water is a basic requirement for drinking and domestic use, in drilling, in conditioning construction materials, as a means of dust suppression, washing of ore to improve the quality and as an aid in establishing vegetation on post mining land reclamation and rehabilitation. Water plays an important role in mobilising environmental contaminates and is the primary medium for the transport of contaminants off the mine site into the water environment. It is therefore necessary to maintain the quality of effluent discharged from the mines to protect the receiving water bodies including ground water. The quality and quantity of mine effluent discharged mainly depend on the following major functions:

- Method of mining
- Climatic variables
- Hydrological and hydro-geological factors
- Topography
- Geo-chemical characteristics of the rock material

6.3.2 Sources of Effluents and Parameters of Concern

The major source of effluent generation from the iron ore mines is from the ore washing operation. Other sources are from workshops / garages, seepage from the tailings ponds & exposed waste dumps etc. In some of the areas like in western region, the mining is being carried out below the water table, huge quantity of water is being pumped out from the mine pit to facilitate excavation of ore. The various sources of the effluent generation from the iron ore mines are discussed below:

Process Effluent from Ore Washing

This mainly gets generated where the mine is equipped with the wet beneficiation process for washing of iron ore to improve the quality by removing excess of silica and alumina. The effluents get generated in the form of thickened slurry known as tailings and are led to a dam or pond known as tailings pond via open channel or closed conduit.

Effluents from the Workshops / Garage

Water is being used for washing / cleaning of HEMM, light vehicles and others auxiliary equipment in the Workshops / Garages. The wash water generated from the workshop / garage contains suspended solids and oil & grease. These effluents are being treated in ETPs for removal of oil & grease and suspended solids.

Mine Pit Water

Wherever mining is carried out below the water table, dewatering of pit water is done to facilitate the excavation of the ore. The mine pit water is normally laden with suspended solids derived from within the pit. In western region, a large percentage of ore is located below the water table and numbers of mines are now operating below the water table. In most of the mines, the mine pit water is being discharged to the exhausted pits and used for ore washing purpose.

Seepage Water

Seepage comprises water discharged to the environment by seepage from waste management areas (eg. tailing ponds, waste rock dumps) or waste water impoundment areas (eg. tailing ponds, clarification ponds, mine water ponds). Seepage may be intercepted by premier collection ditches or drain directly to the environment.

Storm Water

Storm water from a mining operation comprises surface runoff from rainfall and natural drainage. Typically drainage is diffuse with large no. of discharge points to the environment. This is the main source of pollution from the iron ore mining area which contains lots of suspended solids.

The parameters of concern from Indian iron ore mining are mainly pH, Oil & Grease, Suspended Solids, Dissolved Iron and Manganese. During monsoon, the quantity of surface runoff increases and is directly proportional to the amount of suspended solids in the discharge. The most significant parameter during the period is the total suspended solids (TSS) present in the discharge. In addition to these, the surface run off and the mine effluents may also contain traces of heavy metals like Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc etc. These may either get way to the surface water and ground water aquifer system through leaching of tailings impoundments, waste dumps etc or get dissolved with the mine effluent and surface runoff due to mining (by exposing the rocks) and beneficiation.

6.3.3 Quality of Effluent Discharged from Iron Ore Mines

Water quality monitoring was conducted at the iron ore mines in the Eastern Zone i.e. Kiriburu Iron Ore Mines and Meghahatuburu Iron Ore Mines for four seasons through out the year. All the effluents generated from various sources have been analysed for relevant parameters mentioned in the discharge quality standards under the Schedule – VI of Environment

(Protection) Rules, 1986. Surface and ground water quality were also monitored in and around the both the mines. In addition to this, water quality data of the major iron ore mining operating all over India in the four identified zones were collected. The existing water quality for all the four zones are discussed in Section Four of the Report, while discussing the impact on air quality of the respective mining zones.

It was observed from the analysis of the data generated and collected from various sources, Suspended Solids, Oil & Grease, pH, Iron and Manganese are most relevant parameters in the effluents generated from the iron ore mines. The other parameters including heavy metals were found well below the standards and mostly below detectable limits. The quality of effluents discharged from the various sources in the iron ore mines of the four different zones are given in the table below:

Table. No. 6.3.3.1 Quality of Effluent Discharged from Iron Ore Mines in India

(Unit : mg/l except for pH)

Zone	*Eastern*		*Western*		*Southern*		*Central*	
Parameter	*Max.*	*Avg.*	*Max.*	*Avg.*	*Max.*	*Avg.*	*Max.*	*Avg.*
Suspended Solids	226	39	266	47	186	75	200	37
pH	9	6.8	9.6	6.9	8.6	7.5	8.1	7.2
Oil & Grease	16.8	3.1	9.8	4.6	18.5	6.2	18	3.25
Iron as Fe	3.34	0.33	8.85	0.48	2.8	0.8	2.8	0.51

6.3.4 Existing Effluent Discharge Standards

6.3.4.1 India

6.3.4.1.1 General Effluent Discharge Standards under Environment (Protection) Act

MoEF notified General Standards for Discharge of environmental Pollutants into various receiving water bodies in Schedule - VI, Environment (Protection) Rules, 1986 in May, 1993. These standards were effective from 1st January, 1994 and applicable to discharge of effluents from industries, operations or processes other than those industries, operations for which standards have been already specified in Schedule - 1. The Schedule - 1, contains industry specific standards, where mining industry was not included. There are standards for about 33 pollutants in the Schedule - VI for discharging into various receiving water bodies. However, the industries need to monitor and comply only for relevant parameters among the 33 specific to that industry. The standards given in the Schedule - VI of the Environment (Protection) Act, 1986 are as follows:

Table No. 6.3.4.1.1 General Effluent Discharge Standards

Sl. No.	Parameters	Standards for Discharge to			
		Inland Surface Water	*Public sewer*	*Land for Irrigation*	*Marine/ Coastal*
1.	Colour and Odor	See Note below	-	See Note below	See Note below

Sl. No.	Parameters	Standards for Discharge to			
		Inland Surface Water	***Public sewer***	***Land for Irrigation***	***Marine/ Coastal***
2	Suspended Solids mg/l, max	100	600	200	
3	Particle size of suspended solids	Shall pass 850 micron IS Sieve			
4	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5	Temperature	Shall not exceed 5^0C above the receiving water temperature			Shall not exceed 5^0C above the receiving water temperature
6	Oil & grease mg/l, max	10	20	10	20
7	Total Residual chlorine, mg/l max	1.0	-	-	1.0
8	Ammonical Nitrogen (as N) mg/l, max	50	50	-	50
9	Total kjeldahl nitrogen (as N); mg/l, max	100	-	-	100
10	Free ammonia (as NH_3), mg/l max	5.0	-	-	5.0
11	BOD (3 days at 27^0C), mg/l, max	30	350	100	100
12	Chemical Oxygen Demand, mg/l max	250	-	-	250
13	Arsenic (as As) mg/l, max	0.2	0.2	0.2	0.2
14	Mercury (as Hg), mg/l, max	0.01	0.01	-	0.01
15	Lead (as Pb) mg/l, max	0.1	1.0	-	2.0
16	Cadmium (as Cd) mg/l, max	2.0	1.0	-	2.0
17	Hexavalent Chromium (Cr^{+6}) mg/l, max	0.1	2.0	-	1.0
18	Total Chromium (as Cr) mg/l, max	2.0	2.0	-	2.0
19	Copper (as Cu), mg/l, max	3.0	3.0	-	3.0
20	Zinc(as Zn) mg/l, max	5.0	15	-	15

Sl. No.	Parameters	Standards for Discharge to			
		Inland Surface Water	*Public sewer*	*Land for Irrigation*	*Marine/ Coastal*
21	Selenium (as Se) mg/l, max	0.05	0.05	-	0.05
22	Nickel (as Ni) mg/l, max	3.0	3.0	-	5.0
23	Cyanide (as CN) mg/l, max	0.2	2.0	0.2	0.2
24	Fluoride (as F) mg/l, max	2.0	15	-	15
25	Dissolved Phosphate (as P) mg/l, max	5.0	-	-	-
26	Sulphide (as S) mg/l, max	2.0	-	-	5.0
27	Phenolic Compounds (as C_6H_5OH) mg/l, max	1.0	5.0	-	5.0
28	Radioactive Materials, μ curie mg/l max a) α - emitters b) β - emitters	 10^{-7} 10^{-6}	 10^{-7} 10^{-6}	 10^{-8} 10^{-7}	 10^{-7} 10^{-6}
29	Bio-assay test	90% survival of fish after 96 hour in 100% effluent	90% survival of fish after 96 hour in 100% effluent	90% survival of fish after 96 hour in 100% effluent	90% survival of fish after 96 hour in 100% effluent
30	Manganese, mg/l	2	2	-	2
31	Iron (as Fe), mg/l	3	3	-	3
32	Vanadium (as V),mg/l	0.2	0.2	-	0.2
33	Nitrate Nitrogen, mg/l	10	-	-	20

Note: All efforts should be made to remove colour and unpleasant odour as far as practicable.

6.3.4.2 International Standards for Effluent Discharge

6.3.4.2.1 World Bank Guidelines for Base Metal & Iron Ore Mining

World Bank issued the following guidelines for effluents normally acceptable to them in making decisions regarding provision of World Bank Group Assistance. Any deviations from these levels must be described in the World Bank Group project documentation. These effluents levels as given in the table below to be achieved during operation of the mine and after the mine closure.

Table No. 6.3.4.2.1 Effluent Limit for Base Metal and Iron Ore Mining

Parameters	Max. value (mg/l except for pH)
pH	6 - 9
TSS	50
Oil & Grease	10
Cyanide	1.0
• Free	0.1
• Weak Acid dissociable	0.5
COD	150
Arsenic	0.1
Cadmium	0.1
Chromium (Hexavalent)	0.1
Copper	0.5
Iron	3.5
Lead	0.2
Mercury	0.01
Nickel	0.5
Zinc	2
Total metals	10

All of the maximum values should be achieved for at least 95 % of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Liquid effluents, including tailing dam outflows, should be monitored daily for pH and suspended solids. Metals, when appropriate, thiosalts and flotation chemicals should be monitored on monthly basis. If treatment is required to control soluble metals, metals and other parameters such as turbidity should be monitored more frequently. Frequent sampling may be required during the start-up and upset conditions.

World Bank has also issued following general guidelines for effluents discharged from tailings impoundments, mine drainage, sedimentation basins, sewerage systems and storm water drainage. They do not apply to direct discharge of tailings to the marine environment.

pH	-	6 to 9
BOD	-	50 mg/l
Oil & grease	-	20 mg/l
TSS	-	50 mg/l

Temperature, at the edge of designated mixing zone - Maximum 5^0C above ambient temperature of receiving water and maximum 3 ^0C if receiving water temperature > 28^0C.

Residual Heavy Metals:

Arsenic	-	1.0 mg/l
Cadmium	-	0.1 mg/l
Cr^{+6}	-	0.05 mg/l
Cr, total	-	1.0 mg/l
Copper	-	0.3 mg/l
Iron, total	-	2 mg/l
Lead	-	0.6 mg/l
Mercury	-	0.002 mg/l
Nickel	-	0.5 mg/l
Zinc	-	1.0 mg/l

- These are recommended target guidelines below which there is expected to be no risk for significant adverse impact on aquatic biotic or human use.
- In cases, where natural background concentrations exceed these levels, the discharge may contain concentrations upto natural background levels.
- Concentration upto 110 % of natural background can be accepted if no significant adverse impact can be demonstrated.

