DIPANKAR SHOME
GANESH MANEKAR
SURAJIT CHAKRABORTY
and
SURANJAN SINHA

Pollution control measures for core and buffer zone as sustainable framework at Dongri Buzurg opencast mine of MOIL Limted

MOIL Limited has been using technologies for sustainable development since its inception. The sustainable development framework (SDF) is addressing on various issues begin with grant of mining lease to final mine closure plan stages of mining life cycle. The SDF is also refers to on economics, environment and social impacts of mining. The mining activities disturb local ecosystem and bio-diversity, moreover causes largescale deforestation, loss of grassy land, soil erosion, contamination of soil and water, noise pollution. It also causes the environment degradations that lead to destruction of wildlife habitat. To achieve the integration of socio-environmental-economic factors it is essential to develop and implement SDF. By recent amendment of Mines and Minerals (Development and Regulation) Act, 1957, implementation and evaluation of SDF have become mandatory. SDF is modelled by international agencies like International Union for the Conservation of Nature and Natural Resources (IUCN) and International Council of Mining and Metal (ICMM) and tailored for Indian conditions. Some of the aspects of SDF are covered in a case study, which was conducted in Dongri Buzurg opencast mine.

The paper presents the SDF used by MOIL at Dongri Buzurg mine for incremental improvement in protection of environmental impacts in core and buffer zone.

Keywords: *Afforestation, blasting, dumps, environment, pollution.*

1. Introduction

Manganese ore is vital for steel and steel related industries. This mineral is produced on large scale from different parts of the world. Indian manganese mining industries shares 6% of the world's production. MOIL Limited is the largest producers of manganese ore and its value added products in the country. It produces annually around more than 1.3 million tonnes of manganese ore of various grades from 11 mines, which are located in the state of Maharashtra and Madhya Pradesh. Out of this, 7 mines are underground and 4 mines are opencast. All the underground mines of MOIL are accessed by vertical shafts while shovel dumper combinations are working in opencast mines. There are two integrated mineral beneficiation plants, located at Balaghat and Dongri Buzurg mine and two processing plants for value addition i.e. electrolytic mmanganese dioxide plant at Dongri Buzurg and ferro-manganese plant at Balaghat mine.

At present, source wise production of the MOIL is as indicated in Table 1.

Table 1

Production: Source-wise		
Underground	Opencast	Dump
52%	38%	10%

2. Dongri Buzurg mine

The mine is located 120 km from Nagpur in Bhandara district of Maharashtra state. Total lease hold area of the mine is 174.860 ha, out of which at present mining area are about 92 ha. It produces around 3 lakh tonnes of manganese ore per year that includes around 10000-15000 tonnes of dioxide ore which is being used for making dry battery and chemicals. Electrolytic manganese dioxide (EMD) plant of 1000 tpa capacity and integrated mineral beneficiation plant of 400000 tpa capacity is operated at mine head.

Manganese ore of the mine consisted secondary oxide minerals such as psilomelane, crptomelane and primary silicate minerals in the form of braunite and jacobsite. The gauge consists of quartz, iron minerals and apatite. The waste rock is mainly mica schist which is lighter and very friable in nature.

2.1 Reclamation and revegetation of mine spoil dumps (Table 2) through integrated biotechnological approach (IBA)

The fertile top soil was removed and used in mixture for application in IBA to fill the pits constructed for plantation of

Mr. Dipankar Shome, Director (Production & Planning), Dr. Ganesh Manekar, General Manager (Mine Planning), MOIL Limited (A Govt. of India Enterprise), 1-A, MOIL Bhawan, Nagpur, 440013, Dr. Surajit Chakraborty, Assistant Professor, ISWBM and Suranjan Sinha, Professor, IIEST, Shibpur. email: suranjan1980@gmail.com / suranjans@mining.iiests.ac.in

saplings. A layer of about 30 cm was laid over spoil dumps for increasing vegetation.

