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Bio-reclamation of Degraded Ecosystem

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Abstract

The flagstone is very valuable mineral used in traditional slabs and tiles, flooring, cladding of columns, building exteriors, stair cases, graveyard, pre-fabricated units, kitchen counters and dividers. It is also exported to earn foreign revenue. For sustainable stability of the ecosystem, selection of suitable species is very important. The native species occurring in adjoining natural forests need to be introduced along with N-fixing and fast growing tree species, shrubs as well as fruit bearing species attracting birds and other faunal population. On the sloppy areas seeds of grasses and legumes need to be broadcasted for preventing the soil erosion and to increase the water holding capacity. Since the area is rocky the introduction of ferns and fern allies would be useful to develop the natural ecosystem. On the basis of phyto-scociological studies and keeping the criteria of species selection in view, a number of tree, shrub and herb species were identified for reclamation of five flagstone mines.

Keywords: *Ecosystem stability, flag stone mines, phyto-scociology, reclamation*

1. Introduction

Opencast mining destroys the original land ecosystem and microbial community due to mining and stockpiling of mine rejects on adjoining land, is of great concern to environmental issues (Prasad, 1988). The site, thus, made available for reclamation and re-vegetation poses inhospitable conditions. The restoration to its original state is a very daunting task. Mining creates formation of wastelands, formation of gullies, ravines, overburdens, reduced water infiltration and increased runoff. The life support ability of the habitat is reduced. Pits are formed which during rains get filled up. Natural plant communities get disturbed and the habitats become impoverished due to mining presenting a very rigorous condition for plant growth. To combat the consequences of land degradation due to mining some remedial measures are required for the reclamation of degraded land with a view to restore its productivity and fertility. Reclamation of mined out areas is often difficult due to its chemical, physical and biological traits. Absence of topsoil is the most common feature of the mine spoils dumps.

Since the progress of natural vegetation process is very slow on mine spoils, selective plantation of suitable native species is desired in most cases. Restoration of these recalcitrant mined out sites with tree plantation along with suitable organic amendment is important for developing the vegetation canopy and to improve the properties of mine spoil such as its structural aggregation, nutrient cycling and availability, thereby improving its productivity and fertility. Application of ecological principles and concepts is the foundation for sustainable development. The other considerations are of socio-economic and cultural aspects. None of the above can be ignored; otherwise they are bound to suffer from ecological

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un-sustainability. The present paper deals with the biological reclamation of flagstone mines of Shivpuri district, Madhya Pradesh (India).

2. Materials and Methods

2.1. Study Area

The flagstone mining of Shivpuri district (Madhya Pradesh State Mining Corporation Limited, India) is done through opencast method. The total forest lease area of the mining is 217.063 ha for excavation of flag stones. The break-up of the lease area is given in Table 1.

Table 1. Physiographic Details of Five Mine Areas in Shivpuri District

S.no.	Name of Village	Tahsil	Comptt. No. of forest	Area (ha.)	Lease period
1.	Budhonrajpur	Pichhor	309	81.483	8.02.2011 to 7.02.2021
2.	Bhilari	Kolaras	288	10.000	07.09.2010 to 06.09.2020
3.	Tehta	Shivpuri	649	24.930	07.09.2010 to 6.09.2020
4.	Khada	Shivpuri	644	90.650	08.2.2011 to 07.02.2021
5.	Loharachha	Khaniadhana	P-430	10.00	07.09.2010 to 06.09.2020
			Total lease area	**217.063 ha.**	

The lease area of the 5 villages can be approached from district headquarters Shivpuri by own conveyance. The nearest railway station is located at Shivpuri. The opencast mining operation has been initiated in all the five villages. All mining works including excavation of flagstones, removal of overburden material and loading of dumpers *etc.*, are being done both mechanically by JCB machines and manually using hand tools like crowbars, spades, chisels and hammers and subsequently filled in dumpers. Full thickness of the mineral will be mined to avoid loss of mineral of ground. The haul roads of 5m width up to the floors of quarry will be made for easy movements within the quarry. The project area lies in Shivpuri district of Madhya Pradesh (India) has alluvium lateritic soil. The overburden dumps (O.B. dumps) consist of loose sand, weathered sand, stone and boulders in varying proportion devoid of nutrients, moisture retention capacity and microbial population.

