

Breakthrough in Improvement of Environment and Forest Ecosystem Through Rehabilitation of Mines and Reclamation of Biodiversity in Iron Ore Mines at Bellary Sector of Karnataka India.

Dr. U.V.Singh I.F.S (rtd)

*Member, Monitoring Committee of Hon'ble Supreme Court,
Khanija Bhavan, Bengaluru- 560001
uvsingh@yahoo.com*

ABSTRACT

Mining is one of most destructive red industry responsible for degradation of all major components of the environment i.e. land, water, and air. The illegal mining coupled with excess illegal extraction of iron ore fueled to pollute the environment of Bellary sector during the first decade of this millennium. After series of investigations and reports, the Hon'ble Supreme Court of India took the cognizance and directed State Government to rehabilitate and reclaim the mining leases which are under operation/inactive. The task of preparation of rehabilitation and reclamation plans (R&R Plans) of all mines of iron ore in the Bellary sector was assigned to Indian Council of Forest Research and Education, Dehradun. The monitoring committee appointed by the Hon'ble Supreme Court was requested to monitor the implementation of R&R Plans. The author is one of the members of the three-member Committee. Various engineering structures for rehabilitation and biological measures for reclamation of biodiversity have been discussed in this article. Overall an area of about 10913.00ha. of 166 mines at the cost of Rs. 362.83 crores have been rehabilitated. Photographs of various works carried out in mines have been displayed. The implementation of R&R Plans is the milestone in overall improvement of environment in the history of mining sector. The environment, state of mining, illegalities, investigation and rehabilitation works as discussed in this article for Bellary sector is a result of direct contribution of the author for eighteen years.

Key words: mining leases, retaining wall, over burden dumps, inactive dumps, settling ponds, reclamation, biodiversity, rehabilitation, gullies and check dams, monitoring committee.

1 Introduction

Since the beginning of this Millennium/ Century, the iron ore mines in the Country was known with bad reasons .The Hon'ble Supreme Court of India while delivering a landmark Judgement dated 18.04.2013 in WP 562 of 2009 has observed that the present is a case of mass destruction of the forest wealth of this country resulting not only in a plunder of scarce natural resources but also causing irreparable ecological and environmental damage and degradation and the extent of illegal mining that had happened in the three districts of the State of Karnataka is unprecedented.

With this background, the Hon'ble Supreme Court of India has directed the Government of Karnataka to formulate Rehabilitation and Reclamation Plans (R&R Plans) for all leases in the mine affected districts viz., Bellary, Chitradurga and Tumkur. The task was entrusted to Indian Council of Forestry Research and Education (ICFRE), Dehra Dun, by the Government of Karnataka, vide letter

No.DMG/MLS/R&R/2011-12, dated, 27.12.2011. The ICFRE prepared the plans and approved by the Central Empowered Committee New Delhi.

While preparing R&R Plan, data such as topography, production technology, overburden dump, top soil, soil conservation measures, environmental quality etc. were collected for assessment of the existing scenario and environment to assess impacts and formulation of site-specific model R&R plans.

It is to state here that each mine has a mining plan prepared and approval by the Indian Bureau of Mines. In the said plan there is provision to rehabilitate and reclaim the mine at the end of closing lease period and also to take measures during mining to keep the lease to maintain healthy environment. But due to failure in system, it has never been materialized. Further the lessees are requiring to take prior approval under the Section 2 of Forest (Conservation) Act 1980 to maintain the greenery in the non-mining areas as condition but this also could not be implemented properly.

The heavy mining has changed the physical, biological and socioeconomic environment in terms of land degradation and in the process large unscientific overburdens dumps have been accumulated. The planning has been aimed for topographic reconstruction with engineering and biological measures for erosion control, re-vegetation, adequate soil amendments including mycorrhizal fungi for re-establishment of nutrient cycle for sustainable restoration.

The engineering structures in the restoration process have been discussed based on the hydrological condition on the micro watershed basis and compatibility of the surrounding area stability and drainage density. The plans include the enlisting of the existing and proposed engineering structures within and outside the lease areas.

The biological measures for management of overburden dumps, mine pit area, refractory sites, mine drainage, surface water, haul road etc., with suitable techniques to improve the ability and to support the vegetation growth has been incorporated with the application of organic matter, and use of geotextile/geo-matting with adequate water facilities during lean seasons and requirement basis.

The biodiversity conservation of the lease area has been taken care to set aside an area of 2.0 ha or so considering the importance of the surrounding forest ecosystem in terms of its environmental services. Suitable local floral species have been employed for restoration of the mined areas for overall ecosystem development and in long term to make use as timber, fodder, fuel wood and medicinal plants to meet the community requirement.

The Forest types in the area belongs to Southern tropical dry deciduous forests according to Champion and Seth Classification 1968. The area falls under the mixed deciduous sub-classification. But as per the classification of Legris and Pascal (1982), the area comes under Deciduous climax forests. The plant resources inside and outside the mine lease area contains more than 200 species of herbs, shrubs and trees. Many of them are potential medicinal values

The inactive dumps as identified by the Joint team in survey were taken into consideration for rehabilitation and reclamation. The height of waste dumps varies from mine to mine and measure of treatment were suggested based on height, slope and nature of the waste dumps. The angle of the slope of the dumps in some mines were found to be very steep.

Rehabilitation and reclamation plans will be useful in providing a framework and process to various target groups, the industry, regulatory agencies, the mine companies and others interested stake holders in iron ore mining for undertaking scientific rehabilitation and reclamation of mined out areas. Plans will also provide the essential insight in environmentally safe planning of mining activities in future.

The rehabilitation and reclamation program are basically aimed at developing an ecosystem with floral, faunal and soil characteristics to a certain extent similar to that of the pre-mining stage. The cost of Rehabilitation and Reclamation Plans shall have to be borne by the respective lessees. Overall an area of about 10913.00ha. of 170 mines/leases at the cost of Rs. 362.83 crores have been spent under rehabilitation plans.

