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SCREENING OF PROBABLE PLANT SPECIES (BASED ON VEGETATION SURVEY) FOR REVEGETATION OF IRON ORE MINE WASTELANDS IN GOA

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Abstract

Selected physical and chemical analysis of mine rejects and tailings have been carried out. Chemical analysis of the mine rejects and tailings revealed that both rejects and tailings are low in macro- and micro- nutrients. Hence, a search for plants thriving under low nutrient and other stress conditions was attempted. For this, vegetation survey on and aroundvarious mine rejects and tailings, and plateaus with sparse vegetation was carried out. This paper reports an exhaustive list of plants (ferns, herbs, shrubs and trees) screened out as probable species for revegetation of iron ore mine rejects and tailings based on survey studies.

INTRODUCTION

Much of the world's wealth is derived from mining activities. Goa, a prime exporter of iron ore since 1950, has an area of approximately 3702 sq.km. lying on the west coast of India between 15°48'00" N and 14°53'54" N Latitude and 74°20'13" E and 73°40'33" E Longitude.

Present production of iron ore is of the order of 15 mt/yr., which constitutes 40% of the total iron ore production in the country and 50% of its export. The estimated reserve iron ore as on today is around 400 million tonnes and is expected to last for another 25-30 years, at the present rate of mining.

The mining operation is such that, two classes of wastes are produced *viz.*, piles of surface overburden waste rock and lean ore, which constitutes the reject dumps, and a fine grained waste resulting from the ore beneficiation process and deposited in large man made basins called tailing ponds. The later kind of waste materials are termed as tailings.

It is true that, in the process of winning mineral resources from the earth, disturbance to environment and ecosystems are unvoidable. In other words, mining is to some extent is an unavoidable destructive process. However, when one considers the two properties of the ecosystem, *viz.*, self-sustaining and capacity to develop, then one may presume that after mining disturbance there is no need for any revegetational afforts i.e. a self-sustaining vegetational cover will develop naturally. This is of course true, but the process of natural succession will be even much slower. It is quite possible that further degradation could take place, especially by erosion, which could haveserious effects on the surrounding land.

The aim of revegetation of mining sites is to achieve vagetation cover within a few years, so that the later succession will take place at a rapid pace thereby increasing biodiversity of the area. Hence, a survey of plants that appear on the abandoned reject dumps and tailings, surrounding mining sites and plateaus would provide a source of potential plant species for rehabilitation efforts.

MATERIALS AND METHODS

A. ANALYSES OF MINE WASTES: Twenty samples of waste material were taken in a stratified random manner, from each of the two sites. Samples were taken to a depth of 15cm, sieved through a mesh in the field and air-dried before being sent to the U.K. for analysis.

Soil texture was determined by the hydrometer method by Day (1965) after dispersion in the Na-hexametaphosphate. The pH was measured in 0.01M $CaCl_2$. Electrical conductivity (EC) and Cation concentrations were deretmined in 1:1 water:waste extracts. Cation concentrations were measured by Atomic absorption spectophotometry. Mineral (available) nitrogen was determined after extraction in 2M KCl (Bremner, 1965a) and total nitrogen determined after acid-Kjeldahl digestion (Bremner, 1965b). Phosphorus was determined using Olsen and Dean's (1965) method. Total water-soluble sulphate-sulphur was mesured turbidimetrically (ADAS, 1981).

All analyses were carried out on air-dried material but results are expressed on an oven-dry (105°C) weight basis after correction for moisture content.

B. SURVEY STUDIES (Fig.1): Vegetation survey was cnducted on and around eight fairly established mining dumps *viz.*, Lisboa, Dhat, Torino, Napoli, Sardinha and Plot No. 4 in Sanquelim village and Orasso Dongor dump in Assonora village, owned by sesa Goa, Ltd. Five plateaus having sparse vegetation *viz.*, Taleigao, Porvorim, Ponda, Verna and Zuarinagar were surveyed. The plants species collected were identified by using local floras. Criteria for abundance is based on the frequency of each species occuring on the mining dumps, surrounding mining sites and plateaus separately.

RESULTS AND DISCUSSION

A. ANALYSES OF MINE WASTES: For reclamation of any degraded area, knowledge of physicochemical parameters of the degraded land is essential. However,the exact assessment of these parameters at the entire area is difficult, as the comcentration of the soil varies even at the close proximity of the sampling sities due to the random dumping of the topsoil overburden, rock waste and due to the interaction of various factors.

Selected physical and chemical analyses of rejects and tailings are given in Table 1 and 2 respectively. Soil texture is used extensively as a guide to evaluate soil water storage, water availability, surface erosion, land stability, and chemical properties (Shertron and Trettin, 1984). It is seen that the rejects and the tailings contain high clay content, which is known to give undesirable compactness. This results in reduction of moisture infilteration adn poor plant growth. This undesirable assemblage of materials often renders the spoils liable to water and wtnd erosion.

The mean pH was slightly higher for tailings (pH 6.48) than for the rejects (pH 6.02). The pH values at both the sites were neither acidic nor alkaline and would there fore pose no problems for plant growth. Melclean and Dekker (1976) studied the pH of different mine wastes and reported a large variation in acidity among different sites ranging from pH 1.5 to above 10. Varying soil pH changes the soil concentration

of many nutrients and toxic ions in soil solution as well as the concentration of hydrogen ions (Russel, 1973). In acid soils there are often higher concentrations of aluminium and manganese ana lower concentrations of calcium, magnesium and molybdenum in soil solutions than in alkaline soils (Porter *et al.* 1987).

There is less mineral and total nitrogen (N) for the tailings but more calcium (Ca) and sodium (Na). Otherwise the results for both the sites were similar.

