PROSOPIS JULIFLORA ON BARITE MINE TAILINGS: A CASE STUDY FROM MANGAMPETA REGION, CUDDAPAH DISTRICT, ANDHRA PRADESH, INDIA[1]

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Abstract. The barite is mined from the opencast mine and waste overburden is removed and dumped in the nearby areas. The dumps are invariably associated with pockets of soil/carbonaceous tuff overburden or waste rock incorporated into the tailings. The disintegrated soils, the rock waste and tailings are often very unstable and become sources of pollution. *Prosopis juliflora* is extensively and exclusively developed on these mine tailings. Leaves and twigs of *Prosopis juliflora* along with their soil samples were analysed for mineral elements viz., Ba, Sr, Mn, B, Cu, Zn, Pb, Ni, Co and Cr. Huge amounts of Ba, Sr, B, Cu, Pb and Zn have been accumulated in both the organs of this plant. Further, this study has given greater scope on the plant-soil relationship in the mining area and their significance in environmental studies. The existence of plants on the mine wastes and metal contaminated soil led to the belief that metal tolerant species grow by natural selection. The biological absorption coefficient (BAC) is used to characterize the absorption of chemical elements by plants from their substrate. The ubiquitous thorny shrub *Prosopis juliflora* has an extraordinary ecologic amplitude and tolerance for a variety of elements. Hence, it is envisaged that this plant species can be used for reclaiming the tailings in barite mining area of Mangampeta for the purpose of stabilizing the area.

Additional Key Words: Reclamation, Biological absorption coefficient

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Introduction

Surface mining operations have the potential to affect flora and fauna, and contaminate soil, air and water in the surrounding areas (Safaya, 1979; Dhar and Thakur, 1995; Salomons, 1995; Marques et al., 2001). Mine spoil poses adverse conditions for soil microbe and plant growth, due to its low organic matter and other essential nutrient concentrations, poor structure - either coarse or compact, and isolation from vegetation (Meyer, 1973; Harthill and Mckell, 1979). Considerable amounts of heavy metals are transferred off-site even after the closure of a mine (Merrington and Alloway, 1994). The direct effects of mining wastes include loss of cultivated land, forest or grazing land, and overall loss of production (Wong, 2003). The indirect effects include air and water pollution. These effects will eventually lead to the loss of biodiversity, amenity and economic wealth (Bradshaw, 1993) since mining activity degrades the environment both directly and indirectly. Not only are mine spoil dumps are important sources of metal contamination in the environment, they are characterized by high metal concentrations and particular physical and chemical conditions that make metals environmentally liable and free to move in the surrounding environment, through normal biogeochemical pathways, to sinks such as sediments, soils or biomass (Davies 1983).

Plants that hyper accumulate metals have tremendous potential for application in remediation of metals in the environment. This approach is emerging as an innovative tool with greater potential for achieving sustainable development and also to decontaminate metal polluted air, soil, water and for other environmental restoration applications through rhizosphere biotechnology (Desouza et al. 1999; Wenzel et al. 1999). Metal hyperaccumulating plants are thus not only useful in phytoremediation, but play a significant role in biogeochemical prospecting, and have implications on human health through food chain (Kabata-Pendias, 2001). Therefore, plant populations accumulate high amounts of heavy metals in their tissues without showing growth inhibition have involved in their survival in these extreme situations.

In recent years, increasing emphasis on opencast method of excavation has resulted in unprecedented increase of mine spoil dumps in India. This paper presents the results of a study examining the potential of *Prosopis juliflora* for reclaiming and stabilising barite mine tailings in the Mangampeta region of Andhra Pradesh, India.