TABLE 2: DUMP AREA DURING EXPERIMENTATION PERIOD

Total area of the dump in ha	Area established by dumps in ha	Percentage of used dump
32	28	87.5

TABLE 3: TOP SOIL GENERATED AND STORED DURING EXPERIMENTATION PERIOD

Top soil generated in m³	Quantity of top soil stored in m³	Quantity of top soil utilised in m³	Percentage of utilisation
493350	107375	412075	83.52

2.2 Approach plan

An approach plan for rejuvenation of land productivity and reclamation of spoil dumps was prepared, based on the physico-chemical-microbiological properties of mine land and mine spoil dumps and need of technological intervention involving integrated biotechnology to achieve stable ecosystem restoration.

The integrated biotechnological approach (IBA) envisages the use of industrial wastes like press-mud from sugar mill industry as an organic amendment for the spoil and use of nitrogen fixing bacteria like rhizobium and azotobacter which can tolerate high manganese concentration and VFM fungi. The use of bio-fertilizers reduces the environmental risk of using chemical fertilizers.

2.3 Field and laboratory study

Extensive laboratory and field studies were undertaken to evaluate the physico-chemical and biological properties of mine spoil and selection of appropriate blend of spoil and press-mud. Laboratory and field studies were also undertaken to select the most suitable plant species for the dumps. On the basis of this study different plant species like teak (tectona grandis), shishum (dalbergia sissoo), shiwan (gmelina arborea), neem (azadirachta indica), karanj (pongamia pinnata), cassia (cassia seamea), awala (emblica officinalis) and bamboo (dendrocalamus strictus) were selected for plantation on manganese spoil mine dump. Plantation of these species was carried out by pitting method and plants were inoculated with specific bio-fertilizer cultures and VAM.

3. Integrated biotechnological approach (IBA)

The IBA is a systematic procedure towards scientific reclamation of mine spoil dumps by:

- Co-recycling of mine spoil, with a sugar mill waste known as press-mud. It helps resolve waste disposal problems and the organic waste provides suitable substance for proliferation of soil microflora.
- Besides, it involves inoculation of plants with specialised cultures of endomycorrhizal fungi of glomus spp and bio-fertilizers like rhizobium and azotobacter for improving nodule formation, solubilization of phosphate, profuse root development. There is no groundwater pollution due to nutrient leaching. Further, micro organisms also secrete hormones, auxins etc., which helps improve plant establishment and growth.
- Ecological cycles in rhizosphere are restored in just 18 to 20 months time, which otherwise takes decades. IBA also helps establish fruit trees like mango, sapota and pomegranate etc.

3.1 Methodology used for plantation at different sites

Pitting technique was adapted for plantation on slopes of mine spoil dumps. Pits at slope of dump were 0.6 m × 0.6 m × 0.6 m dimension and at elevated level were 1m × 1m × 1m size dimension. Each pit was filled with 4 parts of spoil + 1 part of soil. The most responsive treatment selected for plantation at Dongri Buzurg mine was 4 parts of spoil + 1 part of soil + press-mud @ 100 t/ha. The VAM spores (10g) having approximately 30 spores were applied to each pit by mixing with blending material to enhance the nitrogen fixation, development of profuse root system in plants, solubilization and mobilization of nutrients. Improvement in various physico-chemical properties of mine spoil and microbial population such as bacteria, fungi. Actinomycete, rhizobium, azotobacter and VAM spores were determined from suitable method by NEERI scientists.

3.2 Growth performance of plant

Plants of high timber value like teak, shishum, neem, industrial plants like bamboo and others of ecological importance like cassia, karanj, shiwan etc were planted on spoil dumps. IBA significantly improved plant growth 7 to 9 fold, while survival rate for plants like teak, neem, shishum, shiwan, bamboo etc., ranged from 84 to 92 per cent as depicted in Figs.1 and 2. Further, use of IBA helped plants like teak, shiwan, bamboo develop large leaves.

3.3 Major achievements of IBA

- Plant survival rate increased from 15 to 87%.