6.3.4.2.2 USA

The USEPA has notified effluent guidelines and standards for Iron Ore Mines under Subpart A, Part 440. The norms are applicable to discharges from (a) mines operated to obtain iron ore, regardless of the type of ore or its mode of occurrence, (b) mills beneficiating iron ores by physical (magnetic and non-magnetic) and / or chemicals separation; and (c) mills beneficiating iron ores by magnetic and physical separation. Under the USEPA effluent discharge standards for iron ore mines are given in three categories i.e. BPT, BAT and NSPS. The details are as follows.

The following effluent limitations representing the degree of effluent reduction attainable by the application of the Best Practicable Control Technology currently available (BPT). The standards are applicable for existing point source. The concentration of pollutants discharged shall not exceed:

Parameter	**Effluent Limitations**	
	Maximum for any 1 day	Average of daily values for 30 consecutive days
pH	6.0 to 9.0	6.0 to 9.0
TSS	30 mg/l	20 mg/l
Fe (dissolved)	2.0 mg/l	1.0 mg/l

The following effluent limitations representing the degree of effluent reduction attainable by the application of the Best Available Technology Economically Achievable (BAT). The standards are applicable for existing point source. The concentration of pollutants discharged shall not exceed:

Parameter	**Effluent Limitations**	
	Maximum for any 1 day	Average of daily values for 30 consecutive days
Fe (dissolved)	2.0 mg/l	1.0 mg/l

New Source Performance Standards (NSPS): Any new source must achieve the following NSPS representing the degree of effluent reduction attainable by applying the best available demonstrated technology (BADT):

Parameter	**Effluent Limitations**	
	Maximum for any 1 day	Average of daily values for 30 consecutive days
pH	6.0 to 9.0	6.0 to 9.0
TSS	30 mg/l	20 mg/l
Fe (dissolved)	2.0 mg/l	1.0 mg/l

6.3.4.2.3 CANADA

In Canada, Metal Mining Effluent Regulations (MMER) are notified under "Fisheries Act" to limit the deposit of deleterious substances into waters frequented by fish. The limits for deleterious substances in mine effluent under the MMER, as published in the *Canada Gazette, Part-I, Ottawa, July 28, 2001, Saturday,* are as follows:

Table No. 6.3.4.2.3.1 Authorised Limits of Deleterious Substances

Sl. No.	**Parameter**	**Max^{m} Authorised monthly mean concentration**	**Max^{m} authorised concentration in a composite sample**	**Max^{m} authorised concentration in a grab sample**
1.	Arsenic	0.50	0.75	1.00
2.	Copper	0.30	0.45	0.60
3.	Cyanide	1.00	1.50	2.00
4.	Lead	0.20	0.30	0.40
5.	Nickel	0.50	0.75	1.00
6.	Zinc	0.50	0.75	1.00
7.	TSS	15.00	22.50	30.00
8.	Radium 226	0.37 Bq/l	0.74 Bq/l	1.11 Bq/l
9.	pH	6 – 9.5	6 – 9.5	6 – 9.5

[Note: All concentrations are total values in mg/l except for pH and Radium 226]

The above limits are applicable for all new and existing metal mines in Canada including gold mines that use cyanide in the milling process. The effluent quality shall be monitored at least once in a week. These limits were developed based on a comprehensive review and assessment of national and international mining effluent standards, pollution prevention practices and control technologies of relevance to the mining sector.

6.3.4.2.4 South Africa

There are no specific effluent discharge limits for iron ore mining in South Africa. However, effluent discharges are governed under Regulation 991 of Water Act 54 of 1965. The respective general standards are as follows:

pH - between 5.5 to 9.5

DO - at least 75 % saturation

Typical faecal coli - no typical faecal coli per 100 ml

Temperature - Max^{m} 35^{0}C

Oxygen absorbed - from acid n/80 potassium permanganate in 4 hrs at 27^{0}C not to exceed 10 mg/l

Conductivity - Not to increase by more than 75 milli siemens per metre determines at 25^{0}C above that of intake water

TSS - 25 mg/l

Sodium content - Not to be more than 90 mg/l above that of the intake water.

Oil & Grease - 2.5 mg/l

Residual Chlorine - 0.1 mg/l

Free & saline ammonia (as N) - 10.0

Arsenic as As - 0.5 mg/l

Boron - 1.0 mg/l

Cr^{+6} - 0.05 mg/l

Cr, total - 0.50 mg/l

Copper, Cu - 1.0 mg/l

Phenolic compounds- 0.10 mg/l

Lead as Pb - 0.10 mg/l

Cyanide, CN - 0.50 mg/l

Sulphide, S - 1.0 mg/l

Fluoride, F - 1.0 mg/l

Zinc, Zn - 5.0 mg/l

Manganese, Mn - 0.40 mg/l

Cadmium, Cd - 0.05 mg/l

Mercury, Hg - 0.02 mg/l

Selenium, Se - 0.05 mg/l

In addition to the above, sum of the concentrations of Cd, Cr, Cu, Hg & Pb not to exceed 1 (one) mg/l in the effluents. Provisions are existing to exempt for some / all the parameters and their discharge limit for any particular project. The waste water or effluent may contain no other constituents in concentrations which are poisonous or injurious to humans, animals, fish or other forms of aquatic life, or which are deleterious to agricultural use.

Under the National Water Act, the following guidelines were given for mining and related activities aimed at the protection of water resources:

- Prevent water containing waste or any substance which causes or is likely to cause pollution of a water resource from entering any water course, either by natural flow or by seepage, and to retain or collect such substance or water containing waste for use, reuse, evaporation or for purification and disposal.
- Minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns, through cracked or fissured formations, subsided ground, sinkholes, outcrop excavations, audits, entrances or any other openings.
- Ensure that water used in any process units is recycled as far as practicable.

6.3.4.2.5 AUSTRALIA

In Australia, the environmental aspects of mining operations are controlled by mineral Resources Act. As per this Act, the mining industry have the right to discharge effluents into rivers and streams in the area provided, that any discharge shall not be dangerous or injurious to public health or shall not render the natural water in the river or stream less fit for human consumption by stock or for marine life, shall not cause harmful pollution of waters and shall not contain harmful solids. General effluent discharge standards in Australia under various regulations are as follows:

Table No. 6.3.4.2.5.1 General Effluent Discharge Limits in Australia

Parameter	***EPA Victoria***	***NSW Clean Waters Act***	***Tasmania Env. Protection regulation***
pH	6 – 9	6.5 – 8.5	--
Non metals			
NFR, mg/l	60	--	30 to 60 (>50X)
Cl	--	250	250
CN	--	Total 0.05	0.05
F	--	1.5	1.5
SO_4	--	250	250
Metals			
As	0.50	0.05	0.05
Ba	--	1.00	1.00
Cd	0.10	0.01	0.01
Cr	0.30	0.05	0.05
Cu	0.20	1.00	1.00
Fe	2.00	Filtrate .03	1.00
Pb	0.10	0.05	0.05

Parameter	*EPA Victoria*	*NSW Clean Waters Act*	*Tasmania Env. Protection regulation*
Mn	0.50	Filtrate 0.03	1.0
Hg	0.005	0.002	0.002
Ni	0.50	--	--
Se	0.05	0.01	0.02
Ag	0.10	0.05	0.10
Zn	0.50	5.00	5.00

6.3.5 Proposed Effluent Discharge Standards for Iron Ore Mines

In order to maintain the quality of water in the receiving environment, concentration base standards and restrictions in discharge of effluents are being proposed for the iron ore mines in the country.

6.3.5.1 Proposed Effluent Discharge Standards

After a detailed analysis of quality of effluents discharged from the Iron ore mines and existing standards in India and other countries, the following effluent discharge quality standards are proposed for iron ore mines. It is proposed that the quality of effluents discharged from iron ore Mining, beneficiation and associated activities or any other discharges leaving the mining lease boundary, to natural river / stream / water bodies / sewer / land to conform to the following standards given in the table below.

Table No. 6.3.5.1.1 Proposed Effluent Discharge Standards

S. No	**Parameter**	**Standards**
1.	pH	6.0 – 9.0
2.	Suspended Solids	50 mg/l * 200 mg/l - during monsoon
3.	Oil & Grease	10 mg/l
4.	Dissolved Iron as Fe	2 mg/l
5.	Manganese as Mn	2 mg/l

* Existing iron ore mines are allowed up to 100 mg/l for one year from the date of notification to upgrade existing treatment facilities / installation of new facilities.

6.3.5.2 Guidelines/ Code of Practices for Water Pollution Prevention & Control from Iron Ore Mines

In order to prevent water pollution in and around the iron ore mines, the following shall be practiced:

1. All efforts shall be made to re-use and re-cycle the treated effluents to the maximum possible extent in order to achieve zero effluent discharge.
2. At the beneficiation plant, process waste water to be recycled from the thickener overflow to the maximum possible extent in order to reduce surface water pollution due to less discharge to the surrounding environment and less process water requirement. Thickeners underflow slurry may be sent to tailings pond for further solid-liquid separation.
3. Provision of a suitably designed tailings dam with reclamation of clarified water shall be provided to minimize the discharge and reduce the make-up water consumption.
4. In water scarce areas, recovery of tailings dam seepage water shall be provided by constructing seepage water collection ditch at the downstream side along with the re-circulation facilities.
5. Maximum recovery of iron ore fines/micro fines need to be encouraged by adoption of hydro-cyclones, slow speed classifiers/or any other suitable method depending on nature of the deposit / ore feed in the wet beneficiation circuit in order to reduce slurry discharge and to increase the life of the tailings dam.
6. Surface run off during monsoon from the mining areas, waste dumps & other areas shall be properly collected & treated in series of sedimentation basins before discharge water into natural stream/water courses. Check dams shall be constructed at all strategic points to control the surface run off and carry over of suspended solids. Sedimentation ponds and check dams shall be de-silted at regular interval during non monsoon periods.
7. Surface run off from the stock pile and loading areas shall be collected through network of drains and passed through sedimentation ponds and check dams before discharge water into natural stream/water courses.
8. Pit water discharged from mine working below the water table shall be properly treated & shall be used in ore beneficiation, dust suppression, etc. The treated pit water may be supplied to villages nearby for agricultural purpose if demand arises.
9. Domestic effluents shall be treated in suitable & well-designed oxidation ponds or any other suitable treatment methods.
10. Service centers, i.e., auto shops, HEMM shops, and other areas, wherein, water pollution due to wash outs of oil and grease and suspended solids are expected due to washing of light vehicles, HEMM etc., Effluent Treatment Plant shall be provided (oil catch pits / air flotation units and sedimentation tanks) for treatment of these effluents.

11. Rain water harvesting technique shall be practiced as a measure of conservation of water.

Ground Water

12. Mines which are operating below the water table shall monitor the ground water level [expressed in Reduced Level(RL), m] at the periphery of the mine pit in at least three locations (preferably 120^0 apart each other) in order to assess the trend of depletion.
13. In case the depletion in ground water table has been observed as considerable by Central Ground Water Board, appropriate action shall be taken to control the depletion.

6.4 NOISE & AIRBLAST STANDARDS

Mine sites include a wide variety of equipment which generates a range of noise levels. Continuous exposure to high levels of noise, will come both physiological and phsycho-somatic problems in the workers exposed to it. The major sources of noise in mining and related operations include drilling, blasting, loading, excavation, crushing, screening, beneficiation, movement of heavy earth moving vehicles and wagon loading etc. Planing of noise control in open cast mines is not an easy task, as the noise sources move around the site to different activities. The noise levels in mine working environment in many places in India exceed 90 dB(A).