Prosopis juliflora

Prosopis juliflora (mesquite) was been introduced from the United States as a very promising species useful in afforestating dry and degraded lands. It originates in an area of northern South America into Mexico (Ffolliott and Thames, 1983), and forms a major component in dryland ecosystems in the Americas, Africa and Asia. It is a fast growing hardy and drought-resistant tree, with remarkable coppicing capacity, and is suitable for afforestation of arid and semi-arid lands, growing well even in saline and rocky areas (Jarrel and Virginia, 1990; Tewari et al. 2000). There appear to be four flowering seasons during which pollen grains float in all directions (Abdulrahman et al. 1999). This plant species is a legume with several variations that has been used for the reclamation of saline soils and desert lands and as a wood resource (Bessega et al. 2000; Bener et al. 2002; Bhojvaid, 2005). It is an indicator of alkalinity and fluoride in waters of fluorosis-affected area (Chari et al. 1984). Mehmood and Iqbal, 1995 have reported that *Prosopis juliflora*, along with other plant species occurring near Wasteland of Valika Chemical Industries, have indicated that the soils are of halophytic type with alkaline pH. Allergenicity to *Prosopis juliflora* pollen antigen has been reported from only a few countries, including the US, South Africa, India and Kuwait. In some areas, *Prosopis* has spread from the low rainfall zones in which it was planted, invading water courses, irrigated agricultural land, and adjacent higher rainfall areas. Tiwari et al. (2000) have discussed about the Information concerning the relative invasiveness of *Prosopis* species, reproductive biology and methods for controlling the spread or eradication.

Geology of the Study Area The barite deposit occurring at Mangampeta, Cuddapah District of Andhra Pradesh, is unique in nature as it occurs in bedded form. The area under investigation falls between the latitudes 14° 01' N and longitudes 79° 19' E. The bedded deposit is confined to Pullampet shales of Cheyyair group of Lower Cuddaph Super Group. The deposit occurs as two separate lensoid bodies within the upper Carbonaceous tuff zone of middle Proterozoic Cuddapah Supergroup. Granular barite beds are overlain by a zone of lapilli barite that constitutes the economically significant deposit, with an estimated reserve of over 74 million tons. The barite is associated with copper mineralization, primarily consisting of chalcopyrite, azurite and malachite.

The barite is mined by opencast methods and the deposit is a bedded deposit with tuff as hanging wall and dolomite as foot wall. The deposit strikes N 30^0 W – S 30^0 E and dips 20^0 – 30^0 towards the N-E. The deposit was first described by Karunakaran (1971, 1976), who reported the occurrence of bedded barite at Mangampeta. Other workers have studied the nature and origin (Kurien et al. 1977), geochemical (Neelakantam, 1987; Basu, 1997; Sirish Chandra, 2000), and petrological (Viswanath and Sastry 1983) aspects of this mineralized area and confirmed that the deposit is of volcanic origin.

Materials and Methods

Leaves and twigs of *Prosopis juliflora* were separated, thoroughly washed with distilled water, air-dried, then oven dried at 90°C overnight. The samples were reduced to ash by ignition at 450° C. About 0.2 g of sample of the finer fraction plant ash/soil was digested in 1:1 HNO_3 and HCl and dried in tubes in a water bath. The solutions were made up to 10 ml with distilled water. Both soil and plant samples were analyzed by atomic absorption spectrometry for Ba, Sr, Mn, B, Cu, Zn, Pb, Ni, Co and Cr as per the method given by Brooks et al. (1995) and the values of the elemental data, with minimum, maximum and their average values along with their standard errors are shown in Table 1 and Figure 1.

Results and Discussion

The results of the present study (Fig. 1, Table 1) clearly indicate that leaves and twigs of *Prosopis juliflora* showed variation in concentration of elements. The elemental accumulation for different elements is as follows.

Strontium, Mn, B, Cu, Pb and Zn are less concentrated in soil than in plant ash, and the converse is true for Ba, Ni, and Cr. Furthermore, Ba, B, Mn, Zn, and Cr are more highly accumulated in the leaves than in the twigs. The converse is true for Sr, Cu, Pb and Ni. A huge amount of Ba (mean value of 1675 ppm) is accumulated in the soil, but its concentration in plants is considerably less. The barium that is present in barite is insoluble; enough to be taken up by plants growing on barium rich soils (Norrish, 1975). The average concentration of Ba in leaves is about 460 ppm and in twigs 270 ppm. Nagaraju and Prasad (1997) have noticed that leaves of *Prosopis juliflora* contain higher concentration of Ba than twigs in Nellore mica belt.

The highest concentration of Sr (average value of 422 ppm) is in the twigs. Raju et al. (2000) have shown that *Pterocarpus santalinus* is capable of accumulating large amounts of Sr, Zn and Cu, and *Azadirachta indica* has also been proved as an accumulator of Sr (Nagaraju and Prasad, 2000).