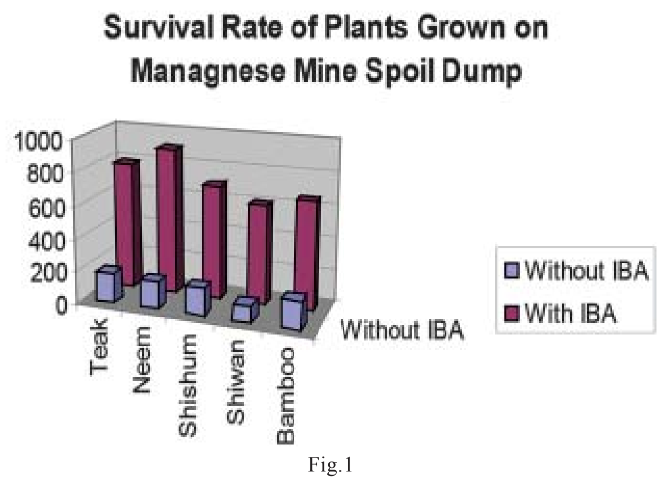

Fig.1

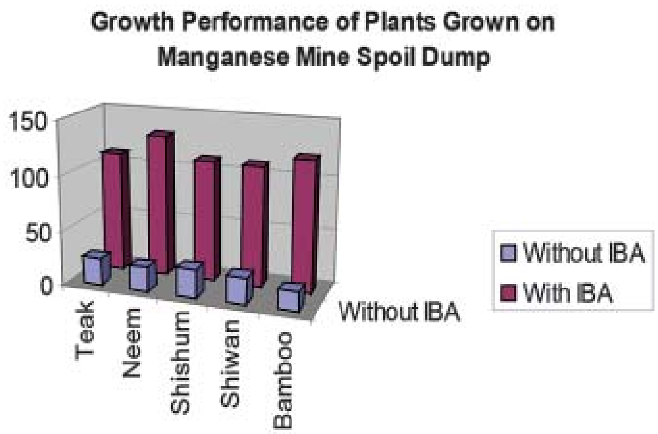

Fig.2

- Plants of teak, shishum, neem, shiwan etc. developed luxuriant green cover.
- Growth rate 7-9 fold higher due to IBA
- Excellent nodulation (250-370) in leguminous plants.

3.4 Environmental protection by afforestation

MOIL Limited is doing excellent work in protecting the environment in and around the mines to achieve ecological balance. The company is doing massive afforestation programme since beginning of 1980's and an average 80000 saplings are planted every year with the survival rate of above 80%. Mine-wise plantation details are given below with survival rate.

4. Study of buffer zone

The Dongri Buzurg opencast mine is located in Bhandara district of Maharashtra (Fig.3). Method of mining is mechanized. Shovel and dumpers are deployed for overburden removal and ore excavation. The study is being conducted by IIEST, Shibpur.

4.1 GIS and principal components analysis (PCA)

The spatial analysis of environmental quality data, around a mine site, was carried out under GIS environment using raster based GIS software ILWIS 3.3 (Integrated Land and Water Information System) academic version. Spatial maps are prepared as outputs showing environmental quality around a specific mine site. The principal components analysis (PCA) was carried out using SPSS software to investigate the factor loadings and weights of the air and soil quality parameters.

4.2. Database on environmental quality parameters

Air quality data are collected from the nine village sites falling within the 5 km buffer zone of the mining lease area and also from eight locations in the core zone (leasehold area) for estimation of mining footprint (air) by spatial analysis using GIS (Table 4).

Table 4: Descriptive statistics of air samples

Variable	Observation	Mean	Standard deviation	Minimum	Maximum
PM_{10}	17	58.576	6.857	47.9	68.3
$PM_{2.5}$	17	18.688	3.491	13.6	23.8

Sixteen soil samples were collected by using hand augers at the two specific levels of the soil horizon, which were at 15 cm and 30 cm from the surface. Samples were either collected from paddy field adjacent to the villages or waste dumps created by mining. In soil sample available nitrogen, phosphorus, potassium (NPK) and organic carbon were analyzed. Descriptive statistics of the soil samples is provided in Table 5.