The iron ore resource area in the sector is a part of residual hills and pediment over Dharwar group with narrow bands of resistant ridges which has poor ground water potential. Good potential of ground water is observed along structurally controlled zones. The most buffer zone pediment over peninsular gneiss, residual hills and resistant ridges/ hemiclinal ridges which acts as poor to moderate ground water potential areas, moderate to good along fractures and hemiclinal ridges along dip ward side. The depth of the working pits may touch maximum of 800m to 1000m (MSL). The water table lies at about 500m (MSL) around the villages situated 2.0 km in periphery. Therefore, there will be no ground water seepage in the working pits. The Sandur hills are characterized by gorges and steep hills with lush green vegetation broken up frequently by numerous mines.

The Karnataka State Pollution Control Board also observes the surface and ground water quality regularly. The results show that the pH value varies between 8.6 (Narihalla dam back water) to 6.7 and is within the permissible limit in most of the samples. The total hardness varied between 88 to 1120 mg/l and has exceeded the permissible limit (600 mg/l). The parameters like magnesium, chloride, sulphate, nitrate, fluoride and iron were well within the permissible limits. However, calcium has exceeded the permissible limit in water samples obtained from Yeshvantnagar (287 mg/l).

Iron ore mines are open cast mining and in the process several changes do take place in the physical, chemical, biological and microbial properties of the mines/soils. The level of changes/degradation depends on climatic conditions and various other factors. Leaching remove the nutrients released by microbiological activity due to the rainwater erosion and in the process the nutrient cycle breaks down, resulting the soil become biologically unproductive.

The Hon'ble Supreme Court vide Judgement dated 18.04.2013 in WP 562 of 2009 set certain guiding factors/framework to be adopted for formulation of Rehabilitation and Reclamation plan as under:

- i. broad design/specification for a) garland drains b) retaining walls c) check dams d) gully plugs and/or culverts (if required)e) geo textile/geo matting of dumps f) afforestation in the safety zones g) afforestation in peripheral area, road side, over burden dumps and other areas.
- ii. dust suppression measures at/for loading, unloading and transfer points, internal roads, mineral stacks etc.
- iii. covered conveyor belts (if feasible) - such as downhill conveyor, pipe conveyor etc.
- iv. specification of internal roads,
- v. details of existing transport system and proposed improvements
- vi. railways siding (if feasible)
- vii. capacity building of personnel involved in the mining and environmental management
- viii. rain water harvesting.

In the above background this work has been taken up.

2 Results and Discussion

The objective of this article is to suggest suitable engineering and biological measures for overall Rehabilitation, Reclamation and management of over burden dumps, surface water greening of mines

for rejuvenation of lost biodiversity and over all land use of the mined-out area for improvement of environment and forest ecosystem through rehabilitation of mines and reclamation of biodiversity within the parameters framed by the Hon'ble Supreme Court.

2.1 Over burden dumps management

Over burden dumps get generated in the mines due to expansion of pits and formation of benches, contain parts of soil, gravel and stones of very low-grade ore. If they are not rehabilitated properly, result in flow of sediments and other materials into nala/stream courses, which contaminate the forest, agriculture and horticulture lands down below the mine lease area. Therefore, to stabilize the dumps and to protect the biodiversity, the rehabilitation and reclamation of dumps is a prerequisite. The existing dumps needs to be treated by using physical and biological measures. The details of engineering and physical measures such as retaining wall, benches and garland drains shall be carried out. An ideal way is to use geo-textile or coir mates (Figure-1) followed by seed broadcasting and planting of seedlings of suitable plant species. Seed broadcasting has to be taken up by using hydro seeding or by spreading slurry manually. Hydro seeding is being successfully practiced to stabilize barren steep slopes and fragile unstable surfaces. The system requires water, seeds, farm yard manure and mulch which are applied on the surface in the form of fine spray. All along the slope of the dumps, garland drains with bottom width of 0.5 m, top width two meter with side slope 1:2 and one-meter height should be constructed and connected to natural drain/nala. Cost effective hydroseeding is suggested for implementation with bioengineering measures especially in afforestation activities. The species suggested for seed broadcasting/hydroseeding are shown in Table -3 These species are capable of getting established in due course of time in disturbed areas. The species recommended for hydroseeding on mine dumps and fragile unstable surfaces are given in Table -3. In addition to hydroseeding, planting of suitable herbs, shrubs, creepers and trees have to be done on the slopes by making holes in geo-textile coir mat. For gentle slopes of dumps, benches and trenches has to be made, followed by seed broadcasting of herbs and planting of seedlings of shrubs and tree species as suggested in table -4 will help in reclamation of vegetation.



Figure 4 Coir mating/ geo-mating on waste dump

2.2 Stabilization of waste dump

In the working mines, there exists two types of waste dumps i.e. inactive and active dumps. Rehabilitation and Reclamation is being carried out for inactive dumps only. The active dumps are in use and shall only be treated once they attain to finality. The most of mine waste contain mainly of limonitic laterite, phyllites/shales, ferruginous clay, silt and dyke etc. There are no toxic or heavy

metal content observed in these wastes which may cause to leach out and pollute the surrounding surface areas or the ground water system in catchment. **(Figure-2)**



Figure 5 Process of coir matting in halfway on the dumps (overburden dumps)

2.3 Inactive dumps

The number of dumps in a mine depends on the size/area of the mine. Over the years gullies have been formed and resulted into uneven surface. In many mines, dumps are placed in the valleys and in the process blocked the water course. The slope gradient varies from gentle to steep. Terracing has not been carried out and the slope of the dump is some times more than 50°. In many mines' dumps have been spread out of the leased area. The surface area covered under dumps also varies from mine to mine. Generally, the quantum of dumps is known by its declaration made to Indian Burro of Mines or volumetric assessment. In some leases the waste has been used for back filling of exhausted pits. For further reclamation and rehabilitation /stabilization of dumps the measures suggested will include terracing to be carried out when the slope of the dump is more than 50° within time bound program. Terracing of the dumps is must if height is more than 30.0 meter. Levelling of outer surface and regular watering is must. Broadcasting of local grasses seeds is essential. On the second-year planting of local leguminous species should be done. Glaricidea (locally known Gubly) cuttings/seedlings may be made use for planting which is found reasonably good. For providing stability to the dumps, construction of retaining walls along the toe of the dumps is must. Coir net / blanket should be spread and native grass seed mix should be broadcasted uniformly on prepared slopes. By this practice the dumps are reclaimed with adequate biodiversity **(Figure-5)**

2.4 Retaining walls

A retaining wall is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil. A basement wall is thus one kind of retaining wall itself. But the term usually refers to a cantilever retaining wall, which is a freestanding structure without lateral support at its top. Retaining wall to be constructed may be of various dimensions in different places but it is desirable to have a dimension of Length X 2.5 X 1.75 m with one-foot RCC at the bottom as foundation.