Most of the HEMM's generate high noise levels and the noise can travel long distance and become annoying to surroundings. Noise level impact is particularly significant at night and is affected by topographic and climatic conditions etc. The environmental noise can be controlled by constructing noise barriers like green belts, quarry boundaries, waste dumps between source and affected areas. Keeping in view of the undesirable noise affects on the mine workers and surrounding environment, standards have been notified under various Acts / Regulations.

6.4.1 Existing Noise & Airblast Standards

6.4.1.1 India

MoEF had notified Noise Pollution (Regulation and Control) Rules, 2000 on 14th. February, 2000 under Environment Protection) Rules, 1986. The following Ambient Air Quality standards in respect of noise were notified under these rules:

Table No. 6.4.1.1.1 Ambient Air Quality Standards in Respect of Noise

Area Code	Category of Area	Limit in dB(A), Leq	
		Day Time	Night Time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

Note:

a) Day time is reckoned in between 6.00 AM to 9.00 PM
b) Night time is reckoned in between 9.00 PM to 6.00 AM
c) Silence Zone is defined as areas up to 100 meters around such premises as hospitals, educational institutions and courts. The Silence Zones are to be declared by the Competent Authority.
d) Mixed Categories of areas should be declared as "one of the four above mentioned categories" by the Competent Authority and the corresponding standard shall apply.

At present, there is no standard for airblast resulting from blasting operations in India.

6.4.1.2 IBM's Standard for Iron Ore Mines

Occupational exposure limits of noise and limits for blast induced ground vibration have already been prescribed by DGMS.

6.4.2 International Standards

6.4.2.1 World Bank Industry Sector Guidelines for Base Metal Mining:

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 days dB(A). Measurements are to be taken at Noise Receptors located outside the project property boundary. The ambient noise standards specified by World Bank Group for Base Metal & Iron Ore Mines are as follows:

Table No. 6.4.2.1.1 Ambient Noise Standards Specified by World Bank for base Metals

Receptor	***Maximum allowable Leq dB(A)***	
	Day (07.00 - 22.0)	***Night (22.00 -07.00)***
Residential, Institutional & Educational	55	45
Industrial & Commercial	70	70

In addition to the above mentioned ambient noise level standards, the following guidelines are issued by the World Bank Group to minimize the work zone noise levels:

1. Feasible administrative and engineering controls, including sound-insulated equipment and control rooms should be employed to reduce the average noise level in normal work areas.
2. Plant equipment should be well maintained to minimize noise level
3. Personal must use hearing protection when exposed to noise levels above 85 dB(A).

6.4.2.2 Australia

Noise standards for various industries are notified under the "Environmental Protection (Noise) Regulations 1997 on 31 October 1997, to come into effect from 31st January, 1998. Noise emissions which exceed the prescribed standard can be regarded as “pollution” and “unreasonable noise” under this Act. Under these regulations, noise standards are specified for certain activities like Agriculture, Blasting, Construction, Community activities etc. The standards / regulations related to the Blasting are as follows;

- ***“blasting”*** is defined as the use of explosives to fracture –
  - rock, coal and other minerals for later recovery; or
  - structural components or other items to facilitate removal from a site or for reuse
- ***“air blast level”*** means a noise level resulting from blasting;
  - The assigned noise levels set in regulations 7 and 8 do not apply to air blast levels from blasting;
  - The regulation on blasting sets specific air blast levels for blasting, which form a “prescribed standard”;
  - These air blast levels apply to blasting carried out on any premises or public place; and
  - The regulation does not address ground vibration from blasting

Day time Blasting : For blasting carried out between 7am and 6pm on any day which is not a Sunday or public holiday, the air blast level received on any other premises must not exceed –

- 125 dB $L_{linear,\ peak}$ for any blast; and
- 120 dB $L_{linear,\ peak}$ for nine in any10 consecutive blasts, regardless of the interval between blasts.

Blasting on Sundays & Public Holydays: For blasting carried out between 7am and 6pm on a Sunday or public holiday, the air blast level received on any other premises must not exceed

- 125 dB $L_{linear,\ peak}$ for any blast; and
- 120 dB $L_{linear,\ peak}$ for nine in any10 consecutive blasts, regardless of the interval between blasts.

Blasting in Other Times: Air blast levels resulting from blasting on any premises or public place must not exceed 90 dB $L_{linear,\ peak}$ at any other premises outside the periods between 7am and 6pm on any day. The only exception to this is that explosives which have previously been placed and primed may be fired if necessary to meet a safety requirement of the Department of Minerals and Energy, in which case the levels must meet those given above for daytime and weekend blasting, for the time when the blast was scheduled to be fired.

6.4.3 Proposed Noise & Airbalst Standards

6.4.3.1 Proposed Noise Level Standards

Keeping in view of the adverse impacts of noise generated from the mining and associated activities, standards for noise levels and guidelines for controlling work zone noise are proposed. The noise levels in the mining and other associated activities shall not exceed the following limits:

Table No. 6.4.3.1.1 Proposed Noise Level Standards for Iron Ore Mines

S. No	Parameter	Noise Limits	
		Day time (6.00 AM to 10.00 PM)	**Night time (10.00 PM to 6.00AM)**
1.	Noise Level – Leq	75 dB(A)	70 dB(A)

Noise levels shall be monitored both during day and night times on the same day while in operation. The noise measurements shall be taken outside the broken area, boundary of ore processing & material handling areas, which include mine site & general offices, statutory buildings, workshops, stores etc.
In addition to this, occupational exposure limit of noise specified by the Director General of Mines Safety (DGMS) shall be complied with by the iron ore mines.

6.4.3.2 Proposed Airblast Standard

Airblast level resulting from blasting on any premises or public place must not exceed 120 dB Linear, peak.

Ground vibrations from the blasting operation shall be within the permissible Peak Particle Velocity (ppv) specified by DGMS at the foundation levels of various types of structures in mining areas depending on dominant excitation frequencies.

6.4.3.3 Guidelines / Code of Practices for Pollution Prevention & Control of Noise, Vibration & Airblast in Iron Ore Mines

Iron ore mining and mineral processing activities generate obnoxious levels of noise and vibration. Generally noise and vibration is created by impact/operation of fixed plants, movement of HEMM and due to blasting. Drills, movement of HEMM, material handling facilities, crushing, screening and beneficiation plant equipments are prominent noise and vibration sources, besides blasting operation. The noise causes detrimental effects on health of the workers exposed at the worksite, if proper precautions are not taken.

The following measures shall be practiced for reduction in noise from mining & associated activities, and ground vibration & airblast resulting from blasting operations;

1. Noise is best abated at source by selecting right machinery and equipment, by proper mounting of equipment, and by providing noise insulating enclosures or padding as far as possible.
2. Noise barriers shall be constructed between sources and affected areas (thick belt of trees around mine boundaries, waste dumps, hills and mountainous land forms can act as such barrier).
3. Lining noise-impacting components of processing plants (eg bins, hoppers, chutes) with resilient material to dampen vibrating surfaces.

4. Enclosing high noise sources (eg transfer points, vibratory screens, crushers) with high-mass acoustic enclosures.
5. Regular repair and maintenance of HEMMs, ore crushing, screening and loading plant equipment etc. as per the recommendation of the manufacturers.
6. Improved design mufflers of HEMMs and enclosing its engine part with thick quality isolating material shall be provided.
7. Avoid secondary blasting by using hydraulic rock breakers, wherever feasible.
8. Safety fuse shall be covered with sand layer of 15 cm thick in order to reduce noise level during blasting operation.
9. Ground vibration, airblast and dust cloud resulting from the blasting operations, shall be minimized through (a) site-specific optimum blast design, (b) selecting right explosive matching with the nature of rocks to be blasted (c) reducing the maximum instantaneous charge per delay, (d) avoiding overcharging the holes, (e) adopting air-decking technique (wherever feasible), (f) use of delay detonators, (g) adopting in-hole initiation system, (h) proper stemming of holes and (i) adopting controlled blasting technique etc.

6.5 GUIDELINES / CODE OF PRACTICES FOR SOLID WASTE MANAGEMENT AND WASTE DUMP REHABILITATION

6.5.1 Necessity of Waste Management

Mining operations, especially opencast mining, generate considerable quantities of spoils depending upon the nature of occurrence of deposit, method of mining, processing methods etc. The solid waste management is an essential component of any mining operation as it is one of the critical factors causing degradation of land and effects siltation and rolling mass downhill. Sometimes dumps are the major sources of dust which gets airborne and affects surrounding land and nearby habitats where this dust finally settles. The major types solid wastes generated from the iron ore mines are as follows, Top soil, Overburden, Subgrade rock and tailings. Disposal of these wastes is done in predetermined locations usually within the leasehold and they need proper design, stabilisation and revegetation to contain the degradation of land.

In addition to these, other types of main wastes generated from the service centres and repair & maintenance activities, are metallic wastes, non-metallic wastes, used batteries, used oils and oil contaminated wastes. The metallic wastes are of iron and steel scrap, are generally stored and sold. The non-metallic wastes like, tyres, tubes, rubber conveyers etc., are also stored and sold. The used oils generated from generated from various sections are also stored grade wise and sold. The other oil contaminated wastes like used filters, muck, jute wastes etc., are categorised as hazardous wastes as per the Hazardous Waste (Management & Handling) Rules, 2003. Some of the big mines have constructed secured hazardous waste pits for disposal of these oil contaminated wastes.

6.5.2 Existing Rules / Guidelines for Waste Management

The Government of India has taken a number of steps and equipped the concerned regulatory agencies and authorities for enforcement of the enactment and regulations related to the environment including waste management. In addition to norms and guide lines for protection of the environment under Air, Water & Environment (Protection) Acts, rules and regulations specific to the mines are notified under the Mineral Conservation & Development Rules (MCDR), 1988 under the Mines and Minerals (Regulation and Development) (MMRD) Act, 1986.

Under the MCDR, 1988, it has now been made obligatory for every holder of Prospecting Licence (PL) or Mining Lease (ML) to take all possible precautions for the protection of environment and control of pollution while conducting prospecting, mining, beneficiation or metallurgical operations in the area. The Rules # 32 & 33 of the MCDR, related to the management of top soil and overburden respectively.

The Rule # 32 stipulates for the storage and utilisation of top soil. The top soil is excavated during the prospecting or mining operations is generally thrown along with other waste rock, hence does not become available for restoration/rehabilitation of the area. It has, therefore, been provided in this rule that every holder of PL and ML shall remove the top soil separately, utilise for restoration or rehabilitation of land or store it in a separate heap for future use since it is necessary for land reclamation and rehabilitation. It is not only the storage but the top soil should also be vegetated to maintain humus and fertility of the soil. The vegetal cover on the top soil will also help in checking it's erosion or escape during monsoon.

The Rule # 33 has been dealt with effective storage of overburden and waste rock etc. Since, insufficient care taken for the dumping and storage of different types of solid wastes generated during mining operations were resulting in environmental hazards, land and stream pollution and adverse impacts on mineral conservation, so it has now been made obligatory that the overburden, waste rock, rejects and fines generated during prospecting and mining operations as well as tailings, slimes and fines produced during sizing, storing and beneficiation operations should be stored in separate dumps. Further, it has also been provided that these dumps shall be properly secured to prevent escape of material there from in harmful quantities which may cause degradation of environment and to prevent cause of floods. Providing of vegetal cover or afforestation may be most effective way to prevent the escape of material.

Regarding the site selection for dumps, tailings and slimes the provision under the sub clause (3) states that a site should be as far as possible on an impervious ground to ensure minimum effects of leaching due to precipitation. Sub clause (4) of this rule states that overburden/waste rock etc. should be back-filled into main excavations to the maximum extent possible in order to restore the land to its original form and use as far as practicable. Such a practice will reduce the demand of land for storage and subsequent environmental degradation.