2.2. Phyto-sociological Study

A one hectare plot in 4 forest stands in Shivpuri forest division has been laid out to analyze the vegetation in qualitative and quantitative terms using quadrate method (Mishra, 1968). In each quadrate enumeration of tree, shrubs and herbs was done, the community structure was ascertain by calculating Importance Value Index (Curtis, 1959). The IVI was calculated by adding the values of relative frequency, relative density, and relative dominance. On the basis of IVI, association of dominant and co-dominant species was determined and termed as community type. The density and basal area ha^{-1} was calculated using the formula of Curtis and Mc Intosh, (1950).

2.3. Physico-chemical Properties of Mine Spoil

Soil properties in terms of Water Holding Capacity (%), pH, E.C (ms cm^{-1}), Organic matter (%), Available N,P, K, Ca(Kg ha^{-1}) and heavy metals toxicity like Cd, Pb, Ni and Cr (mg kg^{-1}), was tested and analyzed for mine spoil / over burden materials using standard methods prescribed in Tropical Soil Biology and Fertility- A hand Book of methods (edited by Anderson and Ingram), C.A.B. International publication(1990), Piper (1950), Jackson (1976) and by Rubio Montoya and Brown (1984).

2.4. Microbial Analysis of Mine Spoil and Rhizosphere Soil

2.4.1. Soil Sample Collection and Processing: The soil samples along with fine roots were collected in polyethylene bags marked properly. They were kept in the laboratory and were processed.

2.4.2. Isolation of vesicular-arbuscular Mcorrhiza: The collected soil samples were processed for isolation of VAM spores. To extract VAM spores, wet-serving and decanting techniques of Gerdemann and Nicolson (1963) were applied and 100g soil was weighed and mixed in warm water in a large beaker (1lt) and allowed to settle down heavier particles. The suspension was gently stirred several times and poured through a coarse sieve to remove large pieces of organic matter. The particles were re suspended and suspension was decanted through 500µm, 250 µm, 105 µm and 53 µm sieve to retain the VAM spores of different sizes. Sieving collected from wet-sieving and decanting methods. The spores were picked up with the help of specially designed tweezers and observed under dissecting microscope.

2.4.3. Bacteria: For the study of bacterial population, dilution plate count technique was used. After isolation beneficial bacterial isolates were grown in selective growth media namely potato-dextrose agar medium, king B medium for *Pseudomonas* Jenson's medium (for *Azospirillum)* as well as manitol agar (for *Rhizobium*).

2.4.4. Isolation and Identification of Bio-Fertilizer Inoculum for Root Infection of Suitable Species: For isolation of site specific bio-fertilizer strains rhizo-spheric soil samples were collected from plant growing near mine spoil dump sites. These samples were screened for vesicular arbuscular mycorrhizal (VAM) fungi by wet sieving and decanting method (Gerdemann and Nicholson, 1963) for various species. Site specific non-symbiotic nitrogen fixing strains were isolated from rhizospheric soil samples from the tree species found in vicinity of the mine areas. The isolated strains were identified as per Bergey's Manual of determinative Bacteriology (Ludwig and Klenk, 2005). The identified strains shall be used for root inoculation of seedlings of selected species before planting over OB dumps areas.

3. Results and Dscussions

3.1. Characterization of Mining Sites and Dumps

There is an urgent need to develop and extend technological measures to rehabilitate mined out lands for potential use since mining gives rise to sharp changes in the landscape and causes adverse ecological impact through depletion of flora and fauna. In this context, an ecosystem approach for rehabilitation of mine spoils and overburden areas have been proposed with a sequence of activities.