Electrical conductivity (EC) for both sites was very low indicating no likelihood of salinity problems. All the plant macronutrients (N, P, Ca, Mg and S) were present in very low levels, and lack of N, P, and Kwould severly limit plant growth. The plant micronutrients (Fe, Mn, Cu and Zn) were also at low levels, some posibly low enough to cause deficiency symptoms in some plants. None of these metals were present at concentrations likly to be toxic to plants. Nutrient deficiencies are wiedly reported as a major limitation, perticularly in terms of a low or a complete lack of organic matter and nitrogen in the mining wastes. Copr (1962) reported the dificiency of phosphrous as a common feature of mine wastes. Smith and Bradshaw (1970) started that micronutrient deficiencies are frequently encountered in the mine wastes. Wong *et al.* (1983) showed that the tailings were alkaline, lacking in organic matter and nitrogen, but were rich in metals such as Fe, Zn, Cu, Mn, Mg and Ca. Shertron (1983) reported that in iron ore tailings the orgsnic matter and nitrogen are essentially non-exsistent, phosphorus levels are low; Ca, Mg, K and metal range in availability; have alkaline pH and low cation exchange capacity.

Thus, the chemical composition of waste is highly variable even with in a perticular mining operation, not only depends upon the the nature of the original ore but also on the metals extracted, the method of treatment and disposal, climatic conditions and weathering reactions that follow disposal.

Class I: Since these plant species are found occurring at all the three sites, they are probably the most potential species for revegetation and should be taken up for plantation on a large scale on the reject dumps.

Class II: These species are found on two sites viz., reject dumps and on areas around mines and are also potential species which can be used for revegetation of reject dumps.

Class III: These species are common on mine rejects and on plateaus. All these species are introduced on the reject dumps.

Class IV: These species are found growing only on mine rejects. Most of these species are introduced on the mine rejects.

Class V: These species are found growing around mines and on plateaus.

Class VI: These species are found growing only around the mines.

In Class V and Class VI, the absence of plant species on the reject dumps may possibly be due to either because their propagules might not have reached the reject sities or because they may not survive the low nutrient conditions on the reject dumps.

Class VII: These species can tolerate the stress conditions encountered on the plateaus, hence they may be screened out for their potentiality to grow on mine rejects. It is certain that screening of these plant species

would help to increase the biodiversity of the mining area.

Introduction of exotic speices should be made with great care and after consultation, as these species may be very successful and escape out into the neighbouring area, and may turn out to be a nuisance.

The list also includes a few exotic speices *viz., Acacia auriculiformis, Acacia mangium, Casuarina equisctifolia,* etc. These may be used as nurse plants. Initially, a thick plantation of these species would protect the land aganist erosion and help in soil stabilization and building up of soil organic matter. However, it is essential to replace these species by native species in the later stages. This is necessary to avoid monoculture and to bring about plant biodiversity.

The list also includes noxious weeds like *Eupatorium odoratum L. and parthenium hysterophorus L.,* the use of which should be avoided as these speices tend to dominate and eliminate other native species. Based on survey studies, a total of 27 plant species belonging to 26 genera and 17 families have been recorded as probable species for revegetating abandoned tailing sites (Table 5). Large scale plantation of these species would enable early stabilization of the abandoned tailing sites.

Table 1: Summary of selected physical and chemical analyses for a one and a half year old iron ore mine waste dump in Goa

	Mean	Standard deviation	Range
Soil texture			
Sand %	44.3		
Silt %	19.3		
Clay %	33.9		
pH ($CaCl_2$)	6.02	0.18	5.66 - 6.44
EC (ms cm^{-1})	0.051	0.012	0.035 - 0.089
Total N	93.2*	NA	NA
Mineral N	3.8*	NA	NA
P	1.5	NA	NA
SO_4 -S	<0.1	NA	NA
Al	<0.5	NA	NA
Ca	1.76	0.80	0.74 - 3.64
Cd	<0.02	NA	NA
Cr	<0.1	NA	NA
Cu	<0.05	NA	NA
Fe	<0.1	NA	NA
Hg	<3	NA	NA
K	0.76	0.26	0.40 - 1.28
Mg	0.92	0.55	0.33 - 2.69
Mn	0.08	0.18	0.00 - 0.84
Na	2.60	0.54	1.83 - 3.90

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Ni	<0.1	NA	NA
Pb	<0.2	NA	NA
Zn	<0.02	NA	NA
K:Mg ratio	1.0	0.7	0.4 - 3.3

Concentrations in μg g^{-1} oven-dry spoil
NA = Not applicable
EC = Electrical conductivity
* = Mean of two replicates taken from bulked sample

Table 2: Summary of selected physical and chemical analyses for the active iron ore tailings pond in Goa

	Mean	Standard deviation	Range
Soil texture			
Sand %	28.3		
Silt %	30.4		
Clay %	39.1		
pH ($CaCl_2$)	6.48	0.07	6.38 - 6.72
EC (ms cm^{-1})	0.065	0.018	0.042 - 0.103
Total N	60.3*	NA	NA
Mineral N	1.7*	NA	NA
P	1.9*	NA	NA
SO_4-S	<0.1	NA	NA
Al	<0.5	NA	NA
Ca	2.34	0.57	1.41 - 3.65
Cd	<0.02	NA	NA
Cr	<0.1	NA	NA
Cu	<0.05	NA	NA
Fe	<0.1	NA	NA
Hg	<3	NA	NA
K	0.71	0.30	0.34 - 1.42
Mg	0.75	0.17	0.27 - 1.14
Mn	<0.05	NA	NA
Na	4.85	2.94	2.15 - 10.60
Ni	<0.1	NA	NA
Pb	<0.2	NA	NA
Zn	<0.02	NA	NA
K:Mg ratio	1.1	1.0	0.5 - 5.3

Concentrations in μg g^{-1} oven-dry spoil
NA = Not applicable
EC = Electrical conductivity
* = Mean of two replicates taken from bulked sample

Table 3: List of probable plant species for revegetation of iron ore mine wastelands (Based on survey studies)