Sub clause 5 stipulates that the waste dumps should be suitably terraced and stabilised through vegetation or otherwise. Such measures should be started right from the beginning of the dumping so that the escape of the material, if any, may be checked in the initial stages itself. The sub clause (6) provides for disposal of fines, rejects, tailings from beneficiation in a suitable way so as not to cause land degradation or damage to agricultural field, pollution of surface water bodies and ground water. It would mean that a proper tailings pond of suitable design on an impervious ground should be constructed to arrest the flow and store the fines. This will also give the chance to the suspended material to settle down or its treatment to make it suitable for reuse or final discharge to the water streams.

It has now been made obligatory under the Rule 34 that every holder of PL or ML shall undertake the phased restoration and rehabilitation of lands affected by prospecting or mining operations and shall complete this work before conclusion of such operations while earlier there was no attempt on the part of licence or lessee to restore or rehabilitate the land disturbed, damaged or occupied by mining or ancillary operations.

In addition to the above rules, IBM has issued certain guidelines on dump management and rehabilitation. The salient features are given below:

1. The design of the waste dump should accommodate progressive rehabilitation to ensure a minimum area of disturbance at any one time.
2. The height, area and shapes of the waste dump should be designed having regard to the area of land available, the general topography of the area, nature of material being dumped and climatic conditions.
3. All completed surfaces of the waste dump should be stable and able to resist long term erosion.
4. Top soil should be scraped out from the dump site in advance and preserved in low height dumps, duly covered with grass and vegetal cover to increase its life.
5. Previously stockpiled subsoil and top soil should be spread on all completed surfaces where practicable and re-vegetated with suitable vegetation.
6. The design and construction of the waste dumps should be such that the completed out slopes do not exceed 20 degrees from the horizontal.
7. Drainage should be constructed to handle heavy rainfall. Appropriate garland drains should be provided all around and specially to the ultimate boundary of the dump.

6.5.3 Proposed Guidelines / Code Practices for Waste Management

From the review of the existing guidelines and regulations on waste management, it is observed that proper and sufficient guidelines exists in the Indian Regulation for the management of mining wastes. However, additional guidelines are discussed below. These guidelines are mainly intended to handle the mining wastes in the form of overburden and rejects, properly.

6.5.3.1 Guidelines for Mine waste Management

The following guidelines shall be practiced during handling and disposal of various types of wastes generated from the iron ore mines;

1. The top soil (20-30cm) shall be removed separately, utilize for restoration or rehabilitation of land or store it in a separate heap for future use, duly covered with grass and vegetal cover to preserve its fertility / biomass.
2. Overburden(OB) / Interburden (IB) / waste rocks shall be back filled into mine excavations to the maximum extent possible.

3. The OB / IB/waste rock dumps shall be located away from the natural nallas, rivers of the area and on an impervious & non-mineralized area, to minimize the water pollution. Design and construction of the waste dumps shall be such that the completed out slopes do not exceed than 28 degrees from horizontal to avoid excessive erosion and easy vegetation.
4. The OB/IB/waste rock dumps shall be properly dressed, benched, sloped at low angle with terracing and bamboo barricades in the slopes, making retaining walls/stone barriers at the toe of the dumps, gully plugging etc., to prevent the soil erosion during monsoon, besides establishing vegetation on dump top as well as its slope surface. In steep slopes, hydro-seeding technique or use of geo-textiles mat embedded with seeds shall be adopted.
5. To prevent fine particles from OB/IB/waste rock dumps getting washed off due to rains, every year, before onset of monsoon, deep garland type trenches all around the waste dump shall be made to arrest the fine particles in the trenches. The accumulated water in the garland drains shall be passed through check dams/settling tanks to allow the silt to be settled before final discharge to surrounding environment. At the outlet of garland drains, proper de-silting arrangements shall be made before onset of monsoon.
6. Oil contaminated wastes like oil filters, oily muck, cotton wastes etc. generated from workshops, garages and other areas shall be disposed in a secured landfills, specially designed for disposal of hazardous wastes.
7. Tailing ponds shall be located on impervious areas with deep water table. The ground underlying the dam must be structurally sound and able to bear the weight of the impoundment. Wherever practicable, tailings shall be used for filling in the exhausted mine pits.
8. Efforts shall be made for use of tailings generated from wet beneficiation plant for making value added products like ceramic floor tiles, wall tiles, bricks etc.
9. The exposed tailing pond areas shall be properly covered with vegetation. The whole tailing pond area shall be covered through vegetation once the life of the pond is over.

6.5.3.2 Dump Design

External dumps are permanent source of land pollution through wash off with rains and air blown dust through wind action. They also present an ugly and repulsive look to the viewer, if not duly afforested. The following measures are recommended to minimise land pollution due to external dumps.

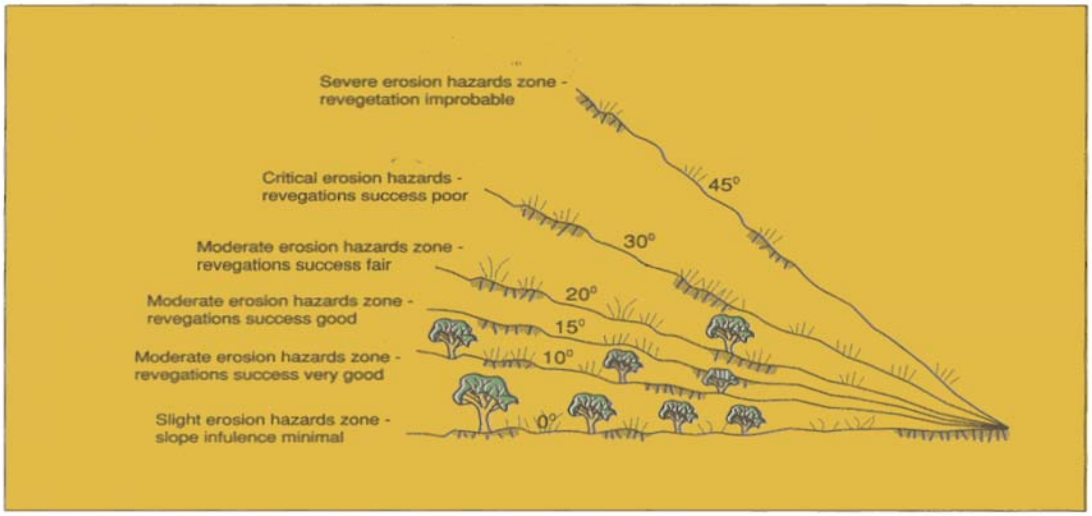
A) The design of the waste dumps should accommodate progressive rehabilitation to ensure a minimum area of disturbance at any one time and to establish final rehabilitation at the earliest opportunity. Alternative uses for part of the material, such as in landfill or road construction, may also be possible. It is advisable to acquire sufficient extra area over and above the mining lease area to cater to a planned external dump.

B) The following basic objectives for waste dump need be considered in the planning phase,

- The height area and shape of the waste rock dump to be designed having regard to the area of land available, the general topography of the area and the vegetation, in the area.
- All completed surfaces of the waste dump should be stable and able to resist long term erosion.
- Wherever it is possible to use a portion of waste dump for building purposes or as road material, such material should be stacked separately so that it is not buried under or mixed with unusable material and can be transported to its place of use whenever necessary.
- Top soil (20 cm) should be scraped out from the dump site in advance and preserved in low height dumps, duly covered with grass and vegetal cover to preserve its fertility/biomass.
- Previously stockpiled subsoil and topsoil should be spread on all completed surfaces wherever practicable and re-vegetated with suitable vegetation.
- The designed land construction of the waste dumps should be such that the completed out slopes do not exceed 20 degree from the horizontal.
- Drainage should be constructed to handle heavy rainfall events. Appropriate garland drains and drains at individual terrace should be provided to guide the rain water to main drainage channel without wash off of the dumps.

In meeting these objectives, it is essential that consideration is given to the aesthetic of the constructed waste dump. The long distance perspective of the shape and colour of the dump in relation to the surrounding landscape needs to be assessed from the main access ways and viewing points of the site. At closer range the view of the dump area should provide the viewer with a impression that the area has been rehabilitated to both blend with the natural land form and that the area supports a stable vegetative cover similar to the surrounding area.

C) Design of dumps : Since external dumps, which can not be used for backfilling of old pits or otherwise, must be afforested for greenery and land stability. Their outer ultimate slopes must be very gentle, preferably not more than 28 degrees, because steeper the slope more difficult it is for biological rehabilitation. As estimated relationship between the angle of dump slope and efficiency of revegetation, as given in Fig. below, may be kept in view for general guidance in this regard.



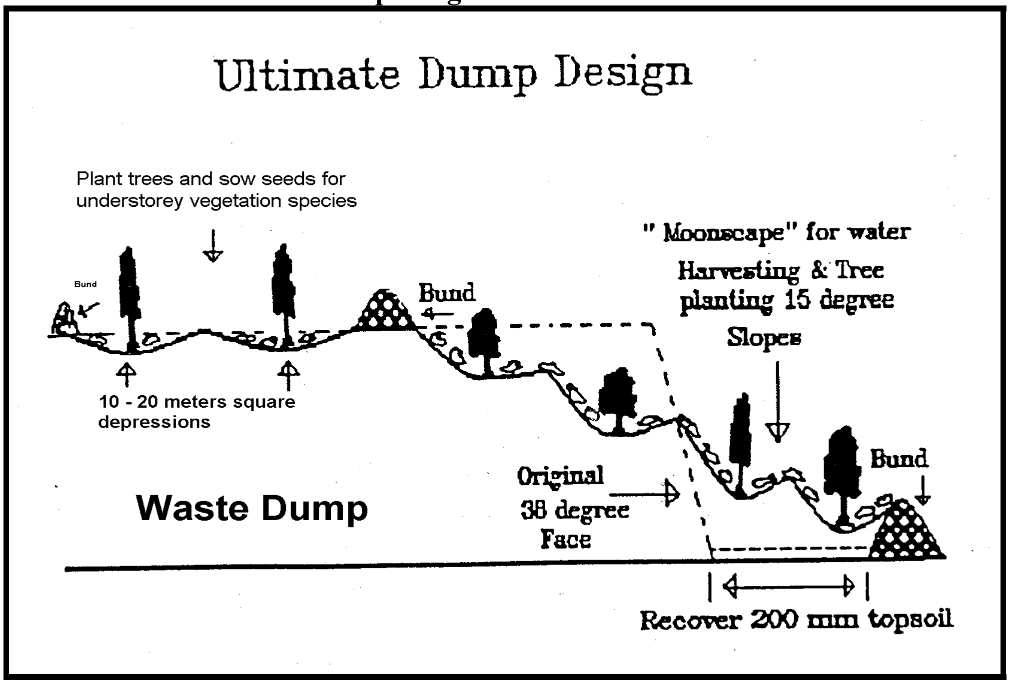
Dumping in Valley : Valleys are natural drains in hilly areas. In mines in hilly terrain where there is no other place for dumping waste material, even deep valleys can be utilised for waste dumping. In such case base of the dump i.e. bottom of the valleys are to be filled with big boulder, above this smaller boulders and still smaller boulders and so on and on top finer materials are to be dumped. This will enable rain water to pass during rains from the voids between big boulders. The thickness of big boulders will depend upon the size of the valley, precipitation in the area and catchment area for water which will flow in that particular valley some fines will be carried away along with rain water and this will require check dams on down stream where fines will settle and clear water will pass away through Hume pipes. These check dams have to be cleared periodically so that after filling with fines to its full capacity, they are not carried further down with rain water. Over this filled material soil can be spread and plantation can be done to add to the aesthetic beauty of the area. By this not only waste can be successfully disposed off, but the necked rocks in the valley can be converted into lush green area. This has been done successfully in a wollastonite mine in Sirohi district of Rajasthan.