2.5 Surface water management

The rainwater accumulating in the worked-out area may get collected in the mining pit. After filtration, this water should be pumped out for making used for dust suppression and green belt development. Suitable garland drains and sedimentation pits all along the active mine areas shall be constructed to prevent soil erosion and runoff.

The run-off water falling directly on the mined-out area, temporary ore dumps, and waste OB dumps are likely to be turbid and may have enriched with heavy metals. Hence, soil conservation measures have to be taken to arrest siltation of all the streams/*nalas* around the mine areas through construction of engineering structures and adoption of biological measures. In this context, engineering measures such as construction of check dams and gully plugs covering such areas should be established.

All the existing drains arising from the mine area should be well connected to natural streams/*nalas* only after passing through bio-engineering structures. Garland trenches should be provided all along the OB dumps, ore and sub grade ore dumps of mine area to prevent soil erosion which may result in siltation of the streams. By adopting the above measures, the aquatic faunal diversity if any may not get affected from the mining activity.

2.6 Gully plugs

Gullies are entrenched channels extending into areas with previously undefined or weakly defined channels. A variety of methods have been used to stabilize, rehabilitate, or restore the effects of gully erosion. Gully plugs are earthen embankments usually constructed for blocking the active and erosion prone gullies for their stabilization. Depending on the runoff, slope and rainfall pattern, the number of Gully plugs shall be constructed. 6mx2mx1m.

2.7 Garland drains

Suitable garland drains Lengthx2mx1m surrounding the waste dumps along the retaining walls and parallel to the mud roads should be constructed, so that water flows out of the mining area in to the valleys where the construction of check dams is proposed. This will also prevent the accumulation of rain water within the pits. garland drains with bottom width of 0.5 m, top width two meter with side slope 1:2 and one-meter height should be constructed and connected to natural drain/*nala*. Regular de-silting has to be carried out, i.e., before and after monsoon season and the silt material can be used for plantation purpose. The species recommended for hydro seeding on mine overburden dumps and fragile unstable surfaces are given in Table -3. In addition to hydroseeding, planting of suitable herbs, shrubs, creepers and trees have to be done on the slopes by making holes in geo-textile coir mat. For gentle slopes of dumps, benches and trenches has to be made, followed by seed broadcasting of herbs and planting of seedlings of shrubs and tree species as suggested in table-4 will help in reclamation of vegetation.

2.8 Masonry check dams

Masonry check dams (length x 3m x3m) are small dams which may be permanently built across a minor channel or drainage (**Figure-3**). Similar to drop structures in purpose, they reduce erosion and gully in the channel and allow sediments to settle. They also lower the speed of water flow during storm events. Frequent removal of silt is required from upper side. Check dams should be built with masonry in general but logs, stone, or sandbags may be used for temporary structures. Check dams are usually permanent or sometimes semi-permanent; and the sandbag check dam is usually for temporary measures

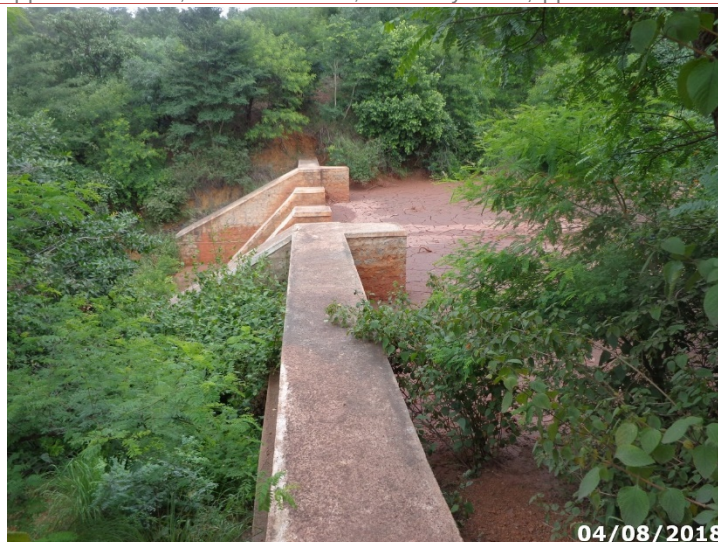


Figure 6 Masonry check dam constructed across the Nallah outside the lease area.

2.9 Settling ponds

Settling ponds (**Figure-4**) are simple ponds that collect water so diverted to them that it can be relatively calm for a period, thereby allowing suspended solids to precipitate or "drop out" of the water. Settling ponds are basically used for:

Impoundments for process of contaminated water derived from floating or dry land dredges or other forms of mining placer that can deposit significant amount of sediment at bottom and water reused. Impoundments for sediment laden water running off from excavated or stripped lands of leased area. Impoundments designed for percolation, infiltration or evaporation of water. May not be advisable in dry areas.

The number of Settling ponds in a lease depend on the quantity of water getting drained off. Likewise, the size of ponds also. 30m x 15m x 3m ponds are suitable size in this region. If space and suitability fits in the leased area it should be preferred within by the side of waste dumps to slow down the flow of water and to arrest the loose sediments from the waste dumps and also to store water for watering the green belt and grasses on dumps. The settling tanks should be constructed in stone masonry in cement sand mortar 1:5 and shall be plastered from inside. Regular de-silting has to be carried out, i.e., before and after monsoon season and the silt material can be used for plantation purpose.



Figure 7 Settling tank for retention of drain off water.