Plant species	Family	Habit	Abundance		
			Dumps	Around mines	Plateaus
Cheilanthes tenuifolia (Burm.) Swartz	Pteridaceae	Herb	8	*	4
Smithia salsuginea Hance	Fabaceae	Herb	8		
Acacia auriculiformis A. Cunn. ex Benth.	Mimosaceae	Tree	8		4
Mimosa pudica L.	Mimosaceae	Herb	8	*	5
Ludwigia perennis L.	Onagraceae	Herb	8	*	4
Ageratum conyzoides L.	Asteraceae	Herb	8	*	4
Eupatorium odoratum L.	Asteraceae	Herb	8	*	4
Alstonia scholaris (L.) R. Br.	Apocynaceae	Tree	8	*	3
Canscora diffusa (Vahl) R. BR.	Gentianaceae	Herb	8	*	3
Lindernia crustacea (L.) F. Muell.	Scrophulariaceae	Herb	8	*	4
Trema orientalis (L.) Blume	Ulmaceae	Tree	8	*	1
Eragrostis unioloides (Retz.) Nees ex Steudel	Poaceae	Herb	8	*	5
Anacardium occidentale L.	Anacardiaceae	Tree	7	*	3
Alysicarpus vaginalis (L.) DC.	Fabaceae	Herb	7	*	5
Geissaspis cristata Wight & Arn.	Fabaceae	Herb	7	*	4
Cassia tora L.	Caesalpiniceae	Herb	7	*	5
Eugenia corymbosa Lam.	Myrtaceae	Shrub	7	*	3
Syzigium cumini (L.) Skeels	Myrtaceae	Tree	7	*	4
Spermacoce hispida L.	Rubiaceae	Herb	7	*	4
Ichnocarpus frutescens (L.) R. Br.	Apocynaceae	Shrub	7	*	5
Calotropis gigantea (L.) R. Br.	Asclepiadaceae	Shrub	7	*	5

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Striga asiatica (L.) O. Kuntze	Scrophulariceae	Herb	7	*	3
Scoparia dulcis L.	Scrophulariceae	Herb	7	*	3
Casuarina equisetifolia Forster & Forster f.	Casuarinaceae	Tree	7	*	
Cyperus iria L.	Cyperaceae	Herb	7	*	4
Oplismenus burmannii (Retz.) P. Beauv.	Poaceae	Herb	7	*	2
Lygodium flexuosum (L.) Swartz	Schizaeaceae	Herb	6	*	1
Adiantum philippense L.	Pteridaceae	Herb	6	*	2
Selaginella tenera (Hook. & Grev.) Spring	Selaginellaceae	Herb	6	*	
Impatiens kleinii Wight & Arn.	Balsaminaceae	Herb	6	*	2
Leea indica (Burm. f.) Merr.	Leeaceae	Shrub	6	*	5
Alysicarpus bupleurifolius (L.) DC.	Fabaceae	Herb	6	*	5
Desmodium triflorum (L.) DC	Fabaceae	Herb	6	*	4
Geissaspis tenella Benth.	Fabaceae	Herb	6	*	4
Indigofera prostrata Willd.	Fabaceae	Herb	6	*	4
Smithia conferta Sm.	Fabaceae	Herb	6	*	3
Zornia gibbosa Spanoghe	Fabaceae	Herb	6	*	5
Acacia mangium Willd.	Mimosaceae	Tree	6		
Calycopteris floribunda (Roxb.) Lam.	Combretaceae	Shrub	6	*	5
Osbeckia truncata Don ex Wt. & Arn.	Melastomaceae	Herb	6	*	2
Neanotis foetida (Hook. f.) W.H. Lewis	Rubiaceae	Herb	6	*	4
Spermacoce ocymoides Burm. f.	Rubiaceae	Herb	6	*	2
Emilia sonchifolia (L.) DC.	Asteraceae	Herb	6	*	4
Ipomoea obscura (L.) Ker-Gawler	Convolvulaceae	Twiner	6	*	4
Habenaria marginata Coleb	Orchidaceae	Herb	6	*	
Eriocaulon cinereum R.Br.	Eriocaulaceae	Herb	6	*	4

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Eriocaulon xeranthemum Mart.	Eriocaulaceae	Herb	6	*	4
Fimbristylis ferruginea (L.) Vahl	Cyperaceae	Herb	6	*	4
Digitaria ciliaris (Retz.) Koeler	Poaceae	Herb	6	*	5
Zizyphus mauritiana Lam.	Rhamnaceae	Tree	5	*	4
Atylosia scrabaeoides Benth.	Fabaceae	Twiner	5	*	1
Crotalaria pallida Ait.	Fabaceae	Herb	5	*	2
Desmodium heterocarpoon (L.) DC.	Fabaceae	Shrub	5	*	1
Delonix regia (Hook.) Raf.	Caesalpiniceae	Tree	5		1
Eucalyptus tereticornis Smith	Myrtaceae	Tree	5		1
Psidium guajava L.	Myrtaceae	Tree	5		1
Hedyotis corymbosa (L.) Lam.	Rubiaceae	Herb	5	*	5
Vernonia cinerea (L.) Less.	Asteraceae	Herb	5	*	5
Centranthera hispida R. Br.	Scrophulariceae	Herb	5	*	3
Ramphicarpa longiflora Benth.	Scrophulariceae	Herb	5	*	3
Jacaranda mimosifolia D. Don	Bignoniaceae	Tree	5		
Justicia procumbens L.	Acanthaceae	Herb	5	*	4
Jatropha curcas L.	Euphorbiaceae	Shrub	5		1
Phyllanthus fraternus Webster	Euphorbiaceae	Herb	5	*	2
Sapium insigne (Royle) Trimen	Euphorbiaceae	Tree	5	*	3
Ficus racemosa L.	Moraceae	Tree	5	*	1
Ficus hispida L. f.	Moraceae	Tree	5	*	1
Dioscorea bulbifera L.	Dioscoreaceae	Twiner	5	*	1
Cynaotis cristata (L.) D. Don	Commelinaceae	Herb	5	*	1
Murdannia semiteres (Dalz.) Sant.	Commelinaceae	Herb	5	*	4
Pteris pellucida Presl	Pteridaceae	Herb	4	*	
Sida rhombifolia L.	Malvaceae	Herb	4	*	3
Urena lobata L.	Malvaceae	Shrub	4	*	2
Microcos paniculata L.	Tiliaceae	Shrub	4	*	4