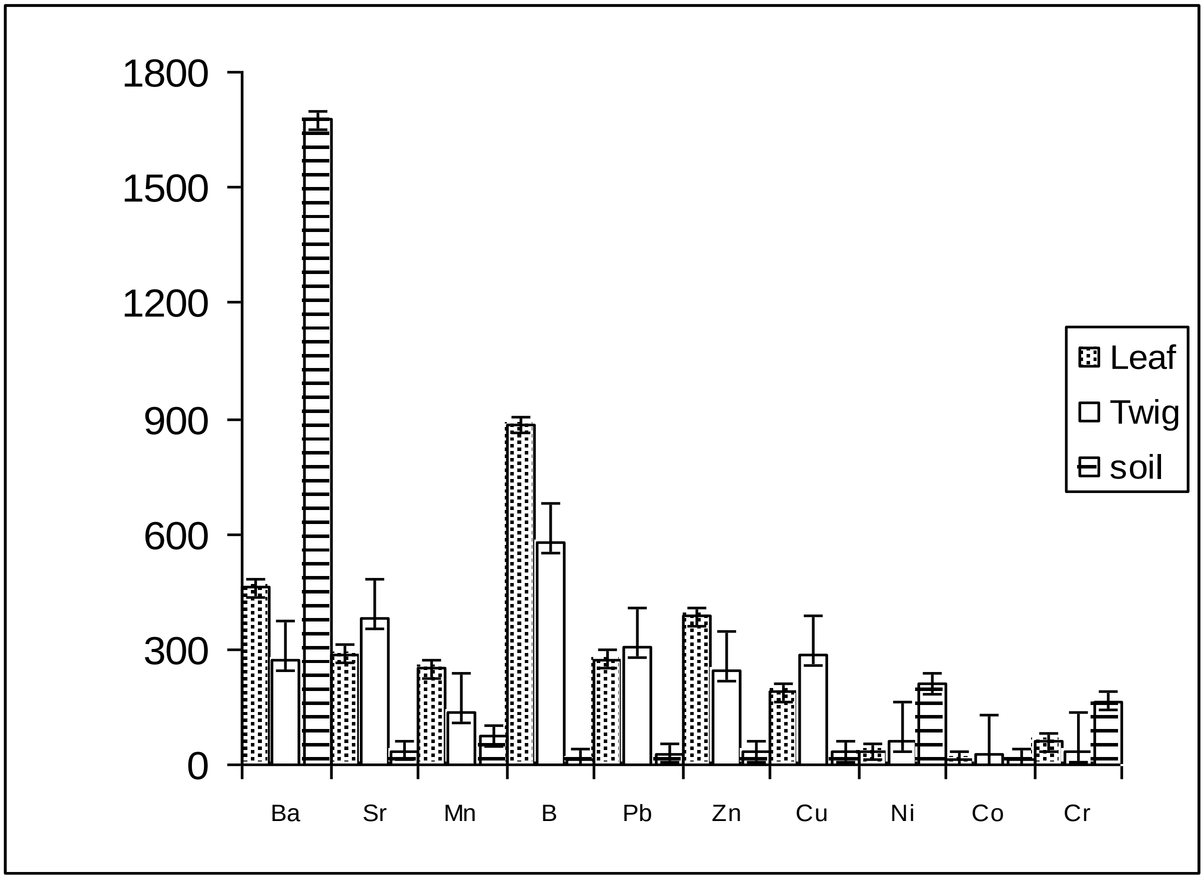

Figure 1 Average concentrations of different elements in ppm along their standard error.

Boron concentrations in leaves of *Prosopis juliflora* are consistently higher than stem concentrations. This element is relatively immobile in plants, and frequently the B content increases from the lower to the upper plant parts (Oertli and Richardson, 1970). High concentration of boron (1650 ppm) are also reported from leaves of *Prosopis juliflora* from the Nellore mica belt (Nagaraju and Prasad, 1998, 1999). Obviously, this species appears to have developed tolerance for boron.