3.2. Physico-chemical Status of Mine Spoils

The results with respect to physico-chemical properties of mine spoil depicted in Table-2 indicated that pH is toward alkaline side and rating of the different values of N,P,K, Ca, are towards lower side and need FYM , bio-fertilizers for its amendments before plantation. The heavy metals values indicate very negligible quantity of traces of Cd, and Cr contents. However the value obtained for Pb and Ni content are far below the standard permissible limit of 50-140 mg per kg (as per B.I.S). Though, the value of Pb (1.71 ppm) in the mine spoil sample at Bhilari is toxic (toxic level 1-10 ppm) for plant growth and root development of seedlings and need some amendments during plantation.

Table 2. The Physico-Chemical and Biological Characteristic of Mine Spoils

S. No	Properties	Mining sites				
		Budhon Rajapur	Bilhari	Tehta	Khada	Loharachha
1.	Water Holding Capacity (%)	43.65	39.64	40.83	32.61	39.09
2.	pH	7.21	7.02	7.11	7.31	6.95
3.	E.C (ms cm^{-1})	2.74	1.18	0.88	0.75	0.89
4.	Organic matter (%)	0.957	1.164	0.698	1.247	1.241
5.	Available N(Kg ha^{-1})	224.00	256.00	180.00	271.00	271.00
6.	Available P (Kg ha^{-1})	13.64	10.92	12.28	13.64	13.64
7.	Available K (Kg ha^{-1})	77.00	77.00	111.00	103.00	94.00
8.	Available Ca (Kg ha^{-1})	1448.00	1448.00	1527.00	1586.00	1714.00
9.	Cd (mg kg^{-1})	Traces	Traces	Traces	Traces	Traces
10.	Pb (mg kg^{-1})	0.61	1.71	0.38	0.55	0.01
11	Ni (mg kg^{-1})	0.09	0.36	0.00	0.11	0.13
12.	Cr (mg kg^{-1})	Traces	Traces	Traces	Traces	Traces

3.3. Microbial Status of Mine Spoil and Rhizosphere Soil of Different Tree Species

The results with respect to microbial properties of mine spoil depicted from Table-3 to 5. On the basis of colony count method, the colony of Fungi, Bacteria and *Actinomycetes* were counted. In most of the sample fungi were more followed by bacteria, however the colonies of *Actinomycetes* were less and recorded in few samples. The representative samples of mine soil from Flagstone area showed fewer colonies of all microbes. Fungi and bacteria colonies were very less while *Actinomycetes* were negligible.

Mining causes massive damage to landscape and biological communities of the earth. Natural plant communities (forest) get disturbed and the habitats become impoverished due to mining, presenting a very rigorous condition for plant growth and thus pose serious threats to the environment, resulting in reduction of forest cover. There are many other associated loses like erosion of soil, pollution of air, water and reduction in biodiversity. Mine spoils represents very rigorous condition for plant and microbial growth because of low organic matter contents, low organic carbon, and unfavorable pH and may take several years for the creation of self- sustaining ecosystem.

The potential of soil microorganism has been recognized widely in improvement of soil quality, soil formation, aggregation and re-vegetation through their activities in litter decomposition and nutrient cycling. Their activities such as phosphate solubilization, nitrogen fixation, oxidation of various inorganic components of soil or mineralization of inorganic components and mycorrhizal symbiosis are major beneficial activities that play very important role in soil system functioning. Soil microorganisms which are inhabitating the rhizosphere environment interact with plant roots and mediate nutrient availability to the plants. Implications of plants and their symbionts like mycorrhizal fungi, N-fixing bacteria and free living rhizosphere population of bacteria promote plant establishment and growth. Thus role of soil microorganisms in nutrient cycling is unique. In addition to their effects on soil fertility, they also enhance soil structure by binding together soil practices. An active soil microbial biomass is an essential factor in the long term fertility of soils.