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Zizhiphus oenoplia (L.) Mill.	Rhamnaceae	Shrub	4	*	3
Dalbergia sympathetica Nimmo ex Grah.	Fabaceae	Tree	4	*	2
Cassia fistula L.	Caesalpiniaceae	Tree	4		
Acacia pennata (L.) Willd.	Mimosaceae	Shrub	4		1
Leucaena leucocephala (Lam.) de Wit.	Mimosaceae	Tree	4		1
Passiflora foetida L.	Passifloraceae	Twiner	4	*	
Mukia maderaspatana (L.) M. Roemer	Cucurbitaceae	Twiner	4	*	3
Ixora coccinea L.	Rubiaceae	Shrub	4	*	5
Blumea mollis (D.Don) Merr.	Asteraceae	Herb	4	*	5
Cosmostigma racemosum (Roxb.) Wight	Asclepiadaceae	Shrub	4	*	
Cryptolepis buchanani Roemer & Schultes	Asclepiadaceae	Shrub	4	*	
Exacum lawii C.B.Clarke	Gentianaceae	Herb	4	*	
Clerodendron viscosum Vent.	Verbenaceae	Shrub	4	*	2
Peperomia pellucida (L.) H.B. & K.	Piperaceae	Herb	4	*	3
Bridelia scandens (Roxb.) Willd.	Euphorbiaceae	Shrub	4	*	4
Euphorbia hirta L.	Euphorbiaceae	Herb	4	*	3
Macaranga peltata (Roxb.) Muell. Arg.	Euphorbiaceae	Tree	4	*	2
Phyllanthus madaraspatensis L.	Euphorbiaceae	Herb	4	*	2
Ficus heterophylla L. f.	Moraceae	Tree	4	*	
Dioscorea pentaphylla L.	Dioscoreaceae	Twiner	4	*	
Amorphophallus commutatus Engler	Araceae	Herb	4	*	
Cyperus compressus L.	Cyperaceae	Herb	4	*	4
Cyperus odoratus L.	Cyperaceae	Herb	4	*	1
Fimbristylis dichotoma (L.) Vahl	Cyperaceae	Herb	4	*	2
Echinochloa colona (L.) Link	Poaceae	Herb	4	*	5
Heteropogon contortus (L.) P. Beauv.	Poaceae	Herb	4	*	4
Isachne elegans Dalz.	Poaceae	Herb	4	*	2

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Paspalum scrobiculatum L.	Poaceae	Herb	4	*	2
Setaria pumila (Poir.) R. & S.	Poaceae	Herb	4	*	4
Annona squamosa L.	Annonaceae	Tree	3		
Polygala elongata Klein ex Willd.	Polygalaceae	Herb	3	*	5
Sida acuta Burm. f.	Malvaceae	Herb	3	*	4
Bombax ceiba L.	Bombacaceae	Tree	3	*	4
Helicteres isora L.	Sterculiaceae	Shrub	3	*	3
Melochia corchorifolia L.	Sterculiaceae	Herb	3	*	4
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	Tree	3		
Ochna obtusata DC.	Ochnaceae	Shrub	3	*	5
Mangifera indica L.	Anacardiaceae	Tree	3	*	2
Crotalaria filipes Benth.	Fabaceae	Herb	3	*	2
Phaseolus sublobatus Roxb.	Fabaceae	Herb	3	*	3
Gliricidia sepium (Jacq.) Kunth ex Walp.	Fabaceae	Tree	3		
Cassia alata L.	Caesalpiniaceae	Shrub	3		
Bauhinia purpurea L.	Caesalpiniaceae	Tree	3		
Acacia torta (Roxb.) Craib	Mimosaceae	Shrub	3		1
Melastoma malabaricum L.	Melastomaceae	Shrub	3	*	1
Solena amplexicaulis (Lam.) Gandhi	Cucurbitaceae	Climber	3	*	2
Mullugo pentaphylla L.	Aizoaceae	Herb	3	*	2
Pimpinella adscendens Dalz.	Apiaceae	Herb	3	*	2
Hemidesmus indicus R. Br.	Asclepiadaceae	Twiner	3	*	5
Merremia tridentata Hallier f.	Convolvulaceae	Twiner	3	*	2
Physalis minima L.	Solanaceae	Herb	3	*	2
Leucas aspera Spreng.	Lamiaceae	Herb	3	*	4
Euphorbia notoptera Boiss.	Euphorbiaceae	Herb	3	*	4
Artocarpus heterophyllus Lam.	Moraceae	Tree	3		
Caryota urens L.	Arecaceae	Tree	3	*	4
Cyperus pulcherrimus Willd.	Cyperaceae	Herb	3	*	3
Pycreus pumilus (L.) Nees ex C.B.Clarke	Cyperaceae	Herb	3	*	2
Rhynchospora wightiana Steud.	Cyperaceae	Herb	3	*	5