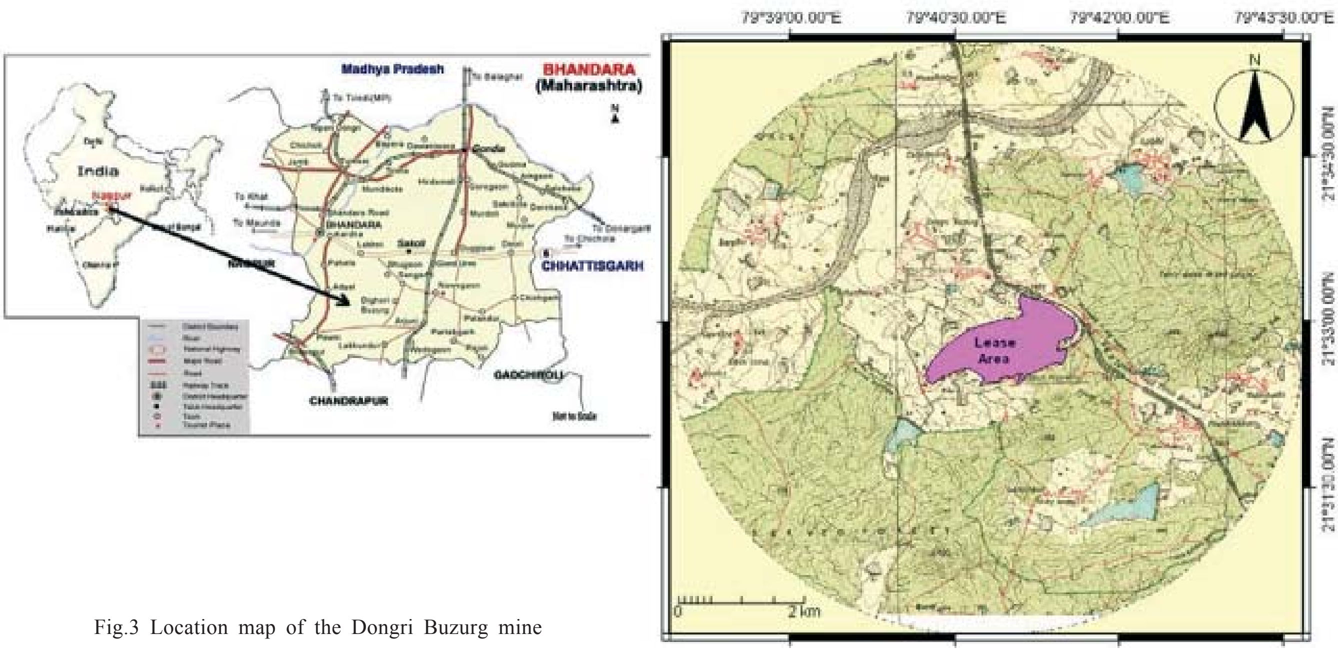

Fig.3 Location map of the Dongri Buzurg mine

TABLE 5: DESCRIPTIVE STATISTICS OF SOIL SAMPLES

Parameter	No. of samples	Mean (lbs/acre)	Standard deviation
Nitrogen	16	285.97	40.96
Phosphorous	16	18.41	1.64
Potassium	16	39.58	4.03
Organic carbon	16	1.03	0.25

Water samples are collected from eleven sampling locations. Results are within the permissible limit Therefore the sample results are not discussed and further analyzed.

4.3. SOCIO ECONOMIC DATA

Village level household database is examined to find out the basis on which households can be stratified for detailed questionnaire survey. Household-wise information is collected on education level, land holdings, animal husbandry, employment, asset, income level. Only employment pattern amongst households show significant variation. Hence, the village households can be stratified on the basis of primary employment of each household. Ten per cent households from each types of employment pattern are interviewed.