3.3.1. Status of Microbes in Soil Sample: The details observation on bacterial and VAM status are recorded. On the basis of the colony count method the colonies of fungi, bacterial and *actinomycetes* were counted. In most of the sample fungi were most followed by bacteria. However the colonies of *actinomycetes* were less and recorded in few samples. The representative samples of mines soil from flagstone area showed fewer colonies of all microbes. Fungi and bacterial colonies were very less, while *actinomycetes* were negligible.

The four genera of bacteria were recorded in different unexcavated soil from different species. They were *Rhizobium, Azotobacter, Azospirullum and Pseudomonas fluorescens.* There were considerable variations in the bacterial species. *Rhizobium* was in more number in rhizosphere of leguminous plants. However, the bacterial species were represented by *Azotobacter* spp. in all samples of unexcavated soil. But *Pseudomonas* was presented in sample 27 and 28 while *Azosporillum* spp. could be recorded in sample 31.

The VAM populations vary to a considerable extent in all samples. The unexcavated forest soil of different species showed species of *Glomus* which is represented by *G.mosseae, G. intraradices* and *G.deserticola* while one species of *Acaulospora* i.e., *Ascrobiculata* could be noticed. All VAM species vary in frequency in different species. Grasses harbor more VAM. The spore number in most of the sample vary from 86 to 145. The population of in forest soil is less. The mined soil showed only the representation of *Glomus* and *Acaulospora* species. The spore number was varying less in mined soil i.e. from 78 to 83. The diversity of VAM species was very less in mined soil.

On the basis of the study on status of microbes in flagstone soil samples, the following recommendations can be made:

1. Comparatively the unexcavated forest soils from different species have more bacterial fungal, VAM and *actinomycetes* population compared to mined soil.
2. On basis of the colony count, species examination and spore population of VAM species are less in mined soil.
3. The pH is towards alkaline side.
4. Afforestation of the mined area need seedlings boosted up with the representative microbial species of the area. The seedlings raised in the nursery can be boosted up by such microbial consortium for undertaking the plantation.

Table 3. Microbial Status of Mine Spoil and rhizosphere Soil of Different Tree Species

S. N.	Parameters	Mining sites				
		Budhon Rajapur	Bilhari	Tehta	Khada	Loharachha
1.	Fungal colony (C.F.U)	4	3	4	-	5
2.	Bacterial colony (C.F.U)	2	2	1	-	2
3.	Actinomycetes	-	-	-	-	-
4.	Bacteria	*Pseudomonas fluorescens*, *Azotobacter* sp.	*Pseudomonas fluorescens*, *Azotobacter* sp.	*Azotobacter sp.*	--	*Aztoobacter sp., Azospirillum sp.*
5.	VAM Fungi	*Glomus intraradices, Acaulospora* sp.	*Glomus intraradices, Acaulospora* sp.	*Glomus mosseae, Acaulospora*	-	*Glomus intraradices, Acaulospora, Gigaspora*
6.	No. of VAM spores $100g^{-1}$ soil	78	78	83	-	80

Table 4. Microbial Status in rhizosphere of important tree species

S. N.	Plant Species	Fungus (C.F.U)	Bacteria (C.F.U)	Actinomycetes (C.F.U)
1.	*Diospyros melanoxylon*	10	5	1
2.	*Holarrhina antidysenterica*	5	4	2
3	*Butea monosperma*	9	3	1
4.	*Soalnum nigrum*	12	8	0
5.	*Lagerstroemia parviflora*	8	3	1
6	*Madhuca latifolia*	4	5	0
7	*Ziziphus xylopyrus*	6	3	2
8	*Carica opaca*	9	4	1
9	*Cassia tora*	11	5	0
10.	*Aristida adscensionis*	10	6	0
11.	*Acacia catechu*	11	4	1
12.	*Gymnosporia montana*	6	5	0
13.	*Flacourtia indica*	6	4	1
14.	*Alysicarpus indica*	6	3	0
15.	*Hyptis suaveolens*	5	5	1
16	*Anogeissus pendula*	8	4	2
17	*Boswellia sevrala*	7	3	1
19.	*Achyranthes aspera*	9	5	1
20.	*Cenchrus cilaris*	7	6	0
21.	*Acacia leucophloea*	6	4	0
22.	*Prosopis juliflora*	8	3	1