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Ischaemum semisagittatum Roxb.	Poaceae	Herb	3	*	4
Panicum notatum Retz.	Poaceae	Herb	3	*	1
Cyclea peltata (Lam.) Hook.	Menispermaceae	Twiner	2	*	1
Sida cordifolia L.	Malvaceae	Herb	2	*	2
Corchorus tridens L.	Tiliaceae	Herb	2	*	4
Impatiens balsamina L.	Balsaminaceae	Herb	2	*	2
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	Tree	2		
Dalbergia sissoo Roxb.	Fabaceae	Tree	2	*	
Erythrina variegata L.	Fabaceae	Tree	2		1
Pongamia pinnata (L.) Pierre	Fabaceae	Tree	2		
Teramnus labialis (L.f.) Sprengel	Fabaceae	Twiner	2	*	2
Cassia absus L.	Caesalpiniceae	Herb	2	*	3
Cassia mimosoides L.	Caesalpiniaceae	Herb	2	*	5
Tamarindus indica L.	Caesalpiniaceae	Tree	2	*	1
Acacia nilotica (L.) Del.	Mimosaceae	Tree	2		
Samanea saman Merr.	Mimosaceae	Tree	2		1
Wagatea spicata Dalz.	Mimosaceae	Shrub	2	*	
Terminalia crenulata Roth.	Combretaceae	Tree	2	*	4
Lawsonia inermis L.	Lythraceae	Shrub	2	*	
Mussaenda laxa Hutchin.	Rubiaceae	Shrub	2	*	2
Spermococe stricta L.f.	Rubiaceae	Herb	2	*	4
Wendlandia thyrsoides Roemer & Schultes) Steudel	Rubiaceae	Tree	2	*	
Senecio bombayensis Balakr.	Asteraceae	Herb	2	*	1
Maesa indica Wall.	Myrsinaceae	Tree	2		
Gymnema sylvestre (Retz.) R.Br. ex Roemer & Schultes	Asclepiadceae	Twiner	2	*	
Wattakaka volubilis (L.f.) T. Cooke	Asclepiadceae	Twiner	2	*	
Canscora perfoliata Lam.	Gentianaceae	Herb	2	*	1
Evolvulus alsinoides (L.) L.	Convolvulaceae	Herb	2	*	4
Lindernia oppositifolia Mukr.	Scrophulariaceae	Herb	2	*	3
Sopubia delphinifolia (L.) D. Don	Scrophulariaceae	Herb	2	*	2
Vitex altissima L. f.	Verbenaceae	Tree	2	*	
Hyptis suaveolens (L.) Poit.	Lamiaceae	Herb	2	*	4
Ocimum tenuiflorum L.	Lamiaceae	Herb	2	*	4
Celosia argentea L.	Amaranthaceae	Herb	2	*	4
Ficus benghalensis L.	Moraceae	Tree	2	*	3
Ficus religiosa L.	Moraceae	Tree	2	*	1

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Burmannia coelestis D. Don	Burmanniaceae	Herb	2	*	
Liparis nervosa Lindl.	Orchidaceae	Herb	2	*	
Curcuma decipiens Dalz.	Zingiberaceae	Herb	2	*	
Gloriosa superba L.	Liliaceae	Climber	2	*	
Commelina forskalaei Vahl	Commelinaceae	Herb	2	*	
Fimbristylis sieberiana Kunth	Cyperaceae	Herb	2	*	2
Aristida hystrix L.f.	Poaceae	Herb	2	*	1
Cynodon dactylon L.f.	Poaceae	Herb	2	*	2
Dimeria woodrowii Strapf	Poaceae	Herb	2	*	2
Manisuris acuminata (Hack.) O. Kuntze	Poaceae	Herb	2	*	4
Vetiveria zizanioides (L.) Nash	Poaceae	Herb	2		
Blechnum orientale L.	Blechnaceae	Herb	1		
Michaelia champaca L.	Annonaceae	Tree	1		
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	Tree	1		
Anamirta cocculus (L.) Wight & Arn.	Menispermaceae	Twiner	1	*	1
Cocculus hirsutus (L.) Diels	Menispermaceae	Twiner	1	*	1
Tinospora cordifolia (Willd.) Miers	Menispermaceae	Twiner	1	*	
Tinospora malabarica Miers	Menispermaceae	Twiner	1	*	
Flacourtia montana Grah.	Flacourtiaceae	Tree	1		4
Garcinia indica Choiss.	Clusiaceae	Tree	1	*	1
Gossypium arboreum L.	Malvaceae	Shrub	1		
Hibiscus vitifolius L.	Malvaceae	Herb	1		
Thespesia populnea (L.) Sol. ex Corr. Serr.	Malvaceae	Tree	1		
Sterculia foetida L.	Sterculiaceae	Tree	1	*	
Sterculia urens Roxb.	Sterculiaceae	Tree	1	*	2
Waltheria indica L.	Sterculiaceae	Herb	1	*	
Corchorus capsularis L.	Tiliaceae	Herb	1	*	
Triumfetta rhomboidea Jacq.	Tiliaceae	Herb	1	*	1
Biophytum sensitivum (L.) DC.	Oxalidaceae	Herb	1	*	
Naregamia alata Wight & Arn.	Meliaceae	Herb	1	*	4
Ziziphus rugosa Lam.	Rhamnaceae	Shrub	1	*	3
Leea asiatica (L.) Ridsdale	Leeaceae	Shrub	1	*	
Holigarna arnottiana Hook. f.	Anacardiaceae	Tree	1	*	1

contd..

Crotalaria prostrata Rottler ex Willd.	Fabaceae	Herb	1	*	4
Derris scandens (Roxb.) Benth.	Fabaceae	Twiner	1		
Pueraria tuberosa (Roxb. ex Willd.) DC.	Fabaceae	Twiner	1	*	
Smithia sensitiva Ait.	Fabaceae	Herb	1	*	2
Tephrosia coccinea Wall.	Fabaceae	Herb	1	*	1
Tephrosia purpurea (L.) Pers.	Fabaceae	Herb	1	*	1
Caesalpinia pulcherrima (L.) Sw.	Caesalpiniaceae	Shrub	1		
Cassia siamea Lam.	Caesalpiniaceae	Tree	1		
Peltophorum pterocarpum (DC.) Backer ex K. Heyne	Caesalpiniaceae	Tree	1		
Parkia biglandulosa Wight & Arn.	Mimosaceae	Tree	1		
Pithecellobium dulce (Roxb.) Benth.	Mimosaceae	Tree	1		
Drosera indica L.	Droseraceae	Herb	1	*	1
Terminalia bellerica (Gaertner) Roxb.	Combretaceae	Tree	1	*	
Terminalia catappa L.	Combretaceae	Tree	1	*	
Terminalia paniculata Roth	Combretaceae	Tree	1	*	
Careya arborea Roxb.	Lecythidaceae	Tree	1	*	5
Memecylon umbellatum Burm.f.	Melastomaceae	Shrub	1	*	5
Woodfordia tomentosa Bedd.	Lythraceae	Tree	1	*	
Momordica dioica Roxb. ex Willd.	Cucurbitaceae	Twiner	1	*	
Hydrocotyle asiatica L.	Apiaceae	Herb	1	*	1
Tamilandia uliginosa (Retz.) Tirvengadum & Sastre	Rubiaceae	Tree	1	*	
Cyathocline lyrata Cass.	Asteraceae	Herb	1	*	
Parthenium hysterophorus L.	Asteraceae	Herb	1	*	
Spilanthes calva DC.	Asteraceae	Herb	1	*	1
Tricholepis glaberrima DC.	Asteraceae	Herb	1	*	3
Lobelia alsinoides Lam.	Campanulaceae	Herb	1	*	1
Manikara zapota (L.) P. Royen	Sapotaceae	Tree	1		
Nyctanthes arbor-tristis L.	Nyctaginaceae	Shrub	1	*	
Carissa carandas L.	Apocynaceae	Shrub	1	*	4