2.10 Reclamation of biodiversity of the leases

The forests of Bellary sector fall under two sub-groups, namely, Southern Tropical Dry Deciduous and Southern Tropical Thorn Forests. Considering the importance of the forest ecosystem in terms of its environmental services suitable floral species are required to be planted for restoration of the mined-out areas for timber, fodder, fuel wood and medicinal plant to meet the community requirement and overall ecosystem development. Establishment of nursery for the species to be planted in the area shall be established involving unemployed youth and women by providing adequate training, in a buy back mode, for sustainability and income generation for the society. Inoculation of microbial bacteria and fungi in the nursery stage for the planting stock will improve the growth and establishment of planting. Educated local people may be brought in for employment for planting and regular monitoring of the afforested areas. To cater to the needs of plantation activities, a nursery may be established in each lease with the criteria of: a). Minimum of one acres of land should be reserved for setting up the nursery. b). Local people who are familiar with the local flora may be employed. c). Seeds of the species as prescribed for various purposes should be procured locally for raising the seedlings d). Unemployed youth and women may be employed in the nursery. They should be given adequate training in nursery techniques.

The habitat management in and around the mine lease areas must be adapted by planting suitable fodder species to enable wild herbivores to thrive upon. A dense green belt consisting of shrubs and trees of different species must be created around the mine lease areas and also along the haul roads. This will act also as a sound and noise barrier. Awareness programs amongst the local people as well as mining staff regarding the importance of wild life, their habits and habitats should be organized.

2.11 Biological measures

Over the past several years the large-scale mining operations in the forest areas, have resulted in substantial impact on the ecosystem like land degradation, deforestation, disappearance of many valued species of plants, displacement of wildlife, besides adverse effect on aquatic eco-system. Various mining activities like excavation, transportation and ore processing of overburden's disposal etc, have caused extensive damage to the ecosystem.

It is absolutely necessary to take measures to implement good mining practices. Apart from engineering measures, biological measures are equally essential. Biological measures when implemented will result in the establishment of system that will be self-sustaining. As vegetation climax involves succession, any hindrance causes an imbalance in nature's operational process. To implement biological measures all the operational activity should be planned well in time.

Utmost care should be taken preserve the adjoining natural forests around the mine lease area. Management plan for Flora and Fauna has been provided below.

2.12 Afforestation

Afforestation of the mined - out and other available areas which are not fragmented but are degraded due to mining activity is the main component of re-vegetation process to mitigate the negative impacts of the mining on environment. By afforestation, restoration of the ecosystem if not as the original but almost similar vegetation prior to pre-mining period is possible and can be accomplished. In the context of the mines under study the mine lease area though not fully mined out, an afforestation plan has been formulated considering the conceptual closure plan of the mines. The afforestation covering 1000 trees and 2500 shrubs per ha, inclusive of maintenance for five year has been worked out as per the norms of State Forest Department, Karnataka.

Afforestation shall be carried out through: Propagates (seeds, lignotubers, corms, bulbs, rhizomes and roots) stored in the topsoil; and sowing seed; Planting nursery-raised seedlings by seed dibbling. Transplants of individuals from natural areas. Transfer of undisturbed soil along with vegetation – the transfer of substantial amounts (around 1 m² or more in area and 200–300 mm depth) of relatively undisturbed soil with its vegetation intact from natural areas could be transferred for improving the degraded soil.

2.13 Species Selection

While selecting the plant species care should be taken such that natural habitat surrounding the mine lease area is not altered. The balance between soil, microflora and the surrounding atmosphere must be maintained. The ultimate objective of biological measures is to restore the natural biodiversity occurring in and around the area. The native species which occur in the natural vegetational area are the ideal species to be introduced. Exotics and weedy species which colonize and invade the natural habitat should not be planted. Naturally occurring legumes should always be preferred for their ability to improve soil fertility. The habitat improvement in and around the mine lease areas should be adopted by planting suitable fruit, fodder and shade bearing species to encourage faunal/avian/insects' population. Encouraging the native fauna to return to the areas cleared for mining is a fundamental part of any rehabilitation program that aims to restore a natural ecosystem which includes the important management plans for the conservation of fauna.

The grasses/ herbs/ shrubs/trees species as available locally in abundance can be used for biodiversity reclamation. For stabilization of steep slopes rows of grasses are to be planted. Clumps of grasses can be collected from adjacent and nearby areas without destroying the grass cover of the adjacent areas. This has been suggested since the grasses are drought tolerant and can colonize fast in low nutrient soil. Due to the presence of fibrous roots grasses can reduce soil erosion as they are the best sand binders.

The important grass species such as - *Bothriochloa pertusa*, *Chrysopogon fulvus*, *Cymbopogon flexuosus*, *C. martinii*, *C.citratus*, *Cynodon dactylon*, *Dichanthium annulatum*, *Eleusine indica*, *Heteropogon contortus*, *Pennisetum pedicellatum*, *Saccharum spontaneum*, etc., can be used for for planting in the form of slips and root stocks . It is suggested that the above grasses may be grown and multiplied in the nursery.

2.14 Importance of leguminous species

The Legumes play an important role in increasing the soil nitrogen for they have symbiotic nitrogen fixing bacteria. Seeds of species like *Atylosia scarabaeoides*, *Crotalaria albida*, *C. juncea*, *C. retusa*, *C. verrucosa*, *Indigofera cassioides*, *Cassia auriculata*, *Cassia occidentalis*, *Mimosa pudica*, *Stylosanthes fruticosa*, *Tephrosia purpurea*, etc., can be collected with less effort from adjacent locations and can be used for propagation.