C.F.U - Colony Forming Unit

Table 5. Microbial Status of Bacteria and VAM Fungi in Rhizosphere of Different Tree Species at Different Mining Sites

S. N.	Plant species	Mining site	Bacteria	VAM Fungi	No of spores $100g^{-1}$ soil
1.	*Diospyros melanoxylon*	Bhudhonrajpur	*Azospiruillum, Azotobacter, Rhizobium*	*Glomus intraradices, Acaulospora, Scuteltospora, Gigaspora*	98
2.	*Holarrhyna antidysenterica*	Bhudhonrajpur	*Azospirillum, Pseudomonas fluorescens, Azotobacter*	*Glomus mosseae, G. deserticola, Acaulospora, Scuteltospora*	134
3.	*Butea monosperma*	Bhudhonrajpur	*Rhizobium, Azotobacter, Pseudomonas fluorescens*	*Glomus, Acaulospora scrobiculata,Scuteltospora, Gigaspora*	112
4.	*Solam nigrum*	Bhudhonrajpur	*Azotobacter, Azospirillum*	*Glomus mosseae, Acaulospora, Gigaspora, Sclerocystis*	127
5.	*Lagerstroemia parviflora*	Bhudhonrajpur	*Azospirillum, Rhizobium, Pseudomonas fluorescenes*	*Glomus intraradices, Acaulospora, Gigaspora*	140
6.	*Madhuca indica*	Loharchha	*Azospirillum, Pseudomonas fluorescens, Azotobacter*	*Glomus intraradices, Glomus, Acaulospora scrobiculata, Gigaspora margarita*	130
7.	*Ziziphus xylopyrus*	Loharchha	*Azospirillum, Pseudomonas fluorescene, Azotobacter*	*Glomus deserticola, Acaulospora, Gigaspora*	134
8.	*Carica opeca*	Loharchha	*Azospirillum, Azotobacter, Pseudomonas fluorescens*	*Glomus intraradices, Acaulospora, Gigaspora margirita*	120
9.	*Cassia tora*	Loharchha	*Azotobacter, Pseudomonas Azospirillum*	*Glomus intraradices, Acaulospora, Gigaspora, Gigaspora*	125
10.	*Aristida sp.*	Loharchha	*Azospirillum, Azotobacter, Pseudomonas fluorescens*	*Glomus mosseae, G.intraradices, Acaulospora, Gigaspora*	103
11.	*Acacia catechu*	Bhilari	*Rhizobium, Azotobacter, Pseudomonas fluorescens*	*Glomus mossae, Glomus sp, Acaulospora, Gigaspora*	145