contd..

Ervatamia heyneana Cooke	Apocynaceae	Tree	1	*	3
Holarrhena pubescens (Buch.-Ham.) Wallich ex Don.	Apocynaceae	Shrub	1	*	5
Rauvolfia serpentina (L.) Benth. ex Kurz.	Apocynaceae	Shrub	1	*	3
Ceropegia attenuata Hook.	Asclepiadaceae	Herb	1	*	1
Holostemma ada-kodien Schultes	Asclepiadaceae	Twiner	1	*	
Pergularia daemia (Forssk.) Chiov.	Asclepiadaceae	Herb	1	*	1
Tylophora dalzellii Hook. f.	Asclepiadaceae	Twiner	1	*	
Tylophora fasciculata Ham.	Asclepiadaceae	Herb	1	*	2
Strychnos nux-vomica L.	Loganiaceae	Tree	1	*	3
Exacum bicolor Roxb.	Gentianaceae	Herb	1	*	1
Argyreia involvucrata C.B.Clarke	Convolvulaceae	Twiner	1	*	
Argyreia osyrensis (Roth.) Choisy	Convolvulaceae	Twiner	1	*	
Solanum surattense Burm. f.	Solanaceae	Shrub	1		1
Dopatrium junceus (Roxb.) Buch.-Ham. ex Benth.	Scrophulariaceae	Herb	1		2
Lindernia viscosa (Hornem.) Boldingh	Scrophulariaceae	Herb	1	*	
Tecoma stans (L.) Kunth.	Bignoniaceae	Shrub	1		
Sesamum lacinatum Klein ex Willd.	Pedaliaceae	Herb	1	*	
Sesamum mulayanum Nair	Pedaliaceae	Herb	1	*	2
Lepidogathis lutea Dalz.	Acanthaceae	Herb	1	*	
Rungia linifolia Nees	Acanthaceae	Herb	1	*	3
Callicarpa tomentosa (L.) Murray	Verbenaceae	Shrub	1	*	1
Clerodendrum inerme (L.) Gaertner	Verbenaceae	Shrub	1	*	
Clerodendrum serratum (L.) Spreng.	Verbenaceae	Shrub	1	*	3
Lantana camara L.	Verbenaceae	Shrub	1	*	4
Tectona grandis L.f.	Verbenaceae	Tree	1	*	1
Vitex negundo L.	Verbenaceae	Shrub	1	*	1
Colebrookea oppositifolia Smith	Lamiaceae	Shrub	1	*	
Bougainvillea spectabilis Willd.	Nyctaginaceae	Shrub	1		1
Alternanthera sessilis (L.) R. Br.	Amaranthaceae	Herb	1	*	4

contd..

Amranthus viridis L.	Amaranthaceae	Herb	1	*	3
Gomphrena celosioides C. Martius	Amaranthaceae	Herb	1	*	4
Polygonum plebeium R.Br.	Polygonaceae	Herb	1	*	
Bridella retusa Spreng.	Euphorbiaceae	Tree	1	*	
Phyllanthus emblica L.	Euphorbiaceae	Tree	1		
Euphorbia thymifolia L.	Euphorbiaceae	Herb	1	*	2
Phyllanthus simplex Retz.	Euphorbiaceae	Herb	1	*	
Securinega virosa (Roxb. ex Willd.) Baill.	Euphorbiaceae	Shrub	1	*	1
Tragia involucrata L.	Euphorbiaceae	Herb	1	*	1
Musa paradisiaca L.	Musaceae	Tree	1		
Ananas comosus (L.) Merr.	Bromeliaceae	Herb	1		
Agave cantala Roxb.	Agavaceae	Shrub	1		
Asparagus racemosus Willd.	Liliaceae	Herb	1	*	
Smilax zeylanica L.	Liliaceae	Climber	1	*	2
Cocos nucifera L.	Arecaceae	Tree	1		
Colocasia esculenta (L.) Schott	Araceae	Herb	1	*	
Cyperus rotandus L.	Cyperaceae	Herb	1	*	
Fimbristylis miliacea Vahl	Cyperaceae	Herb	1	*	1
Fimbristylis tetragona R. Br.	Cyperaceae	Herb	1	*	1
Kallinga brevifolia Roxb.	Cyperaceae	Herb	1	*	2
Arundinella ciliata (Roxb.) Nees ex Miq.	Poaceae	Herb	1	*	4
Arundinella spicata Dalz.	Poaceae	Herb	1	*	1
Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae	Herb	1	*	4
Eragrostis viscosa (Retz.) Trin	Poaceae	Herb	1	*	1
Ischaemum rugosum Salisb.	Poaceae	Herb	1	*	2
Paspalidium flavidum (Retz.) A. Camus	Poaceae	Herb	1	*	1
Stephania japonica Thunb.	Menispermaceae	Shrub		*	3
Capparis spinosa L.	Capparidaceae	Shrub		*	4
Capparis zeylanica L.	Capparidaceae	Shrub		*	1
Cleome viscosa L.	Capparidaceae	Herb		*	1
Portulaca oleracea L.	Portulacaceae	Herb		*	1
Mammea suriga (Buch.-Ham. ex Roxb.)	Clusiaceae	Tree		*	2
Hibiscus rosa-sinensis L.	Malvaceae	Shrub			1
Malacra capitata L.	Malvaceae	Herb		*	1

contd..