6.5.3.3 Dump Rehabilitation

Establishing a vegetative cover is the only best term strategy for stabilisation and erosion control. To begin this process the topsoil should be replaced to all similar depths as that removed from the site originally (i.e. 200 - 300 mm). If topsoil is in short supply it may be necessary to place the topsoil in strips. This at least provides areas of improved surfaces for regeneration.

To increase the success of vegetation establishment, rehabilitation techniques should aim to increase rainfall infiltration. The term used for this approach is “water harvesting”, the concept of which is shown in the figure below:

Fig. No. 6.5.3.3.1 Concepts of Moon Scaping, Terracing and Water Harvesting for the ultimate Dump design



Many specific techniques have been developed for various applications. The most basic of these techniques is to leave the surface of the dump as rough as possible by deep ripping along the contour after the topsoil has been spread. The roughness and ripping allows for water penetration and provides places for seeds to lodge. Replacing pre-stripped vegetation also helps this process and reduces wind erosion. Creating a surface which enhances water harvesting will also help to leach soil salts out of the surface profile and aid the revegetation programme. In all cases the surface and faces of waste dumps will need to be ripped to break composition and to allow water penetration. This ripping will usually be carried out by a dozer after the topsoil and old vegetation material is spread. It is stressed that water harvesting and erosion control are the key issues in establishing the final surface for the rehabilitation programme.

It is widely recognised that waste from iron ore mines are very difficult material for vegetation. The reasons that iron ore mine wastes present difficulties for the plant growth are complex. In some case the main cause is the mineralogy of the original mineral. In addition it also has very adverse and different chemical and physical properties from natural occurring soil and are totally unsuited to plant growth. The chemical properties that can create difficulties for reclamation include lack of plant nutrients, excessively low or high pH and presence of toxic substances particularly metals. For establishment of a mat of vegetation is an important element in rehabilitation program. Application of organic matter, hydraulic seeding, chemical stabilisation, vegetative restoration by planting are some of the ways of rehabilitation of waste dumps. Some of the following techniques are recommended for revegetating the waste dumps.

Organic Materials: This method is normally applicable for the areas where topsoil is not available as surface layer and the physical structure of the site is poor for rehabilitation. The surface layer is poor in organic matter and in most of the cases surfaces tend to crust after rains and dry out rapidly, raising the temperatures. Mulching of surface may help in such areas due to its moderating temperature change and by conservation of soil moisture. Mulching also helps by decreasing erosion, adding to fertility and by detoxifying toxic metals and moderating temperature near the ground. A variety of materials are used for mulching depending on site conditions, availability, cost etc. Use of pulp, fibre, straw, sawdust, wood chips, cured hay chemical are used as in situ mulch.

Hydro seeding & Hydro mulching: Recently hydraulic seeding is being successfully practised to stabilise barren steep slopes and fragile unstable surface. The system requires large volumes of water, seed fertiliser and mulch, which are applied on the surface in the form of a fine spray. Non-toxic dyes can be used by the operator to confirm the area covered. Some studies suggest the use of hydraulic seeding device to provide a plug of vegetative material for transplanted trees on stony ground.

Any organic material which is capable of being shredded can be used in hydro seeding. Shredded bark wastes mixed with fines to avoid clogging. Studies in U.S. have shown that wood mulch at 2.5 ton./ha prevent soil crusting. In UK, 2.5 tonnes/ha. of previously moistened sphagnum peat have been used on China clay wastes. Use of mixture of grass seed, fertiliser and mulch of composted garbage material has also been recommended by some workers.

Hydro seeding has been found to be most useful for establishment of grass cover, however, a few tree and shrub species also germinate and survive well. Use of hydraulic seeders for higher slopes developed a prototype hydro seeding device for use in barren in rocky surfaces. A number of hydraulic mulching materials have been tried all over the world these include chemical as well as biopolymers and natural fibre based.

Chemical Stabilisers: A number of chemical stabilisers have been used as substitutes of mulch. Most common and useful among these are bitumen or tar materials used as sprays to hold the sand as an alternative to costly brush material mulch hydrophobic bituminous emulsion and hydrophilic polyacrylamide solution as soil conditioner. Use of a numbers of stabilizers like polymers, lignin, and resins. However, chemical stabilizers have been found to be less effective than peat mulch when hydro mulching combated the steep surfaces. Economically, also chemical stabilizers appear to be more costly if they are to be used on large scale as required in mine rehabilitation programme.

Geo-textiles: Coir Geo-textiles have the mechanical strength necessary to hold soil in place and prevent erosion. The netting breaks up run-off from heavy rains and dissipates the energy of flowing water. Coir also promotes the growth of new vegetation by absorbing water and preventing the topsoil from drying out. Coir geo-textile resembles natural soil in its capacity to absorb solar radiation. This means that there is no risk of excessive heating which is sometimes a problem with synthetic geo-textiles. When the coir geo-textile eventually disintegrates, it leaves only humus. Thus is no need for post installation work. This is particularly of much help in the heavy rainfall zones. M/s Sesa Goa has successfully applied geo-textiles in their waste dump rehabilitation. Some of the photographs of the application of geo-textiles in the waste dump stabilisation in the Codli Mines of M/s Sesa Goa are shown below:

Use of Geo Textiles for Waste Dump Stabilisation in the iron Ore Mines

6.5.3.4 Guidelines for Disposal of Oil Contaminated Wastes

Oil contaminated wastes like waste cotton, oily muck, oil filters etc., generated from the workshops, garages and other areas of iron ore mines, are categorized as hazardous wastes as per the Hazardous Waste (Management & handling) Rules, 2003. As per these rules, the generator / occupier, shall design and set up disposal facilities for hazardous wastes. There are two feasible methods are available for treatment and disposal of these oil contaminated wastes i.e. incineration and disposal into hazardous waste pit.

Incineration: Incineration is a controlled high temperature oxidation process that converts all organic hazardous substances into gases and incombustible residue, quickly and safely. The flue gases are required to be cleaned before being finally emitted to the atmosphere. The residue produced can be disposed in ordinary landfill.

Hazardous Waste Pit: Disposal of hazardous wastes into secured landfill / pit is the predominant method of disposal and has proved to be cost effective in many countries. A properly sited and designed secured landfill minimizes the adverse impacts on the human health and environment.

Owing to inherent advantages of the secured landfill / pit, it is recommended that each mine shall have secured hazardous waste pit for disposal of oil contaminated wastes. Guidelines published by CPCB under the “Criteria for Hazardous Waste Landfills – HAZMAS/17/2000-01)” can be considered while designing of the Hazardous Waste Pit. Details of hazardous wastes pit and design consideration have been briefly given in the following sections.

6.5.3.5 Hazardous Waste Pit

A Hazardous Waste Landfill / pit is defined as that system designed and constructed to contain the waste so as to minimize releases of contaminants to the environment. A simplified cross section of a hazardous waste landfill indicating main elements is given in the figure below;

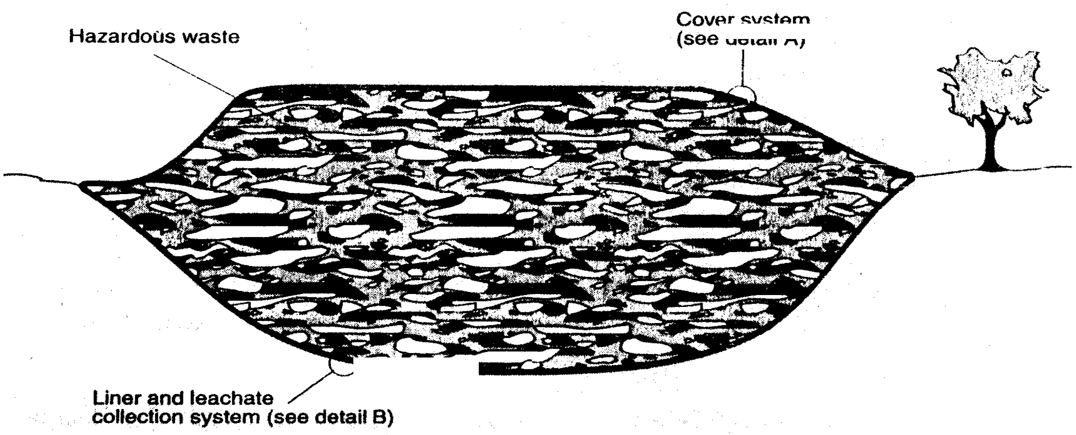


***Fig*. No. 6.5.3.5.1 Cross-section of Hazardous Waste Pit**

The main aspects need consideration while designing an construction of a hazardous waste landfill are briefly given as follows:

- Site selection
- Design life
- Waste Compatibility
- Waste Volume & Pit Size
- Pit Layout and section
- Liner and leachate collection system
- Final cover system
- Closure and Post Closure care

Site Selection: Hazardous waste pit should not be located within a certain distance from specific areas like ponds, lakes, rivers, wetlands, flood plains, highways, habitation, water supply wells etc. Preferably, the landfill should be located in areas of low population density, low alternative land use, low ground water table & contamination potential and at sites having high clay content in the subsoil. In addition to these issues, the logistical issue of transportation and nearness to the waste generation sources, ought to be considered during the site selection.

Design Life: A landfill design life will comprise of an ***active period*** and a ***closure*** and ***post closure*** period. The active period shall comprise of the period for which waste filling is in progress at the landfill and typically range form 10 - 15 years. The closure and post closure period for a landfill is generally about 20 years.

Waste Compatibility: Many wastes may react with each other, resulting in the potential for heat, combustion, and or toxic fumes. A landfill must comprise separate cells / units for disposal of compatible wastes. In iron ore mines, only oil contaminated wastes will be dumped in the hazardous waste pit, which are compatible to each other, hence does not require any separate cells. The hazardous waste pit at the mines can have one cell for disposal of these oil contaminated wastes.

Landfill Area: Area required for the landfill should be computed on the basis of waste volume and designed height of the landfill (usually 5 to 10 m). Approximately 20 - 30 % area more than the area required for landfill should be allotted to accommodate all infrastructure and support facilities as well as to allow the development of a green belt around the landfill.

Landfill Layout & section: Landfills may have different types of sections depending on the topography of the area. The landfills may take forms like above ground landfills, below ground landfills, slope landfills, valley landfills and combination of the above. Generally, the landfills are operated in phases because it allows the progressive use of the landfill area, such that at any given time a part of the site have final cover, a part being actively filled, a part being prepared to receive waste, and a apart undisturbed. Each phase is generally designed for a period of 12 months. Above and below ground landfill is generally preferred as it not only provides cover material but also enables easy disposal of wastes.

Liner & Leachate Collection System: Liner and leachate collection system is the main component of the hazardous waste landfill and its objective is to control the bottom of the landfill to maximize the collection of leachate and minimize the contaminant transport through the bottom to the surrounding environment. The bottom of the landfill shall consists of (a) alternating layers of materials to provide barriers to contaminants attempting to migrate from the landfill and (b) layers providing collection of these contaminants through collection system. Various types and combinations of landfill bottoms have been developed for hazardous waste landfills. Two types of liner systems are presently used in hazardous waste landfills viz., single composite liner system and double composite liner system. Line diagram of these two systems depicting various components are shown in following figures.