Table -1 Grass species to be used and their propagation method for soil moisture conservation (SMC) and slope stabilization

Sl. No.	Species	Propagation method
1	<i>Aristida setacea</i>	Slips
2	<i>Bambusa arundinacea</i>	Rhizome/Seeds
3	<i>Bothriochloa pertusa</i>	Seeds
4	<i>Chrysopogon fulvus</i>	Slips
5	<i>Cymbopogon citratus</i>	Slips/Seeds
6	<i>Cymbopogon flexuosus</i>	Slips
7	<i>Cymbopogon martini</i>	Slips
8	<i>Cymbopogon nardus</i>	Slips
9	<i>Cynodon dactylon</i>	Rhizome/Seeds
10	<i>Dendrocalamus strictus</i>	Rhizome
11	<i>Dichanthium annulatum</i>	Seeds
12	<i>Eleusine indica</i>	Slips/Seeds
13	<i>Heteropogon contortus</i>	Slips/Seeds
14	<i>Pennisetum pedicellatum</i>	Seeds

Table -2 Nitrogen fixing species of mine areas

Sl. No.	Species	Family	Habit
1	<i>Atylosia scarabaeoides</i>	Fabaceae	Herb
2	<i>Cassia auriculata</i>	Caesalpinaceae	Shrub
3	<i>Cassia hirsute</i>	Caesalpinaceae	Shrub
4	<i>Cassia mimosoides</i>	Caesalpinaceae	Herb
5	<i>Cassia occidentalis</i>	Caesalpinaceae	Herb
6	<i>Cassia tora</i>	Caesalpinaceae	Herb
7	<i>Crotalaria albida</i>	Fabaceae	Herb
8	<i>Crotalaria juncea</i>	Fabaceae	Herb
9	<i>Crotalaria retusa</i>	Fabaceae	Herb
10	<i>Crotalaria verrucosa</i>	Fabaceae	Herb
11	<i>Indigofera cassioides</i>	Fabaceae	Shrub
12	<i>Mimosa pudica</i>	Mimosaceae	Herb
13	<i>Stylosanthes fruticosa</i>	Fabaceae	Herb
14	<i>Tephrosia purpurea</i>	Fabaceae	Herb
15	<i>Tephrosia villosa</i>	Fabaceae	Herb

Table -3 Species and its habit suitable for hydroseeding

Sl. No.	Species	Family	Habit
1	<i>Calotropis gigantea</i>	Asclepiadaceae	Shrub
2	<i>Calotropis procera</i>	Asclepiadaceae	Shrub
3	<i>Cassia auriculata</i>	Caesalpinaceae	Shrub
4	<i>Cassia sericea</i>	Caesalpinaceae	Herb
5	<i>Cassia tora</i>	Caesalpinaceae	Herb
6	<i>Crotalaria albida</i>	Fabaceae	Herb
7	<i>Crotalaria juncea</i>	Fabaceae	Herb
8	<i>Cymbopogon citratus</i>	Poaceae	Herb
9	<i>Cymbopogon flexuosus</i>	Poaceae	Herb

10	<i>Cymbopogon martini</i>	Poaceae	Herb
11	<i>Cymbopogon nardus</i>	Poaceae	Herb
12	<i>Cynodon dactylon</i>	Poaceae	Herb
13	<i>Dactyloctenium aegypticum</i>	Poaceae	Herb
14	<i>Dichanthium annulatum</i>	Poaceae	Herb
15	<i>Eleusine indica</i>	Poaceae	Herb
16	<i>Heteropogon contortus</i>	Poaceae	Herb
17	<i>Pennisetum pedicellatum</i>	Poaceae	Herb
18	<i>Stylosanthes hamata</i>	Fabaceae	Herb
19	<i>Tephrosia purpurea</i>	Fabaceae	Herb

2.15 Mine pit management and its rehabilitation

During the process of mining and at the end of its finality after extraction of iron ore, all hard overburden/wastes generated during mining operations should be used in back filling of mine pits or dumped in the worked-out area of the mine so as to maintain and bring back the original contour of the terrain as far as possible. The mine pits should be leveled after extraction of the ore to match the contour of the area. The stacked top soil shall be spread over on compacted back filled area in order to facilitate the re-vegetation, which in turn controls silt flow towards the downstream. The mine area shall be rejuvenated with indigenous and other economically important species of grasses, such as shrubs and trees Table-4.

Table -4 Plant species suitable for dumps and mine pit stabilization

Sl. No.	Plant species	Family	Habit
1	<i>Acacia catechu</i>	Mimosaceae	Tree
2	<i>Acacia chundra</i>	Mimosaceae	Tree
3	<i>Acacia nilotica</i>	Mimosaceae	Tree
4	<i>Agave Americana</i>	Agavaceae	Shrub
5	<i>Agave sisalana</i>	Agavaceae	Shrub
6	<i>Albizia amara</i>	Mimosaceae	Tree
7	<i>Albizia lebbeck</i>	Mimosaceae	Tree
8	<i>Albizia procera</i>	Mimosaceae	Tree
9	<i>Annona squamosa</i>	Annonaceae	Tree
10	<i>Anogeissus latifolia</i>	Combretaceae	Tree
11	<i>Azadirachta indica</i>	Meliaceae	Tree
12	<i>Bauhinia racemosa</i>	Caesalpiniaceae	Tree
13	<i>Boswellia serrata</i>	Burseraceae	Tree
14	<i>Bothriochloa pertusa</i>	Poaceae	Herb
15	<i>Calotropis gigantea</i>	Asclepiadaceae	Shrub
16	<i>Calotropis procera</i>	Asclepiadaceae	Shrub
17	<i>Cassia auriculata</i>	Caesalpiniaceae	Shrub
18	<i>Cassia fistula</i>	Caesalpiniaceae	Tree
19	<i>Chloroxylon swietenia</i>	Flindersiaceae	Tree
20	<i>Chrysopogon fulvus</i>	Poaceae	Herb
21	<i>Cymbopogon flexuosus</i>	Poaceae	Herb
22	<i>Cymbopogon martini</i>	Poaceae	Herb