Sida mysorensis Wight & Arn.	Malvaceae	Herb			1
Thespesia lampas (Cav.) Dalz. & Gibs.	Malvaceae	Shrub			1
Ceiba pentandra (L.) Gaertner	Bombacaceae	Tree		*	1
Oxalis corniculata L.	Oxalidaceae	Herb			1
Garuga pinnata Roxb.	Burseraceae	Tree			1
Azadirachta indica A. Juss.	Meliaceae	Tree			2
Cansjera rheedi J. Gmel.	Oleaceae	Shrub			1
Celastrus paniculata Willd.	Celastraceae	Shrub			1
Cissus repens Lam.	Vitaceae	Twiner	1	*	1
Allophylus cobbe (L.) Raeusch.	Sapindaceae	Tree			1
Nothopegia colebrookiana (Wight) Blume	Anacardiaceae	Tree			1
Spondias pinnata (L.f.) Kurz	Anacardiaceae	Tree			3
Moringa oleifera Lam.	Moringaceae	Tree			1
Cannarus wightii Hook.f.	Connaraceae	Twiner			2
Abrus precatorius L.	Fabaceae	Twiner		*	1
Aeschynomene indica L.	Fabaceae	Herb			2
Canavalia gladiata (Jacq.) DC.	Fabaceae	Twiner			1
Clirotia ternatea L.	Fabaceae	Twiner			1
Crotalaria lutescens Dalz.	Fabaceae	Herb			1
Crotalaria medicagenia Lam.	Fabaceae	Herb			1
Crotalaria mysorensis Roth	Fabaceae	Herb			2
Crotalaria triquetra Dalz.	Fabaceae	Herb			3
Crotalaria verrucosa L.	Fabaceae	Herb			1
Desmodium gangeticum (L.) DC.	Fabaceae	Herb			1
Desmodium laxiflorum DC.	Fabaceae	Shrub			1
Desmodium triquetrum (L.) DC.	Fabaceae	Herb		*	2
Desmodium umbellatum DC.	Fabaceae	Shrub			1
Erythrina suberosa Roxb.	Fabaceae	Tree			2
Indigofera dalzellii Cooke	Fabaceae	Herb			3
Indigofera linifolia (L.f.) Retz.	Fabaceae	Herb			2
Indigofera tinctoria L.	Fabaceae	Shrub			2
Mucuna pruriens (L.) DC.	Fabaceae	Twiner			1
Pseudarthria viscida (L.) Wight & Arn.	Fabaceae	Shrub			2

contd.

Sesbania bispinosa (Jacq.) W. Wight	Fabaceae	Shrub		1
Stylosanthes fruticosa (Retz.) Alston	Fabaceae	Herb		1
Caesalpinia bonduc (L.) Roxb.	Caesalipniaceae	Climber		1
Cassia pumila Lam.	Caesalpiniaceae	Herb		1
Albizzia lebbeck (L.) Benth.	Mimosaceae	Tree		1
Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	Herb		1
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	Tree		1
Quisqualis indica L.	Combretaceae	Shrub		1
Terminalia arjuna (DC.) Wight & Arn.	Combretaceae	Tree		1
Ammannia multiflora Roxb.	Lythraceae	Herb		2
Rotala malampuzhensis R.V. Nair	Lythraceae	Herb		4
Woodfordia fructicosa (L.)	Lythraceae	Tree		1
Ludwigia octovalis (Jacq.) Raven	Onagraceae	Shrub		1
Carica papaya L.	Caricaceae	Tree		1
Opuntia stricta Haw.	Cactaceae	Shrub		1
Anthocephalus cadamba Miq.	Rubiaceae	Tree		1
Catunaregam spinosa (Thunb.) Trivengadum	Rubiaceae	Shrub		4
Hedyotis herbacea L.	Rubiaceae	Herb	*	2
Pavetta indica L.	Rubiaceae	Shrub		1
Spermacoce hispida L.	Rubiaceae	Shrub		1
Acanthospermum hispidum DC.	Asteraceae	Herb		*
Blumea lacera (Burm. f.) DC.	Asteraceae	Herb		3
Chrysanthemum indicum L.	Asteraceae	Herb		1
Eclipta prostrata L.	Asteraceae	Herb		2
Synedrella nodiflora (L.) Gaertner	Asteraceae	Herb	*	2
Tridax procumbens L.	Asteraceae	Herb	*	2
Mimusops kauki L.	Sapotaceae	Tree		1
Jasminum malabaricum Wight	Oleaceae	Shrub		3
Allamanda cathartica L.	Apocynaceae	Shrub		1
Cathranthus rosea D.Don.	Apocynaceae	Shrub		1
Nerium indicum Mill.	Apocynaceae	Shrub		1

contd..