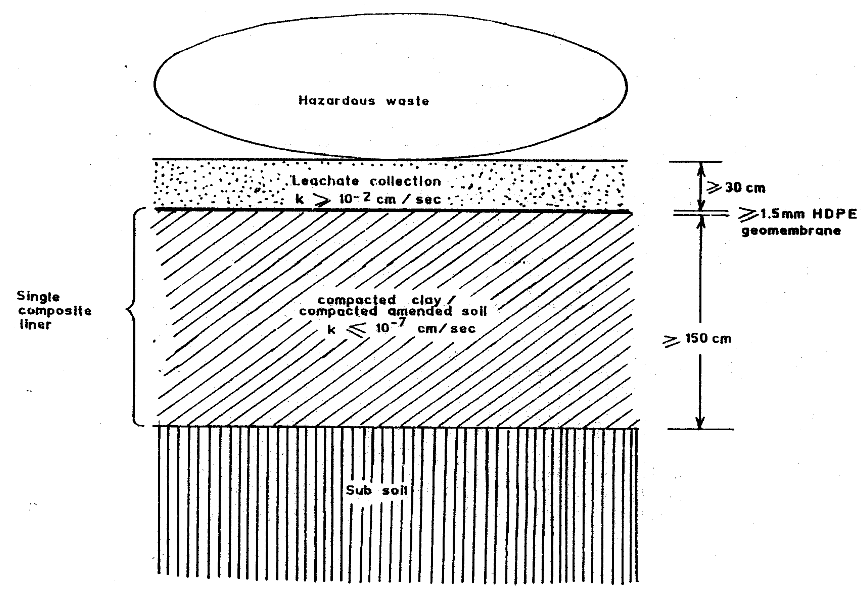


Figure No. . 6.5.3.5.2 Single Composite Liner System

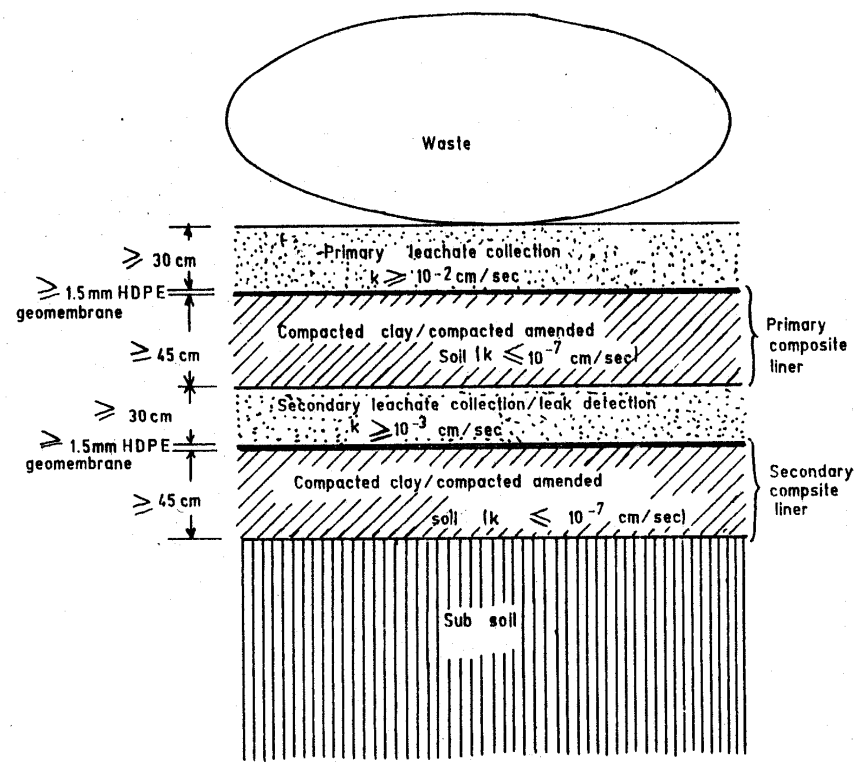


Figure **No. 6.5.3.5.3 Double Composite Liner System**

The double composite liner system is generally preferred in regions where rainfall is high and / or subsoil is highly permeable (e.g. gravel, sand, silty sand) and / or the water table is with in 2.0 to 6.0 m beneath the base of the landfill.

Leachate collection system shall be provided at the base of landfill, which comprises a drainage layer, a perforated pipe collection system, collection tank. The collected leachate shall be treated for adjustment of pH and reduction in level of contaminants to below the discharge quality standards before discharging to natural receiving water bodies.

Final Cover System: Main objectives of final cover system are to enhance surface drainage, minimize infiltration, supports vegetation to prevent erosion and control of release of landfill gases. A final landfill cover, comprising of several layers each with a specific function. General final cover for hazardous waste landfill showing the details of various components is given in following figure.

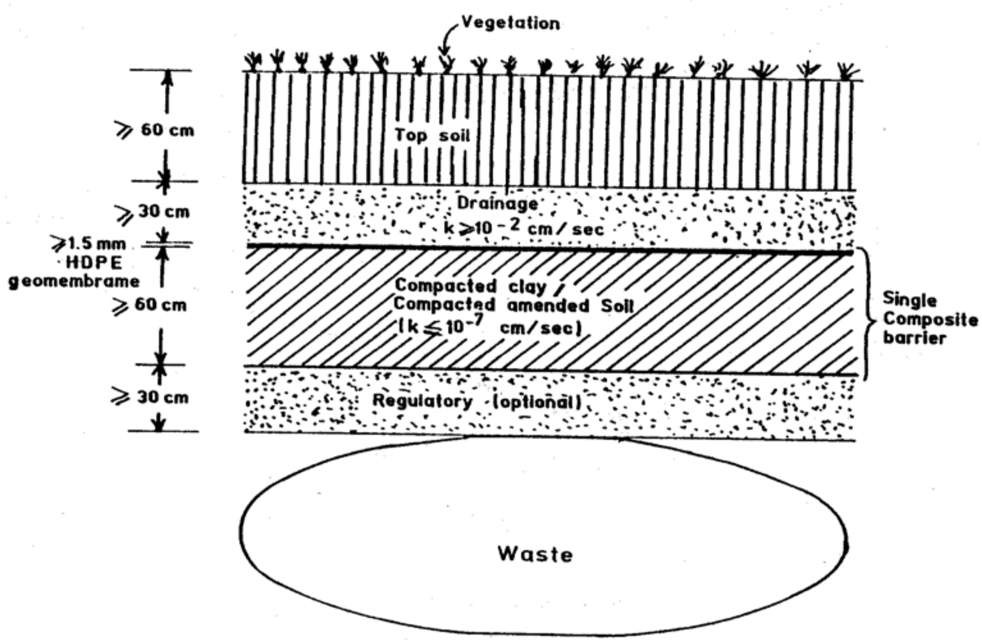


Figure No. 6.5.3.5.4 Final Cover for Hazardous Waste Landfills

Closure & Post closure Care: The closure of hazardous waste landfill facility should minimize or eliminate, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff to the ground or surface waters or to the atmosphere. The closure and post-closure plan for the hazardous waste landfills must be evolved and should indicate the following components:

- Plan for vegetative stabilization of the final landfill cover and side slopes
- Plan for management of surface water runoff when effective drainage system
- Plan for periodical inspection and maintenance of landfill cover facilities
- Plan for post closure management of leachate
- Plan for post closure environment monitoring.

Period of inspection and routine maintenance of a closed hazardous waste landfill shall be carried out for a period of 30 years after closure. SPCB shall inspect all facilities during the closure and post-closure period at least once in a year. The owner / operator of the landfill shall provide a copy of the environmental monitoring report to the respective SPCB once in year.

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7.1 INTRODUCTION

Monitoring of pollutants of concern in the environment is required to obtain reliable information which documents the quality of the media as a part of an environmental management system, both in public and private sectors. Such information provides the basis for decision-making, and the development of environmental management strategies. In order to be sure that such decisions are on a sound basis, it is essential to be confident that these measurements reflect the existing situation, in other words, the data must be clearly defined and documented quality. The ultimate purpose of monitoring is not merely to collect data, but to provide the information necessary for the planners, policy makers and the operators to make *informed decisions* on managing and improving the environment. Environmental monitoring is to be directed to address the key environmental issues. The key environmental issues are to:

- Develop improved practices and procedures for environment protection
- Detect short and long term trends
- Measure impacts
- Recognise environmental changes and enable analysis of their cause
- Check the accuracy of predicted impacts
- Develop improved monitoring systems, and
- Provide information on the impact of mining activities

Presently all the major iron ore mines in India are conducting regular environmental monitoring, mostly aimed at satisfying the regulatory requirement including consent compliance conditions and EMS - ISO 14001 (wherever certified) requirements. The air quality monitoring is mostly aimed at monitoring of the work zone and ambient at a varying frequency from mine to mine. Water quality monitoring is also being done by most of the major iron ore mines mainly for the surface water quality in and around the mine and at the final outfalls (discharge points) only for the parameters as per the requirement of "Consents to Discharge". Noise quality monitoring is also being done in the work zone and ambient areas.

Present environmental monitoring results of the major iron ore mines of India are given in a separate booklet. It is apparent that the present monitoring practices are not uniform and adequate with respect to;

- Network
- Parameters
- Frequency

So, it is very much essential to standardise the environmental monitoring practices for all the iron ore mines in India with respect to:

- ➢ What to measure
- ➢ Where to measure
- ➢ When to measure
- ➢ How to measure
- ➢ Evaluation methods to be used

7.2 STANDARDISATION OF MONITORING PRACTICES

The effectiveness of a monitoring programme depends mainly how best the objective of the monitoring is addressed through its core elements e.g.

- Monitoring Network
- Frequency of Monitoring
- Parameters to be Monitored
- Method and Duration of Sampling
- Method of Analysis

Monitoring plans are designed and implemented for collecting data on ambient air, water quality and noise levels as well as releases of pollutants of concern from the major point sources. The elements of a monitoring plan normally include selecting the parameters of concern, method of collection and handling of samples (specifying the location, frequency, type and quantity of samples and sampling equipment) sample analysis and a format for reporting the results. Development of standardisation of a monitoring programme should also address to other issues like manpower and facility (equipment) requirement.

The existing systems and practices at Indian Iron Ore Mines demand a need for standardised monitoring programme applicable to all the iron ore mines. The proposed monitoring schedule for the air, water and noise monitoring are given in the subsequent sections.

7.2.1 Air Quality Monitoring

Intense mining activities and transport of ore by open dumpers / trucks through public / private corridors are deteriorating the air quality in villages surrounding mines and traffic corridors. Near by villages are also getting affected considerably due to exposed ore stockyards and transport activities. It is therefore essential to have air quality monitoring stations in the nearest residential and commercial establishments around the mining and allied operations to assess the pollution levels throughout out the year. This would facilitate to develop better management practices to ensure compliance with the standards and protect human health. According to USEPA guidelines for network design, three factors i.e. surface influences, demographic influences and meteorological influences, are of paramount importance while selecting monitoring stations.

The main sources of the fugitive emissions in the mining are mining /broken area (drilling, blasting excavation), haul roads, overburden dumps, crushing, screening and beneficiation plant, stock piles, loading point / railway siding, abandoned / exhausted tailings pond. Based on the local conditions and dust sources, monitoring stations can be located in consultation with the SPCB. The number of sampling stations will depend on the local conditions, but should not be less than 4 locations around the mine. The stations would be located in various mining and non-mining villages to assess the status of ambient air quality. Monitoring of background concentration is useful to understand the contribution of pollutant due to the mining activities to air environment. The Suspended Particulate Matter (SPM), Respirable Particulate Matter (RPM), Sulphur Dioxide (SO_2) and Oxides of Nitrogen as NO_2 are the parameters of concern for iron ore mining industry and hence shall be monitored at all the selected ambient locations.