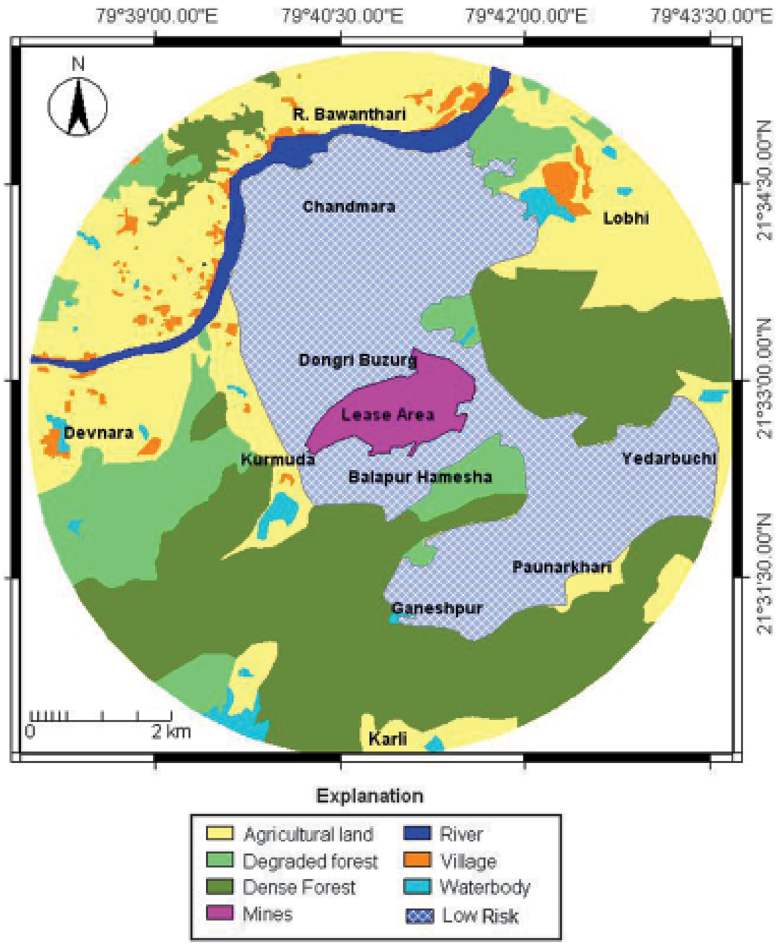

Fig.4 Combined map showing air quality in the region

TABLE 6: FERTILITY RATING

Indicators	Standard values		
	High fertility	Medium fertility	Low fertility
Available phosphorous	>21.95	8.92 to 21.95	<8.92
PH	>0.75	0.50 to 0.75	<0.5
Available nitrogen	>499.62	249.8 to 499.62	<249.8
Available potassium	>249.81	96.35 to 249.81	<96.35

Source: Department of agriculture and cooperation, Ministry of Agriculture, Government of India dated as Jan, 2011

4.4 RESULTS

4.4.1. Spatial and statistical data analysis of air samples

Using the derived weights air quality index for each air quality parameters as well as the overall air quality index is calculated. The derived value of overall air quality permissible limit is 113.12. This implies that any air quality index above this value comprises risk. Therefore, an air quality index 113.12 is a cut-off value above which the air quality in the area is high risk. The maximum value of air quality index is 64.98, which is much below the cut-off value 113.12. By GIS software a composite thematic map using the value of PM_{10} and $PM_{2.5}$ is prepared showing the distribution of air quality index in the buffer zone. The Fig.4 is a composite map showing air quality indices at each pixel. Air quality index below 113.12 are no risk zones.

4.4.2 Spatial and statistical data analysis of soil samples

Using sample results, composite soil quality map is prepared. Similar procedure for map preparation, as described in the earlier subsection with respect to air quality, is followed. Soil sample data are interpolated by using GIS software ILWIS 3.3. Different soil fertility ratings are shown in Table 6. Any value below this rating indicates that there is risk of major changes in fertility status of the soil.

4.4.3 Statistical analysis of socio economic database

Statistical analysis is done to develop knowledge base about the villager's perception on unresolved issues pertaining to sustainable development. Table 7 shows distribution of the villagers based on their need priorities that they have expressed during their personal interviews. Village level database is built based on survey in 1071 households. Households are stratified on based on primary employment of the households. Detailed questionnaire survey was conducted in 107 households. Need priorities for sustainable living based on the responses of the villagers is furnished in below:

Table 7: Showing needs priorities of villagers

Need priorities of villagers	Frequency	Percentage
Enhancing land quality and irrigation facility – Natural capital	41	38.32
Employment generation and training – Human capital	6	5.61
Infrastructure facilities – Physical capital	45	42.06
Cannot say	15	14.02
Total number of respondents	107	100