The concentration of Cu ranged from 149 ppm to 325 ppm, Pb from 189 to 383 ppm and Zn from 209 - 413 ppm in both the leaves and twigs of the *Prosopis* species studied. Lead concentrations were not significantly high due to the relatively low soil Pb contents and low availability Pb to plants (Thornton, 1983; Jung and Thornton, 1996). Earlier studies have indicated the accumulations of heavy metals such as Cu, Zn and Pb in *Prosopis juliflora* (Iqbal et al. 1999; Nagaraju and Prasad, 1999). Certain studies have indicated the accumulation of B, Cu, Mn, Ni, Ba and Sr in some plants and soils (Do van et al.1972; Lombini et al. 1998).

Mn concentrations are from 109 ppm to 295 ppm. Lounama (1956) has quoted on the manganese content of leaves and stems of several conifers and deciduous trees and shrubs growing on different rocks. He found generally that the leaves contained more Mn than the stems. Further Ni content varied from 21 ppm to 72 ppm and Co 10 to 32 ppm. The concentration of Cr in ranged from 27 to 63 ppm. The metal uptake is strongly controlled by the amount of metal available in soil solution for uptake by plants. Cr has a low mobility in soil suggesting that the metal uptake might be dependent of the amount of metal available in the soil but depends on the metabolism of each species having selective absorption of the metals (Lombini et al., 1998).

The composition of plant tissues reflect the composition of the soil in which the plant grows. This interrelationship however, is modified in many plants by tolerance mechanisms. Thus plants are able to accumulate most chemical elements, and many species are sensitive indicators of the chemical environment in which they grow, and also the elemental content of different of the same plants may be widely divergent (Kovalevskii, 1987; Erdman, 1990; Brooks et al. 1995).

Biological absorption coefficient (BAC)

The biological adsorption coefficient (BAC; Kovalevskii, 1969) indicates the intensity of absorption of chemical elements by plants from their substrate. It is defined as follows:

$$BAC = C_p / C_s$$

Where C_p is the concentration of an element in plant ash and Cs is the concentration of the same element in the substrate. The range of BAC values varies widely from 0.001 - 100. It is one of the important biogeochemical parameters used in mineral exploration (Sabinin, 1955; Perelman, 1966); Brooks, 1983; Kovalevskii, 1987). Alloway et al. (1988) concluded that plant uptake of elements can be evaluated by using this simple index. Further, they suggested that the water-soluble fraction is likely to represent a metal fraction available for plant uptake. BAC values have been classified by Perelman (1966) into five groups: ‘intensive absorption' (BAC 10-100); 'strong absorption' (BAC 1-10); ‘intermediate absorption' (BAC 0.1-1); 'weak absorption' (BAC 0.01-0.1); and 'very weak absorption' (BAC 0.001-0.01).

The BAC values of *Prosopis juliflora* in the study area were calculated and are shown in Table 2. Based on the classification of BAC values suggested by Perelman (1966) the behaviour of plants under study is as follows. Boron shows intensive absorption, and Sr, Zn and Pb show both intensive absorption and strong absorption. Copper and Mn show strong absorption and Ni, Cr, and Ba exhibit intermediate absorption. Finally, Co shows both intermediate and strong absorption.

Denali and Lombini (1994) studied the geochemical behaviour of some elements (Cr, Fe, Ni, Cu and Zn) in iron and copper sulphide mine spoil dumps of the Vigozano northern mining area of Northern Apennines by adopting this parameter. It is concluded that the different organs of a species exhibit different behaviour with respect to elemental concentrations and their mobile nature. Most plants establish at their root tips barriers to absorption of some elements, and each plant species has a different requirement for, and tolerance to, trace elements (Dunn et al. 1996).