In addition to the ambient air quality monitoring, fugitive dust levels (RPM & SPM) shall be monitored at all the dust prone areas to check the efficiency of the dust control measures adopted to achieve compliance with the proposed standards. The locations of the various mining areas to be covered under the fugitive dust monitoring are given in the following table;

Table No. 7.2.1.1 Fugitive Dust Monitoring Locations

Area	**Sources of Dust Generation / Monitoring Location**
Mine face / benches	Drilling, Excavation & Loading (Not required for benches operating below water tables. However applicable for operating benches above water table)
Haul Roads / Service Roads	Haul roads leading to Ore Processing Plant, Waste dumps & Loading areas and Service Roads.
Crushing Plant	Run-off-mine unloading at Hopper, Crushing Areas, Screens, Transfer Points
Screening Plant	Screens, Transfer Points
Ore Storage & Loading	Intermediate Stock Bin / Pile areas, Ore stock bin / pile areas, wagon / truck loading areas
Waste Dump Areas	Active waste / reject dumps

Methods for monitoring of SPM, RPM and SO_2 and NOx are given in the following table.

Table No. 7.2.1.2 Methods for Air Quality Monitoring

Sl. No	Parameter	Apparatus	Method/ Reference	Method of Analysis
1	RPM & Total dust	Respirable Dust Sampler and High Volume air sampler	BIS 5182 Part IV – 1973 (Average flow rate not to be less than 1.1 m^3/minute)	Gravimetric
2	Sulphur Dioxide	Respirable Dust Sampler and High Volume air sampler	BIS 5182 Part II – 1969 Improved West & Gaeke method (Pararosaniline method)	Colorimetric Ultraviolet fluorescence
3	Nitrogen Oxides	Respirable Dust Sampler and High Volume air sampler	BIS 5182 Part VI – 1975 Jacob & Hochheiser modified (Na-Arsenite) method	Colorimetric Gas phase Chemiluminescen ce

Frequency of Sampling:

- Fugitive dust (SPM & RPM) shall be monitored at all the locations for 8 hourly basis in any working shift at least once in a month other than monsoon.
- Ambient air quality monitoring shall be monitored as per the National Ambient Air Quality Standards i.e. twice in week at each location for 24 hourly at uniform intervals so that minimum 104 measurements can be taken in a year.

7.2.2 Stack Emissions

Dedusting systems are installed in some of the mines at crusher and screening houses and material handling areas in order to control the fugitive emissions. The dedusting systems are mainly designed to capture and clean the dusty emissions generated from the various sources. Therefore, the particulate matter (PM) is only concerned parameter for dedusting stacks. The PM emission from dedusting stacks is entirely dependent on performance of the installed pollution control unit. Proposed monitoring schedule for the de-dusting stacks is given below:

Stack Monitoring Requirement For De-dusting Systems

Sl. No.	Stack	Frequency	Parameters
1.0	Dedusting stacks	Monthly	PM

Method of Monitoring:

The Central Pollution Control Board (CPCB) has published comprehensive document on emission testing regulations (“ Emission Regulations Part- 3, 1985) which is an extremely useful guide to source emission testing. There is a number of useful additional procedures and expressions that are of relevance to measurement of stack emissions, which are recommended to supplement the CPCB procedures. Those procedures relevant to the PM monitoring are summarised below:

<u>Particulate Matter (PM)</u>
The CPCB method and IS 11255 (Part - 1) adopt a very similar approach to particulate sampling. There are some differences in the expressions used, but they are generally of no practical significance. It is recommended that the CPCB method be adopted.

<u>Equipment Calibration</u>
For accurate testing of emission sources, it is essential that components of the sampling train be calibrated against known secondary standards which are kept on-site especially for that purpose. The secondary standards should in turn be calibrated against a primary standard from an accredited standards laboratory.

7.2.3 Effluent Quality Monitoring

The water quality monitoring network needs to be established so as to check the efficiency of the control measures adopted to achieve compliance with the proposed standards. Water quality standards are set with source specific controls devised for abatement of water pollution. Water quality monitoring programme in the iron ore mines shall have the following objectives:

- To check the compliance status of mining companies, it is essential to monitor the water quality parameters for the effluents arising out of the mining operations for all the parameters.
- To identify sources of pollution and to plan proper management strategy to maintain the quality of receiving water bodies.

The primary parameters of concern for iron or mines are SS, pH, Oil & Grease, Mn and Fe, which need to be monitored in all point sources on regular basis. Special attention must be paid to sampling and for the preservation and handling of samples prior to analysis. Methods of analysis of proposed parameters in the effluents are given in the following table.

Table No. 7.2.3.1 Methods for Effluent Quality Monitoring

Sl. No	Parameter	Method of usual Practice	Suggested Method
1	Suspended Solids	Gravimetric Method	Gravimetric Method
2	O & G	Soxhlet Method	DR 3000 / SQ 118
3	pH	Colorimetric	pH Meter
4	Fe	Colorimetric	DR 3000 / SQ 118
5	Mn	Colorimetric	DR 3000 / SQ 118

Sampling and Frequency of Monitoring:

- The discharge from tailings dam, workshop effluent (washings of HEMM & light vehicles), pit water, check dams or/and any other discharge leaving the lease boundary of the mine need to be monitored *at a frequency of once a fortnight*.
- Grab samples to be collected at the point of discharge to the natural stream/ river/ natural water bodies/ sewer/ land or at the place, where the discharge is leaving the lease boundary or the treatment facility.
- Dissolved iron is considered to be that passing through 0.45 µm membrane filter but colloiadal iron may be included. For accurate determination of dissolved iron, immediately after collection filter the sample through a 0.45 µm membrane filter into a vacuum flask containing 1 ml of con. HCl/100 ml sample. Analyze the filtrate for total dissolved iron as per the standard procedure.
- Mines which are operating below the water table shall monitor the *ground water level* (expressed in RL, mm) at the periphery of the mine pit by setting up at least three pizometric stations / wells (preferably 120^0 apart to each other) to assess the impact of pumping out water on the ground water table at least once in a quarter.

7.2.4 Noise & Airblast Monitoring

The major sources of noise in mining and related operations include drilling, blasting, loading, excavation, crushing, screening, beneficiation, movement of heavy earth moving vehicles and wagon loading etc. Most mine equipment noise levels are high and the noise can travel long distance and still be annoying to surrounding residents. Noise level impact is particularly significant at night and is affected by topographic and climatic factors, as well as proximity.

Noise levels shall be monitored both during day and night times on the same day while in operation. The noise measurements shall be taken outside the broken area, boundary of ore processing & material handling areas, which include mine site & general offices, statutory buildings, workshops, stores etc. The noise monitoring to be conducted continuously for 30minutes or till the Leq gets stabilised, both during day and night time at random at least once in a month for each location.

Airblast level resulting form blasting operations shall be monitored at the nearest authorised premises and public places at least once in a month. Airblast level shall be monitored in dB Linear.

7.3 RESOURCE REQUIREMENT

Most of the iron ore mines in India are getting the environmental monitoring conducted by engaging outside consultants/ laboratories. Few big iron ore mines are conducting the environment quality monitoring (mostly air, water and noise quality monitoring) by their own resources. Smaller mines are normally not conducting the environmental quality monitoring, and if at all, it is very in-frequent. However, in almost all the mines, persons are earmarked to handle the issues relating to environment management (rather to address the issues arising out of regulatory compliance only). Some of the big mining companies like SAIL, NMDC, TISCO, KIOCL, M/s Sesa Goa, etc. have developed organisation structure, adequate to handle the environmental issues and infrastructure for conducting environmental monitoring. Keeping the present practice and the requirements in to consideration, it has become essential that all the mining companies should have dedicated person or organisation structure to take care of the environmental issues. The iron ore mines shall conduct the environmental quality monitoring to satisfy the recommended standards, by engaging CPCB/ SPCB approved laboratory or by their own resources. The minimum tentative manpower and laboratory requirements for any iron ore mines for conducting the environmental quality monitoring are suggested below:

Minimum Manpower Requirement

i. Environmental Engineer - 1no

ii. Chemist - 1no

iii. Field Staff - 2 nos.

Minimum Monitoring Instrument/Equipment Requirement

i.	Respirable Dust Samplers with accessories	-	3nos
ii.	High Volume Air Samplers with accessories	-	3 nos
iii.	Noise Level Meter with accessories (should be capable of measuring Leq, Lmax in dB(A) and duration of monitoring in minutes)	-	1 set
iv.	Electronic balance with accessories (4 digit)	-	1 set
v.	pH meter with accessories	-	1 set
vi.	Double distilled water system	-	1 set
vii.	Spectrophotometer with accessories	-	1set
viii.	Standard laboratory glass wares and accessories.		

All the monitoring instruments shall be calibrated at the recommended frequency specified by the supplier / manufacturers.

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As per the National Steel Policy, 2005 the total demand of iron ore is placed at 290 million tonnes including 190 million tonnes for domestic consumption & 100 million tonnes for export by 2019-20. The current mining capacity of iron ore in the country is around 160 million tonnes. This capacity can be enhanced, through consolidation of leases, mechanised mining operations in Bellary-Hospet area and improvement in the operating capacity of existing mines in Bailadila and opening up of new deposits of Bailadila, new deposits in the eastern sector, Chhatisgarh area, and in Karnataka etc. Through better infrastructure handling, the existing capacity can be expanded in the eastern sector mines such as Kiriburu, Meghahatuburu, Bolani, Kalta etc. and by opening up of new mines in the eastern sector covering Chiria, Malangtoli, Gandhamardan and Dubna deposits and also at Rowghat of central zone.

During the year 2006-07 India has produced 172.296 (Provisional) million tonnes of iron ore including lump, fines and concentrate. The demand for iron ore is expected to increase at a greater pace with a projected requirement of 290 million tonnes by 2019-20. This will obviously lead to opening up of new iron ore mines and as well as capacity augmentation of the existing mines. The exploration, exploitation and associated mining activities will directly infringe upon and affect the natural resources and environment to a larger extent. With the increased mining activity, it is expected that the environmental impacts will further aggravate if proper environment management practices and technologies are not followed. Even the present operations have largely affected the natural pristine environment around the existing iron ore mines in India and this is particularly an issue of concern for the management of forest ecology and landscape, as majority of the iron ore in India are located in dense forest area. Large numbers of smaller mines are operating mostly, either in manual or in semi mechanized manner, with limited resources has further worsened the situation. However, due to increased awareness of the importance on resource preservation and pollution control with increased legislative and regulatory pressure, mine operators today are more concern on proper environment management than earlier. Now, there is a greater need for adopting better operational practices and cleaner technologies in the iron ore mining so as to achieve sustainable development.

The objective of the present study is to develop environmental standards for iron ore mining in India and suggesting appropriate cleaner technologies for achieving the proposed environmental standards. The broad general recommendations are listed below. It may be emphasized that better environment management practices and disciplined operational practices are key to achieve the desired environmental protection. It is important to realize that the manner in which a mine is planned will have major influence on the magnitude and duration of impacts over the life of the development, operation and following the mines closure. As the mining progress from the planning and concept design stages through to operation and possibly for decommissioning, proper planning can reduce environmental impacts, resulting in good environmental performance and enhancing the public perception of the mining as able to operate in an ecologically sustainable way. But, with the operational variations, nature of the deposits and locations, mining techniques to minimize environmental impacts can not be standardized. However, the followings are the general recommendations on different issues, operational practices and management practices.

1. Lease size shall be reasonably large enough so that iron ore can be exploited systematically and in a scientific manner with the scope for proper associated infrastructure development. Small scale iron ore mining should be discouraged.

2. Scientific mine planning with Environmental Protection Plans need to be prepared before commencing mining, to accommodate early simultaneous back filling operations with the waste material generated. There shall be periodic inspection to find out the progress of mining and environmental management as per plans and governing laws by the statutory authorities.