23	<i>Cymbopogon nardus</i>	Poaceae	Herb
24	<i>Dalbergia latifolia</i>	Fabaceae	Tree
25	<i>Dalbergia sissoo</i>	Fabaceae	Tree
26	<i>Dendrocalamus strictus</i>	Poaceae	Shrub
27	<i>Diospyros melanoxylon</i>	Ebenaceae	Tree
28	<i>Dodonaea viscosa</i>	Sapindaceae	Shrub
29	<i>Dolichandrone atrovirens</i>	Bignoniaceae	Tree
30	<i>Eleusine indica</i>	Poaceae	Herb
31	<i>Ficus racemosa</i>	Moraceae	Tree
32	<i>Ficus religiosa</i>	Moraceae	Tree
33	<i>Garuga pinnata</i>	Burseraceae	Tree
34	<i>Givotia rottleriformis</i>	Euphorbiaceae	Tree
35	<i>Gmelina arborea</i>	Verbenaceae	Tree
36	<i>Grewia tiliifolia</i>	Tiliaceae	Tree
37	<i>Haldina cordifolia</i>	Rubiaceae	Tree
38	<i>Hardwickia binata</i>	Caesalpiniaceae	Tree
39	<i>Heteropogon contortus</i>	Poaceae	Herb
40	<i>Holoptelea integrifolia</i>	Ulmaceae	Tree
41	<i>Lagerstroemia parviflora</i>	Lythraceae	Tree
42	<i>Limonia acidissima</i>	Rutaceae	Tree
43	<i>Madhuca longifolia</i> var. <i>latifolia</i>	Sapotaceae	Tree
44	<i>Maytenus emarginata</i>	Celastraceae	Shrub
45	<i>Melia dubia</i>	Meliaceae	Tree
46	<i>Mitragyna parvifolia</i>	Rubiaceae	Tree
47	<i>Morinda pubescens</i>	Rubiaceae	Tree
48	<i>Pennisetum pedicellatum</i>	Poaceae	Herb
49	<i>Phyllanthus emblica</i>	Euphorbiaceae	Tree
50	<i>Pithecellobium dulce</i>	Mimosaceae	Tree
51	<i>Pongamia pinnata</i>	Fabaceae	Tree
52	<i>Pterocarpus marsupium</i>	Fabaceae	Tree
53	<i>Saccharum spontaneum</i>	Poaceae	Herb
54	<i>Santalum album</i>	Santalaceae	Tree
55	<i>Sehima nervosum</i>	Poaceae	Herb
56	<i>Soyimida febrifuga</i>	Meliaceae	Tree
57	<i>Stereospermum personatum</i>	Bignoniaceae	Tree
58	<i>Stylosanthes hamata</i>	Fabaceae	Herb
59	<i>Tamarindus indica</i>	Caesalpiniaceae	Tree
60	<i>Tecoma stans</i>	Bignoniaceae	Tree
61	<i>Terminalia bellirica</i>	Combretaceae	Tree
62	<i>Terminalia chebula</i>	Combretaceae	Tree
63	<i>Vitex negundo</i>	Verbenaceae	Shrub
64	<i>Wrightia tinctoria</i>	Rubiaceae	Tree
65	<i>Ziziphus mauritiana</i>	Rhamnaceae	Tree

Management of refractory sites

Being dry belt, there are many patches found with lack any nutrient containing soil and vegetation. Such areas shall be re-planted with local leguminous species coupled with grasses/shrubs. To start with species like *Agave americana*, *A. sisalana*, *Dodonaea viscosa*, *Euphorbia tirucalli*, *E. tortilis*, *Mimosa hamata*, *Tecoma stans*, *Sterculia urens* etc. which have been proved successful in extreme conditions may be planted

2.16 Rehabilitation of mine drainage

The rain intensity in Sandur area is very high. Therefore, the drainage systems of the mines are important component in rehabilitation. For this purpose following steps are required to be taken:

a) Proper gradient and drainage arrangement at the mine benches and over burden dumping area shall be provided. a) After trapping the suspended solids in garland drains just below the over burden dumps, the water should be allowed to flow down the dump slopes to join natural streams/nalas through settling tank with filtration arrangements, so that all the suspended solids and sediments shall have arrested. c) Plantation of indigenous and other economically important trees, shrubs, herbs and grasses at the point of discharge, where the mine outlet will pass through bio-engineering structures and on dumps has to be taken up, so that the sediment/silt flow will be arrested from the site and soil moisture can be maintained) The drain/nala bunds shall be planted with suitable grasses, herbs, shrubs and trees, as per the list provided in table 5. At steep slopes necessary engineering and biological measures should also be carried out to prevent soil erosion.

Table -5 Plant species suitable for stabilization of nallah/drain courses

Sl. No.	Plant species	Family	Habit
1	<i>Acacia nilotica</i>	Mimosaceae	Tree
2	<i>Agave Americana</i>	Agavaceae	Shrub
3	<i>Agave sisalana</i>	Agavaceae	Shrub
4	<i>Bambusa arundinacea</i>	Poaceae	Shrub
5	<i>Calotropis gigantea</i>	Asclepiadaceae	Shrub
6	<i>Calotropis procera</i>	Asclepiadaceae	Shrub
7	<i>Cassia auriculata</i>	Caesalpiniaceae	Shrub
8	<i>Chrysopogon fulvus</i>	Poaceae	Herb
9	<i>Cymbopogon flexuosus</i>	Poaceae	Herb
10	<i>Cymbopogon nardus</i>	Poaceae	Herb
11	<i>Dendrocalamus strictus</i>	Poaceae	Shrub
12	<i>Ficus racemosa</i>	Moraceae	Tree
13	<i>Heteropogon contortus</i>	Poaceae	Herb
14	<i>Indigofera cassioides</i>	Fabaceae	Shrub
15	<i>Murraya paniculata</i>	Rutaceae	Shrub
16	<i>Pennisetum pedicellatum</i>	Poaceae	Herb
17	<i>Phoenix loureiro</i>	Areacaceae	Tree
18	<i>Saccharum spontaneum</i>	Poaceae	Herb
19	<i>Stereospermum personatum</i>	Bignoniaceae	Tree
20	<i>Syzygium cumini</i>	Myrtaceae	Tree
21	<i>Terminalia arjuna</i>	Combretaceae	Tree
22	<i>Vitex negundo</i>	Verbenaceae	Shrub

2.17 Management of haul roads

Roads connecting to mines from the public roads are called haul roads. Their conditions are not good and caused to one of the main reasons of dust pollution., The roads must be regularly levelled and sprinkled with water to avoid dust during transportation of ore material through trucks. Tarpaulin covering during the transportation of iron ore is a must. All along the haul roads suitable fast growing avenue tree species, namely, *Albizia lebbbeck*, *Azadirachta indica*, *Cassia fistula*, *C. siamaea*, *Ficus benghalensis*, *Ficus racemosa*, *Gmelina arborea*, *Grewia tiliifolia*, *Muntingia calabura*, *Pongamia pinnata*, *Tamarindus indica*, *Tecoma stans*, *Thespesia populnea* and *Terminalia catappa* in three rows on either side should be grown to suppress the noise and dust pollution Table-6.