Plumeria rubra L.	Apocynaceae	Tree		1
Crytpostegia grandiflora R. Br.	Asclepiadaceae	Twiner		1
Hoppea dichotoma Willd.	Gentianaceae	Herb		1
Heliotropium indicum L.	Boraginaceae	Herb		1
Heliotropium supinum L.	Boraginaceae	Herb		1
Ipomoea biloba Forsk.	Convolvulaceae	Twiner		1
Utricularia reticulata Sm.	Lentibulariaceae	Herb		2
Heterophragma quadrilocularis (Roxb.) K. Schum.	Bignoniaceae	Tree		2
Adathoda zeylanica Medikus	Acanthaceae	Shrub		1
Andrographis paniculata (Burm.f.) Wallich ex Nees	Acanthaceae	Herb		1
Lepidagathis clavata Dalz.	Acanthaceae	Herb		1
Lepidagathis prostrata Dalz.	Acanthaceae	Herb	*	5
Lepidagathis trinervis Wall. ex Nees	Acanthaceae	Herb		1
Rungia repens (L.) Nees	Acanthaceae	Herb		3
Duranta erecta L.	Verbenaceae	Shrub		1
Gmelina arborea Roxb.	Verbenaceae	Tree		1
Vitex trifolia L.	Verbenaceae	Shrub		2
Anisochilus verticellatus Hook. f.	Lamiaceae	Herb		1
Leonotis nepetaefolia (L.) W. Ait.	Lamiaceae	Herb		1
Ocimum americanum L.	Lamiaceae	Herb		1
Achyranthes aspera L.	Amaranthaceae	Herb		3
Aerva lanata (L.) Juss.	Amaranthaceae	Herb		1
Amaranthus tricolor L.	Amaranthaceae	Herb		1
Amaranthus spinosus L.	Amaranthaceae	Herb		2
Amaranthus tenuifolius Willd.	Amaranthaceae	Herb		1
Gomphrena globosa L.	Amaranthaceae	Herb		1
Aristolochia indica L.	Aristolochiaceae	Shrub		1
Myristica fragrans Houtt.	Myristicaceae	Tree		1
Loranthus cuneatus Heyne	Loranthaceae	Herb		1
Loranthus longiflorus Des.	Loranthaceae	Herb		1
Breynia retusa (Dennst.) Alston	Euphorbiaceae	Shrub	*	
Croton bonplandianus Baillon	Euphorbiaceae	Herb		3
Phyllanthus emblica L.	Euphornbiaceae	Tree		1
Mallotus tetracoccus (Roxb.) Kurz	Euphorbiaceae	Tree		1

contd..

Manihot esculenta Crantz	Euphorbiaceae	Herb	1
Pedilanthus tithymaloides (L.) Poit.	Euphorbiaceae	Shrub	1
Ricinus communis L.	Euphorbiaceae	Shrub	1
Pilea microphylla (L.) Liebm	Urticaceae	Herb	2
Pouzolzia zeylanica (L.) Benn.	Urticaceae	Herb	2
Artocarpus incisus L.f.	Moraceae	Tree	1
Morus alba L.	Moraceae	Tree	1
Acampe praemorsa (Roxb.) Blatter & Mc Cann	Orchidaceae	Herb	1
Canna indica L.	Cannaceae	Herb	1
Sansevieria zeylanica Willd.	Haemodoraceae	Herb	1
Agave americana L.	Agavaceae	Shrub	1
Monochoria vaginalis (Burm.f.) C. Presl	Pontederiaceae	Herb	1
Commelina bengalensis L.	Commelinaceae	Herb	2
Commelina obliqua Buch.-Ham.	Commelinaceae	Herb	2
Cyanotis fasciculata (Roth) Schultes & Schultes f.	Commelinaceae	Herb	1
Rheo discolor Hance	Commelinaceae	Herb	1
Cyanotis axillaris (L.) D. Don	Commelinaceae	Herb	2
Calamus rotang L.	Arecaceae	Shrub	2
Pothos scandens L.	Araceae	Climber	1
Cyperus leucocephalus Retz.	Cyperaceae	Herb	2
Chloris inflata Link	Poaceae	Herb	1
Chloris virgata Sw.	Poaceae	Herb	1
Eleusine indica Gaertn.	Poaceae	Herb	1
Eragrostis ciliaris (L.) R. Br.	Poaceae	Herb	1
Urochloa panicoides Beauv.	Poaceae	Herb	2

Table 4: Classification of plant species based on their occurrence on mine rejects, around mines and on plateaus

Class	Occurrence			Total number of species present	Percentage
	On reject dumps	Around mines	On Plateaus		
I	+	+	+	185	44.47
II	+	+	-	54	12.98
III	+	-	+	13	3.13
IV	+	-	-	32	7.66
V	-	+	+	16	3.83
VI	-	+	-	2	0.48
VII	-	-	+	112	26.79

+ = Species present; - = Species absent

Table 5: List of plant species suitable for revegetation of iron ore mine tailing ponds in Goa (Based on survey studies)

Plant species	Family	Habit	Abundance
Phyllanthus maderaspatensis L.	Euphorbiaceae	Herb	3
Eragrostis amabilis Wight.	Poaceae	Herb	3
Indigofera prostrata Willd.	Fabaceae	Herb	2
Lindernia crustacea (L.) F. Muell.	Scrophulariceae	Herb	2
Digitaria ciliaris (Retz.) Koeler	Poaceae	Herb	2
Echinochloa colona (L.) Link	Poaceae	Herb	2
Neanotis foetida (Hook. f.) W.H. Lewis	Rubiaceae	Herb	2
Spermococe hispida L.	Rubiaceae	Herb	2
Desmodium triflorum DC.	Fabaceae	Herb	2
Geissaspis cristata W. & A.	Fabaceae	Herb	2
Smithia salsuginea Hance	Fabaceae	Herb	2
Ludwigia perennis L.	Onagraceae	Herb	2
Canscora diffusa (Vahl) R. Br.	Gentianaceae	Herb	2
Casuarina equisetifolia Forster & Forster f.	Casuarinaceae	Tree	2
Atylosia scrabaeoides (L.) Thouars	Fabaceae	Herb	1

contd..

Zornia gibbosa Sphangoe	Fabaceae	Herb	1
Cassia mimosoides L.	Caesalpiniaceae	Herb	1
Cassia tora L.	Caesalpiniaceae	Herb	1
Acacia auriculiformis A. Cunn. ex Benth.	Mimosacae	Tree	1
Psidium guajava L.	Myrtaceae	Tree	1
Leea indica (Burm. f.) Merr.	Leeaceae	Shrub	1
Mukia maderaspatana (L.) M. Roemer	Cucurbitaceae	Twiner	1
Eupatorium odoratum (L.)	Asteraceae	Herb	1
Alstonia scholaris (L.) R. Br.	Apocynaceae	Tree	1
Calotropis gigantea (L.) R. Br.	Asclepiadaceae	Shrub	1
Merremia tridentata Hallier f.	Convolvulaceae	Twiner	1
Paspalum scrobiculatum L.	Poaceae	Herb	1

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