S. N.	Plant species	Mining site	Bacteria	VAM Fungi	No of spores 100g^{-1} soil
12.	*Gymnospora sp*	Loharchha	*Azosprillum, Azotobacter,Pseudomonas fluorescens*	*Glomus mosseae, Glomus sp, Acaulospora scrobiculata, Gigaspora*	139
13.	*Flacourita indica*	Loharchha	*Azotobacter, Pseudomonas fluorescens*	*Glomus deserticola, G.mossae, Acaulospora sp, Gigaspora*	145
14	*Alysicarpus indica*	Loharchha	*Azotobacter, Pseudomonas fluorescens*	*Glomus deserticola, G. mosseae*	110
15	*Hyptis suaveolens*	Tehta	*Pseudomonas sp., Azotobacter sp*	*Glomus deserticola, Gigaspora*	86
16.	*Anogeissas pendula*	Tehta	*Pseudomonas sp, Azotobacter sp.*	*Glomus intraradices, G. microcarpum*	130
17.	*Boswellia servata*	Tehta	*Azotobacter, Pseuomonas fluorescens, Rhizobium*	*Glomus intraradices, Glomus sp, Gigaspora*	122
18.	*Lagerstroemia parviflora*	Tehta	*Azotobacter, Pseudomonas fluorescens, Azospirillum*	*Glomus intraradices, G.mosseae, Gigaspora sp.*	120
19.	*Achyranthes aspera*	Khada	*Azospirillum, Azotobacter, Rhizobium*	*Glomus intraradices, G. mosseae, Acaulospora*	111
20	*Cenchrus ciliaris*	Khada	*Azospirillum, Azotobacter, Pseudomonas fluorescens*	*Glomus mosseae, Gigaspora*	124
21	*Acacia leucophloea*	Khada	*Rhizobium, Azospirillum, Azotobacter*	*Glomus intraradices, Acaulospora*	131
22.	*Prosopis juliflora*	Khada	*Rhizobium, Azospirllum sp*	*Glomus intraradices, Acaulospora, Gigaspora*	139

3.4. Phytosociological Status of Vegetation in the Adjoining Mined Out Area

The forests of Shivpuri forest division are mostly Northern tropical dry deciduous type. According to the revised classification of forest types of India by Champion and Seth, the forest of the locality are grouped as under:

1. Very dry teak forests
2. Northern tropical dry mixed deciduous forest
3. Dry deciduous scrub type
4. Dry grassland
5. *Anogeissus pendula* forests
6. *Anogeissus pendula* scrub
7. *Boswellia* forest

8. *Butea f*orests
9. Ravine thorn forests

The regeneration status is generally poor. The quality of forests varies from IVb to Vb. The forests of the core and buffer area of mine sites are mostly open and denuded mixed forest comprising of *Anogeissus pendula*, *Anogeissus latifolia*, *Acacia catechu*, *Butea monosperma*, *Diospyros melanoxylon*, *Ziziphus jujuba*, *Acacia leucophloea*, *Ziziphus xylopyrus* etc. However, at some places the scattered trees of *Madhuca latifolia*, *Lannea coromendelica*, *Boswellia serrata*, *Azadirachta indica*, *Terminalia belerica* etc are also found occurring in the study areas. Among shrub *Carica opaca*, *Gymnosporia spinosa*, *Balanites aegyptica*, *Woodfordia fruticosa*, *Phoenix acaulis* are common species found in the area. The main features of vegetation of different stands are as under:

Stand no-	Community association	Density (trees ha^{-1})	Basal area ($m^2\ ha^{-1}$)
1.	*Anogeissus pendula- Acacia catechu*	327.00	5.23
2.	*Boswellia serrata- Lannea coromendelica*	276.00	4.93
3.	*Acaica catechu- Anogeissus pendula- Acacia leucophloea*	422.00	5.29
4.	*Acacia catechu- Anogeissus latifolia*	356.00	5.34

4. Conclusions

The mine working is being carried out manually. The past working areas have so far not been reclaimed and back filling is lacking in these areas. There is a need of physical and biological reclamation in mined out area. For sustainable stability of the ecosystem, selection of suitable species is important. The native species occurring in adjoining natural forests need to be introduced along with N-fixing and fast growing tree species, shrubs as well as fruit bearing species attracting birds and other faunal population. On the sloppy areas seeds of grasses and legumes need to be broadcasted for preventing the soil erosion and to increase the water holding capacity. Since the area is rocky the introduction of ferns and fern allies would be useful to develop the natural ecosystem.

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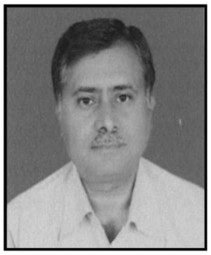

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