Table -6 Plant species suitable for avenue plantation along mine haul roads

Sl. No.	Plant species	Fa	Habit
1	<i>Acacia nilotica</i>	Mimosaceae	Tree
2	<i>Albizia lebbbeck</i>	Mimosaceae	Tree
3	<i>Albizia odoratissima</i>	Mimosaceae	Tree
4	<i>Albizia procera</i>	Mimosaceae	Tree
5	<i>Azadirachta indica</i>	Meliaceae	Tree
6	<i>Cassia fistula</i>	Caesalpiniaceae	Tree
7	<i>Cassia siamaea</i>	Caesalpiniaceae	Tree
8	<i>Dalbergia latifolia</i>	Fabaceae	Tree
9	<i>Dalbergia sissoo</i>	Fabaceae	Tree
10	<i>Ficus benghalensis</i>	Moraceae	Tree
11	<i>Ficus racemosa</i>	Moraceae	Tree
12	<i>Ficus religiosa</i>	Moraceae	Tree
13	<i>Gmelina arborea</i>	Verbenaceae	Tree
14	<i>Grewia tiliifolia</i>	Tiliaceae	Tree
15	<i>Muntingia calabura</i>	Ealeocarpaceae	Tree
16	<i>Pongamia pinnata</i>	Fabaceae	Tree
17	<i>Stereospermum personatum</i>	Bignoniaceae	Tree
18	<i>Tamarindus indica</i>	Caesalpiniaceae	Tree
19	<i>Tecoma stans</i>	Bignoniaceae	Tree
20	<i>Terminalia catappa</i>	Combretaceae	Tree
21	<i>Thespesia populnea</i>	Malvaceae	Tree
22	<i>Trema orientalis</i>	Ulmaceae	Tree

2.18 Green belt development

In order to minimize the impact of mining on environmental components outside the mine lease area, greenbelt zone (**Figure-6**) of 7.5m width should be established as safety zone inside mine lease area. The greenbelt should act as a barrier to trap the suspended dust particles and also suppresses air pollutants. It is also important to create a green belt with tall seedlings (>1 m height) of fast-growing species to hasten the process of greening the area. It is suggested that the areas which are not planted should be planted with the species specified in this report at the earliest. The important tree species as suggested in Table -7 for greenbelt plantation around the mine lease area in three rows (3mx3m spacing) may be planted. The multipurpose plant species recommended for

eco-rehabilitation and reclamation of mine areas are presented in table -7. Overall, all the vacant area within the lease and also outside shall be enriched with the planting of species as listed in Table-8



Figure 8 Successful rehabilitation of waste dump and reclamation of biodiversity at mones



Figure 9 Green belt created along the outer safety zone at the mining lease

Table -7 Plant species suitable for greenbelt development along safety zone

Sl. No.	Botanical name	Family	Habit
1	<i>Ailanthus excelsa</i>	Simaroubaceae	Tree
2	<i>Alangium salvifolium</i>	Alangiaceae	Tree
3	<i>Albizia lebbek</i>	Mimosaceae	Tree
4	<i>Azadirachta indica</i>	Meliaceae	Tree
5	<i>Boswellia serrata</i>	Burseraceae	Tree
6	<i>Cassia fistula</i>	Caesalpiniaceae	Tree
7	<i>Ceiba pentandra</i>	Bombaceae	Tree
8	<i>Dalbergia latifolia</i>	Fabaceae	Tree
9	<i>Dalbergia paniculata</i>	Fabaceae	Tree
10	<i>Dalbergia sissoo</i>	Fabaceae	Tree
11	<i>Ficus benghalensis</i>	Moraceae	Tree
12	<i>Ficus racemosa</i>	Moraceae	Tree
13	<i>Ficus religiosa</i>	Moraceae	Tree
14	<i>Givotia rottleriformis</i>	Euphorbiaceae	Tree
15	<i>Grewia tiliifolia</i>	Tiliaceae	Tree
16	<i>Haldina cordifolia</i>	Rubiaceae	Tree
17	<i>Hardwickia binata</i>	Caesalpiniaceae	Tree

18	<i>Holoptelea integrifolia</i>	Ulmaceae	Tree
19	<i>Lagerstroemia parviflora</i>	Lythraceae	Tree
20	<i>Madhuca longifolia</i> var. <i>latifolia</i>	Sapotaceae	Tree
21	<i>Melia dubia</i>	Meliaceae	Tree
22	<i>Mitragyna parvifolia</i>	Rubiaceae	Tree
23	<i>Phyllanthus emblica</i>	Euphorbiaceae	Tree
24	<i>Pithecelobium dulce</i>	Mimosaceae	Tree
25	<i>Pongamia pinnata</i>	Fabaceae	Tree
26	<i>Schleichera oleosa</i>	Meliaceae	Tree
27	<i>Soymida febrifuga</i>	Meliaceae	Tree
28	<i>Stereospermum personatum</i>	Bignoniaceae	Tree
29	<i>Tecoma stans</i>	Bignoniaceae	Tree
30	<i>Tectona grandis</i>	Verbenaceae	Tree
31	<i>Trema orientalis</i>	Ulmaceae	Tree

Table -8 Multipurpose plant species for eco-reclamation and eco- rehabilitation of