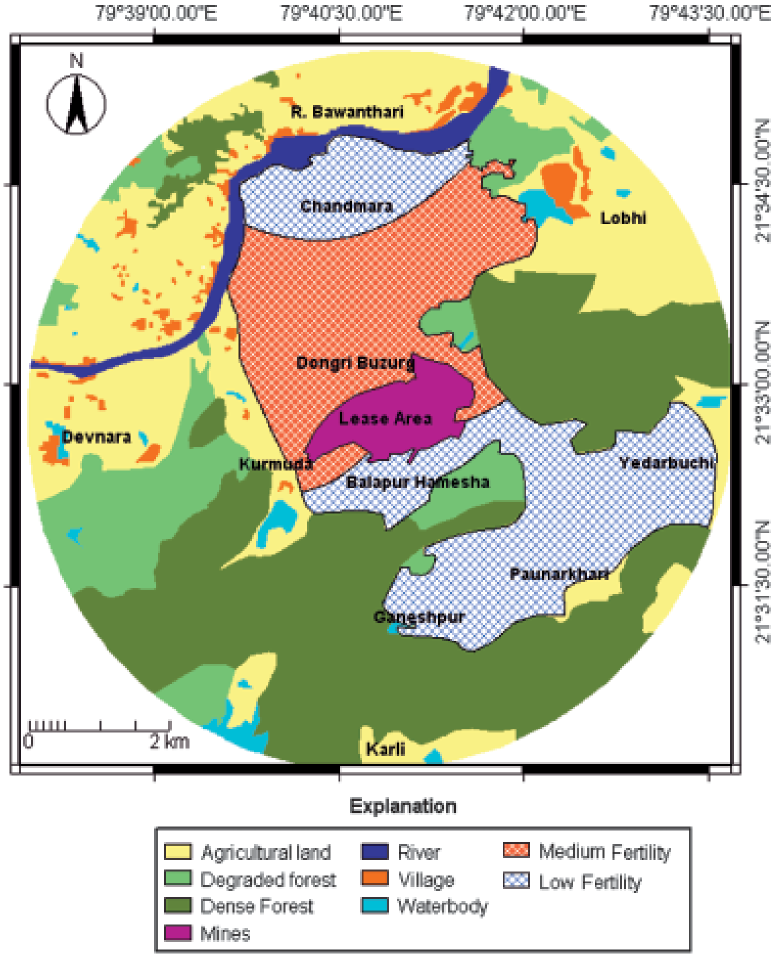

Fig.5 Soil quality map showing fertility status (0-15cm)

5. Conclusions

Continuous use of sustainable development technologies in the Company, employees of MOIL Limited feels that it has been transformed into an entirely different company, what it was a few years back as the quality of life has been improved considerably. It is a matter of great pride that for the first time in the country integrated biotechnological approach has been successfully adopted in MOIL Limited and the mine has been awarded 5 star certification from the Ministry of Mines for 2 years. This activity created eco-friendly environment in the Company and, we believe in the use and not abuse of the abundant wealth of nature and is making efforts toward the maintenance of the ecological balance. SDF has also improved the agriculture activities in the buffer zone area and it is also found that water table is being maintained. Local villagers are also provided with solar lamps and other accessories for their livelihood by MOIL.

References

1. Davis, J.C. (1973): Statistics and Data Analysis in Geology. Wiley. New York, p.550.
2. DFID. (2000): Sustainable Livelihoods Guidance Sheets, Department for International Development, available in website http://www.livelihoods.org/info/info guidance sheets.
3. Harman, H. H. (1967): Modern factor analysis (2nd ed.), Chicago, University of Chicago Press.
4. ICMM, (2008): Planning for Integrated Mine Closure: Toolkit available in website https://www.icmm.com document/310l
5. Wackernagel, M., and Rees, W. E. (1997): Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspective Ecological Economics, 20, 3-24.
6. World Commission on Environment and Development (1987): Our Common Future. Oxford: Oxford University Press. p. 27. ISBN 019282080X
7. Yoshida, Mitsuo. (2008): Environmental Management-Urban Solid Waste and the Project for Improvement of Waste Management in UB City available at website, www.jica.go.jp/english/our_work/.../tech.../mongolia_2012_01.pdf
8. LeBlanc, F. and Rao, D.N. (1975): Effects of air pollutants on lichen brophytes. In: Response of air pollution (Eds: J.B. Mudd and T. T. Kozlowski). Academic Press. New York, 237-272
9. Joshi, P.C. and Swami, A. (2007): Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. *Environmentalist, 27*, 365–374.
10. Liu, Y. and Ding, H. (2008): Variation in air pollution tolerance index of plants near a steel factory: Implications for landscape-plant species selection for industrial areas. *WSEAS Trans. Environ. Develop.,4*, 24-32.