3. It is recommended to explore the feasibility of working in higher bench heights. Higher benches would have the potential to reduce waste stripping and increase the overall effective slope angle there by reducing the final open pit foot print. It is required to undertake rock mechanics study to arrive at optimum safe pit slope. Again, higher bench height means less equipment and less environmental impact.

4. Selection of mining equipment should be based on low cost, high productivity option. For example, minimum truck size should be 85t rear dumpers with appropriately matched hydraulic face shovels. This equipment will reduce overall fleet size and is substantially more cost effective than 50 t rear dumpers and rope shovels. From an environmental impact perspective, larger equipment means less dust and fewer workers. However, this is particularly applicable to big mechanized iron ore mines.

5. Drilling operation need to be conducted as per the recommendations of the manufacturer using sharp drill bits, applying sufficient thrust on the drill bit and providing dust hood at the mouth of drill hole collar to prevent the generation of dust to be air borne.

6. Fugitive dust generated during drilling operation need to be controlled at source by providing suitably designed dust extractor for dry drilling (where there is a scarcity of water) or otherwise wet drilling shall be practiced. The operator's cabin in the drills shall be noise proof and the persons working at high noise prone areas to be provided with ear plugs/muffs, besides adopting proper maintenance schedule for the drills to reduce their noise level and gaseous emissions.

7. Blasting operation is associated with ground vibration, air blast noise, fly rocks, dust and fumes. To minimise the above ill effects of blasting the following measures are recommended.

   - Scientific Blast design using softwares of ICI's SARBEX & VIBREX of IDL
   - Optimised blasting methods i.e., matching the explosives to the drilling pattern, rock characteristics, adequate stemming of holes by proper stemming material and using delay detonators etc.
   - By avoiding over charging of explosives
   - Reduction of charge weight of explosives.
   - Use of milli-seconds delay detonators and controlled blasting techniques.
   - Adopting suitable delays and initiation pattern which will allow adequate release of burden by each blast hole before firing the next one.
   - By using non-electric initiation systems (NONEL) etc. like EXEL of ICI and RAYDET of IDL

- Ensuring a minimum stemming column (with moist drill cutting using water gel, water ampules) of not less than 0.7 times the burden. For better protection, it may be taken as greater than or equal to burden.
- Discouraging practice of collar priming.
- Avoiding blasting at a time when temperature inversion is likely to occur and when strong wind blows towards residential areas
- Clearing of loose pieces of rocks from the blast site before charging
- Surveying fly rock distances for reference
- Conducting ground vibration studies as per the guidelines of DGMS. In this connection DGMS (Tech) (S&T) circular no.7 of 1997 shall be followed.
- Pre wetting of blasting site need to be done.
- Physically guarding the danger zone area shall be done. Mines Act, Regulations, rules etc. to be followed.
- Planting rows of trees in and around the mines and township to mitigate the noise.

In case of secondary boulder blasting, noise and generation of dust shall be avoided by using Hydraulic rock breakers

8. Ripping and dozing machines shall be used (where ever feasible i.e. in soft, friable and fractured Iron Ore/laterite/O.B) replacing drilling and blasting to reduce noise levels and dust emissions. It is also required to undertake seismological studies for ripping over burdens/ iron ore, replacing conventional drilling and blasting.

8. All the service and long life haul roads shall be black topped metal roads to the extent feasible. The speed of dumpers/trucks on haul roads shall be controlled as increased speed increases dust emissions. Overloading of transport vehicles shall be avoided. The operators cabin in the haul dumpers/trucks to be noise proof as far as possible. Proper maintenance schedule of dumpers/trucks to be adopted as per the recommendations of the manufacturer. Dust consolidation on mine haul roads shall be done by spraying water along with chemical binders/wetting agents through water sprinklers at frequent interval in order to reduce water consumption and to improve retention and re-absorption capacity of water. In this connection DGMS India circulated their recommendations vide circular no. 8 (Tech) of 1997 for the use of pulver bond and dust bond for haul road dust consolidation shall be followed. In case of trucks plying on the public roads, the trucks shall be properly covered, leak proof and ply in safe speed.

9. Use of electric rope shovels need to be maximized for its advantages of less vibration, noise and no emission over the other shovels.

10. Establishing in pit mobile/semi-mobile crushing conveying transport systems wherever feasible as an alternative to all dumper transportation system for reducing spread of air-borne dust in to the surrounding mine environment and also to reduce the spread of noise level. Site specific techno economic analysis need to be carried out before selecting the transport system.

11. Adequate dust suppression and/or extraction facilities like bag-filter, wet scrubber, dry fog dust control system etc. need be provided at the ore handling plants, crushing, screening units and the material transfer points. Proper enclosures of crushers and screens are necessary in the reduction of dust emissions. Atomised mist spray of water to be provided at the crusher hopper during unloading operations. To minimise dust pollution measures such as adoption of hoods at transfer points, proper design of chutes, vulcanizing of conveyor belt joints, apart from installation of dust suppression and/or dust extraction system for conveyors are required to be introduced. Dust emissions shall be minimised by installing a telescopic chute or by installing a loading spout during loading into barges, trucks and railway wagons. The falling material shall be enclosed by a flexible duct acting as a chute, which retracts as the height of the material pile increase. At the iron ore stockyard atomised stationary mist spray to be provided to prevent the dust being air borne.

12. To prevent fine particles from OB/waste dumps getting washed off due to rains, every year, before onset of monsoon, deep garland type trenches all around the waste dump shall be made to arrest the fine particles in the trenches. The accumulated water in the garland drains shall be passed through check dams/settling tanks to allow the silt to be settled before final discharge to surrounding environment. At the outlet of garland drains, proper de-silting arrangements shall be made before onset of monsoon.

13. OB/waste dumps shall be properly dressed, benched, sloped at low angle with terracing and bamboo barricades in the slopes, making retaining walls/stone barriers at the toe of the dumps, gully plugging etc. to prevent the soil erosion during monsoon, besides establishing vegetation on dump top as well as its slope surface. In difficult cases, hydro-seedling technique or use of geo-textiles mat embedded with seeds shall be adopted.

14. At stockpile and loading plant area, a network of drains with concrete bottom shall be constructed at a depth of 1.5 meter below the lowest level on the sites parallel to the stockpile area with interconnected box culverts. The sloping of surface shall be given inward to the stockpiles so that, surface water will only infiltrate in to the drain.

15. Sedimentation ponds shall be constructed at strategic points in order to guide all surface run-off water containing sediments for settlement of suspended solids before discharge of water in to natural stream/water courses, during monsoon.

16. At the beneficiation plant, process waste water to be recycled from the thickener over flow to the maximum possible extent in order to reduce surface water pollution due to less discharge to the surrounding environment and less process water requirement. Provision of a suitably designed tailings dam with recirculation of process water and control of seepage water to be provided by constructing seepage water collection ditch at the downstream side of the dam with re-circulation facility along with the wet beneficiation plant. De-silting of tailings shall be done periodically before monsoon and the material need to be either dispatched by rail after screening/processing or stored at a place away from the catchments of natural water courses. Exhausted pit shall also be used for storage of tailings, where there is a scarcity of land for tailings disposal. Early vegetation over tailings pond shall be practiced once its life is over.

17. Maximum recovery of Iron Ore fines need to be encouraged by adoption of hydro-cyclones, slow speed classifiers and thickeners in the wet beneficiation circuit. Installation of WHIMS as an additional unit in the wet beneficiation plant may be provided wherever feasible for recovering substantial quantity of Iron ore fines from slurry tailings and makes available for use as sinter feed in the blast furnace and thereby reduces the discharge by about 50% and will increase the life of the tailings pond.

18. The tailings generated due to wet beneficiation plant can be used as raw materials for making value added products like ceramic floor tiles, wall tiles and bricks. R&D efforts are needed for developing necessary technologies for utilising more and more. Iron Ore fines in the production of steel as a measures of conservation of Iron ores. Blue dust is to be fully utilised to make various value added products. Blue dust can also be used as additive in concentration of Iron Ore fines to the extent of 20-40% for use in steel plants. Conservation of high grade Iron ore should be done by blending with low grade ore as a matter of policy of the Iron ore industry as the reserves of high grade iron ore are limited.

19. Service centres i.e. Auto shops, HEMM shops and other areas where in water pollution due to wash offs of oil & grease are expected, due to washing of light vehicles, HEMM etc., ETP shall be provided.

20. Domestic effluents shall be treated in suitable and well-designed oxidation ponds.

21. Rehabilitation of mined out areas and waste dumps of iron ore mines should take in to account of ecological principles, which would require a completely different procedures from those presently being followed by the mining authorities. Current rehabilitation is directed at restoring visual amenity, stabilizing disturbed areas and growing trees. But the aim of the rehabilitation should be, to restore, as closely as practicable the pre-mining land use of the area. This would involve:

    - Reshaping the mined out areas to a configuration consistent with the surrounding landscape.
    - Re-establishing a suitable growth medium, most likely by the application of a layer of waste rock overlain by a layer of top soil.
    - Re-establishing the full range of plant species and micro-organisms now existing (or were existing during pre-mining era, if baseline data exists) in the area. This does not mean that each species needs to be individually planted, as many species can be expected to emerge from the applied top soil, while others will re-colonise from adjacent, undisturbed areas. What is important is to provide rapid and effective protection against erosion, initiate the natural succession process, and avoid introducing anything (i.e. weeds, or livestock) that could inhibit succession.

    Involvement of State Forest Department through their Social forestry division for afforestation and waste land development will enable the mine management to get better know how to restore the ecology of the area.

22. There is a need to lay down procedures and guidelines on how mine owners should act in the post mining scenario. Proper mine closures plans needs to be developed by the mine authorities. Mine closure should be made mandatory for all mines, irrespective their

location and size. Before, the mine is decommissioned, all reclamation activities including safety, environmental mitigation and social impacts mitigation activities have to be completed. It should be made mandatory for mine owners to furnish financial and performance bonds for ensuring proper mine closure with rehabilitation of the site. It is very important to manage the "residual footprint" of the mine. Residual foot print is that portion of the mining area that can not be fully rehabilitated and a void is left.

23. At the final stage of an open cast iron ore mine, it should be the national policy to create a water body of say, less than 30 meter depth which would be a community asset in providing irrigation water and recharge of ground water in the region, besides water harvesting practices.

24. List of activities which should get addressed for opening up of any new iron ore mine in India is given below:

- Development of a mine plan which minimizes the effective working footprint.
- A mine water (run-off and ground water) management plan development
- Development of water management systems, in and around the open pit
- Visual impact assessment of mining operation both during and after final rehabilitation of the disturbed area.
- Progressive staged mine development and rehabilitation
- A low impact development strategy to open up the deposit
- Detailed site layout for mining activities including ex-pit haul roads, water management bunds and drains, maintenance facilities, refuelling and wash down areas, explosive magazines and associated earthworks etc. This site layout should aim to minimize the amount of disturbed land and base the location of infrastructure on the environment value of the various areas adjacent to the open pit.
- A quantified assessment of waste management options including back dumping /filling in to the open pit.
- Dust and noise minimization strategies for mining operations
- Ore transport options study
- A detailed mine closure plan including options assessment.
- Details of an environmental training and awareness programme for mine site personnel.
- Detail of mine safety programme.
- A technical and environmental risk assessment of mining operations.

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The Cover Photographs used are Controlled Blasting in Bailadila, NMDC, Sluury disposal of KIOCL, Excavation & Loading in KIOCL, Dump stabilization & Dust suppression at Bailadila, NMDC (clockwise from top left)