Sl. No.	Plant species	Family	Habit	Uses
1	<i>Acacia catechu</i>	Mimosaceae	Tree	C
2	<i>Acacia nilotica</i>	Mimosaceae	Tree	T
3	<i>Aegle marmelos</i>	Rutaceae	Tree	M, E, C
4	<i>Agave americana</i>	Agavaceae	Shrub	C
5	<i>Agave sisalana</i>	Agavaceae	Shrub	C
6	<i>Ailanthus excelsa</i>	Simaroubaceae	Tree	C
7	<i>Alangium salvifolium</i>	Alangiaceae	Tree	M,T
8	<i>Albizia amara</i>	Mimosaceae	Tree	T
9	<i>Albizia lebbeck</i>	Mimosaceae	Tree	T
10	<i>Annona squamosa</i>	Annonaceae	Tree	M,E,C
11	<i>Anogeissus latifolia</i>	Combretaceae	Tree	T
12	<i>Argyreia nervosa</i>	Convolvulaceae	Climbing shrub	M
13	<i>Azadirachta indica</i>	Meliaceae	Tree	M, T, F, C
14	<i>Bambusa arundinacea</i>	Poaceae	Shrub	E, C
15	<i>Boswellia serrata</i>	Burseraceae	Tree	M, C
16	<i>Bothriochloa pertusa</i>	Poaceae	Herb	F
17	<i>Calotropis gigantea</i>	Asclepiadaceae	Shrub	M
18	<i>Calotropis procera</i>	Asclepiadaceae	Shrub	M
19	<i>Cassia auriculata</i>	Caesalpiniaceae	Shrub	M
20	<i>Cassia fistula</i>	Caesalpiniaceae	Tree	M
21	<i>Cassia occidentalis</i>	Caesalpiniaceae	Herb	M
22	<i>Cassia tora</i>	Caesalpiniaceae	Herb	M
23	<i>Ceiba pentandra</i>	Bombaceae	Tree	C
24	<i>Celastrus paniculata</i>	Celastraceae	Climber	M
25	<i>Chloroxylon swietenia</i>	Flindersiaceae	Tree	M, T
26	<i>Chrysopogon fulvus</i>	Poaceae	Herb	F
27	<i>Crotalaria juncea</i>	Fabaceae	Herb	F
28	<i>Cymbopogon citratus</i>	Poaceae	Herb	M

29	<i>Cymbopogon flexuosus</i>	Poaceae	Herb	C
30	<i>Cymbopogon martinii</i>	Poaceae	Herb	C
31	<i>Cymbopogon nardus</i>	Poaceae	Herb	C
32	<i>Cynodon dactylon</i>	Poaceae	Herb	F
33	<i>Dalbergia latifolia</i>	Fabaceae	Tree	T
34	<i>Dalbergia paniculata</i>	Fabaceae	Tree	T
35	<i>Dendrocalamus strictus</i>	Poaceae	Shrub	E, C
36	<i>Dichanthium annulatum</i>	Poaceae	Herb	F
37	<i>Diospyros melanoxylon</i>	Ebenaceae	Tree	E, C
38	<i>Eleusine indica</i>	Poaceae	Herb	F
39	<i>Ficus benghalensis</i>	Moraceae	Tree	M, T, F
40	<i>Ficus racemosa</i>	Moraceae	Tree	M,E
41	<i>Ficus religiosa</i>	Moraceae	Tree	M,F
42	<i>Gardenia gummifera</i>	Rubiaceae	Tree	M
43	<i>Givotia rottleriformis</i>	Euphorbiaceae	Tree	C
44	<i>Grewia tiliifolia</i>	Tiliaceae	Tree	T
45	<i>Hardwickia binata</i>	Caesalpiniaceae	Tree	T
46	<i>Heteropogon contortus</i>	Poaceae	Herb	F
47	<i>Holoptelea integrifolia</i>	Ulmaceae	Tree	T
48	<i>Indigofera cassioides</i>	Fabaceae	Shrub	E
49	<i>Jatropha curcas</i>	Euphorbiaceae	Shrub	M, C
50	<i>Lagerstroemia parviflora</i>	Lythraceae	Tree	T
51	<i>Limonia acidissima</i>	Rutaceae	Tree	M, E, C
52	<i>Madhuca longifolia</i> var. <i>latifolia</i>	Sapotaceae	Tree	E, C
53	<i>Melia dubia</i>	Meliaceae	Tree	T
54	<i>Mimosa pudica</i>	Mimosaceae	Herb	M
55	<i>Mitragyna parvifolia</i>	Rubiaceae	Tree	T
56	<i>Morinda pubescens</i>	Rubiaceae	Tree	T
57	<i>Pennisetum pedicellatum</i>	Poaceae	Herb	F
58	<i>Phyllanthus emblica</i>	Euphorbiaceae	Tree	M,C
59	<i>Pithecellobium dulce</i>	Mimosaceae	Tree	E, F
60	<i>Pongamia pinnata</i>	Fabaceae	Tree	M, C
61	<i>Pterocarpus marsupium</i>	Fabaceae	Tree	M,T
62	<i>Santalum album</i>	Santalaceae	Tree	M, C
63	<i>Sehima nervosum</i>	Poaceae	Herb	F
64	<i>Soymida febrifuga</i>	Meliaceae	Tree	M
65	<i>Sterculia urens</i>	Sterculiaceae	Tree	M, C
66	<i>Syzygium cumini</i>	Myrtaceae	Tree	T, E,C
67	<i>Tamarindus indica</i>	Caesalpiniaceae	Tree	T, E,C
68	<i>Tectona grandis</i>	Verbenaceae	Tree	T
69	<i>Tephrosia purpurea</i>	Fabaceae	Herb	M
70	<i>Terminalia arjuna</i>	Combretaceae	Tree	M, T

71	<i>Terminalia bellirica</i>	Combretaceae	Tree	M, C
72	<i>Terminalia catappa</i>	Combretaceae	Tree	E,C
73	<i>Terminalia chebula</i>	Combretaceae	Tree	M, C
74	<i>Vitex negundo</i>	Verbenaceae	Shrub	M
75	<i>Wrightia tinctoria</i>	Rubiaceae	Tree	C
76	<i>Ziziphus mauritiana</i>	Rhamnaceae	Tree	E,C
M=Medicinal; T=Timber; E=Edible; F=Fodder; C=Commercial				

2.19 Establishment and preservation of biodiversity conservation areas

From the mining plans and approval accorded under Forest Conservation Act 1980, it is observed that few areas within the mining lease are untouched and having natural forests of the surrounding area. It is therefore fit to conserve small area for protecting the forests for conserving the local gene pool. This area may be marked and fenced to protect the forest as Biodiversity Conservation within the mining area. This germplasm reserve may be used for collection of seeds, seedlings, propagules which in turn could be used for raising seedlings in the nursery and planting. The main objective is to preserve the biodiversity components which will serve as a repository germplasm bank. In order to avoid anthropogenic pressure and to provide security for the area the lessee is suggested to fence the area with pillars and barbed wire.

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