Table 1 Minimum, Maximum and average concentrations of *Prosopis juliflora* and their soils

Element (ppm)	Leaf				*Twig*				Soil			
	Min	*Max*	*Avg*	*SE*	*Min*	*Max*	*Avg*	*SE*	*Min*	*Max*	*Avg*	*SE*
Ba	390	530	460	22.22	208	390	270	101.85	1545	1750	1675	26.43
Sr	249	330	287	11.40	315	422	378	14.73	32	40	37	1.02
Mn	207	295	248	13.35	109	173	136	8.85	59	92	75	4.35
B	549	1032	883	64.86	386	945	574	71.65	10	13	11	0.43
Pb	228	345	275	17.19	189	383	304	25.17	23	37	30	1.74
Zn	355	413	384	7.20	209	315	244	15.75	26	39	32	1.88
Cu	149	244	188	12.85	251	325	286	11.66	31	43	36	1.70
Ni	21	32	35	1.75	38	72	60	4.95	46	310	208	33.87
Co	13	17	15	0.69	10	32	26	3.05	11	16	13	0.72
Cr	49	63	58	5.24	27	42	35	1.86	147	190	166	5.48

Concentrations are average of 6 samples ± standard error

Table 2 Biological absorption coefficient of different organs of *Prosopis juliflora*

Element	*Prosopis juliflora*		Prosopis juliflora		*Prosopis juliflora*		Prosopis juliflora		Prosopis juliflora		Prosopis juliflora	
	Leaf	*Twig*	*Leaf*	*Twig*	*Leaf*	*Twig*	*Leaf*	*Twig*	*Leaf*	*Twig*	*Leaf*	*Twig*
Ba	0.24	0.16	0.31	0.19	0.25	0.14	0.32	0.23	0.27	0.12	0.26	0.13
Sr	7.88	10.55	7.53	9.79	8.92	11.22	7.89	10.20	7.78	9.84	7.16	10.43
Mn	2.70	1.62	3.29	1.74	4.40	2.58	3.51	1.85	2.89	1.55	3.45	1.71
B	93.82	85.91	54.90	38.60	81.83	48.00	88.20	49.50	74.77	41.15	80.18	46.36
Pb	8.14	11.25	10.78	9.19	7.43	10.35	9.14	6.52	8.14	12.75	13.48	12.43
Zn	14.81	8.04	13.32	10.16	14.11	9.71	9.59	5.68	11.52	6.58	9.67	6.21
Cu	5.44	8.71	5.67	7.37	0.13	0.65	5.47	8.00	4.81	8.77	1.19	1.83
Ni	0.08	0.21	0.13	0.34	0.10	0.22	0.46	0.83	0.10	0.25	0.14	0.37
Co	1.55	2.91	0.87	1.93	0.88	1.94	1.42	0.83	1.08	2.25	1.08	2.23
Cr	0.39	0.26	0.39	0.24	0.31	0.17	0.32	0.19	0.32	0.19	0.36	0.21

The extensively mined land usually does not possess sufficient surface soil to anchor plants, and the plant growth that does take place is inhibited by the presence of toxic metals. Over the long term, open-cast mining reduces forest productivity, damages aquatic and atmospheric ecosystems and sometimes leads to substantial alterations in microclimates. Such changes, in turn, carry adverse economic and social impacts for nearby communities whose residents depend on the region's natural resources for large portions of their incomes.

Mine tailings impose various adverse effects on plant growth through high levels of various heavy metals and other elements in toxic concentrations, low amounts major plant nutrients, acidity, salinity and alkalinity (Bradshaw and Chadwick, 1980). This infers that *Prosopis juliflora* growing on barite mine tailings can tolerate elevated metal concentrations. Therefore, selection of such appropriate plant species which can establish, grow and colonise contaminated soils is important for successful reclamation of degraded mine sites (Nagaraju and Prasad, 1999; Wong, 2003). Similarly, Bu-Olayan and Thomas (2002) have studied on biomonitoring aspects of lead levels in *Prosopis juliflora in* Kuwait. The plants must be tolerant to toxic metals and should be ideal pioneer species to accelerate ecological succession of man-made habitats (Kaul, 1985; Bradshaw, 1993). Further, this species is also being used in revegetation of fly ash land fills (Rai et al. 2004) and this species is also an accumulator of sulpher (Iqbal and Mehmood, 1992).In all cases tolerance has been shown to be element specific although plants from mine wastes which contain multiple toxicities have evolved tolerance to all of the metals involved (Berti and Cunningham, 2000). Unlike other phytoremediative techniques, the goal of phytostabilization is not to remove metal contaminants from a site, but rather to stabilize them and reduce the risk to human health and the environment (Schnoor, 2000).

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