International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 17
November 2016

Uptake and Distribution of Chromium in Various Plants Growing on Mining Area: A Study from Thagadur Area, Nuggihalli Schist Belt, Karnataka

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Abstract

An attempt was made in the present study to characterize some of the plants that naturally colonized in Thagadur chromite mining area to determine the Cr accumulation pattern in the four selected dominant plant species including Cassia ariculata, Tephrosia purpurea, Hyptis suaveolens and Acacia arabica. Chromium content in mine soil and in the stem, leaves of the plants is determined. The values are compared with similar type samples collected from normal vegetation/non-mining area. Generally the chromium concentration in the plants growing on the mining area is higher than the samples collected from non-mining area. In the study area, accumulation of chromium in the plant species and in their organs varies i.e the Cr concentration is higher in leaves than in stems even though all these four plants are growing under identical conditions. Under normal condition chromium concentration is high in Cassia ariculata. Distribution of chromium metal in plant samples collected from mine area revealed that Hyptis suaveolens has special ability to accumulate high amount of chromium followed by Acacia arabica, Cassia ariculata and Tephrosia purpurea.(H. suaveolens >A. Arabica> C. ariculata> T. purpurea). Mechanism of chromium in Hyptis suaveolens is some what different from the other plants growing in the same soil. Hyptis suaveolens has the capability to take up more metal when compared to other three plant species. Hence this plant may be more suitable for removal of chromium metal from the soil In the study area, these plants can ideally be used as the possible application in reclamation and revegetation of adversely affected mining environment, and also for chromium exploration.

Keywords: *Cassia ariculata, Tephrosia purpurea, Hyptis suaveolens, Acacia Arabica*, Chromite mine

Introduction

The plant species which have the ability to successfully germinate grow and reproduce under adversely affected environments to be useful for reclamation and revegetation. Trace metal pollution and the resulting health effects present some of the major challenges currently affecting the world. Accumulation of essential and non-essential trace metals in soil-plant system has become a global concern, as deficiency or excess of essential and non-essential metals poses a health threat to humans and other organisms when accumulated within the biological system (Provot et al 2006; Zhuang et al 2009) .Generally most of the plant species which grow in mineralized areas are known to accumulate metals, relatively in excess amount than in non-mineralized areas. However certain plants have the unusual adaptability to withstand heavy metal toxicity, and such plants are referred to as indicator plants. Metal hyper accumulating plants are useful in phytoremediation and play a vital role in biogeochemical prospecting, and have implications on human health through food chain (Kabata Pendias, 2001). The 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 element content at

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e-ISSN: 2348-795X
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different of the same plants may be widely divergent (Kovaleveskii,1987; Erdman,1990; Brooks et al 1995).Chemical analysis of systematically sampled trees and shrubs for traces of ore metals was one of the geochemical methods to be investigated (Rose et al 1979).Earlier studies of heavy metal tolerance confirm that populations growing in metal-contaminated habitats are different from those growing in clean sites of the same species by possessing genetically based tolerance (Antonovics et al 1971).Phytoremediation is an ideal and important emerging biotechnological application and operates on the principle of biogeochemical cycling (Prasad, 2004). It involves the use of plants that readily transport targeted metals from soil to plant organs, which allows removal of metal by harvesting from the plant. This process takes longer time but helps in the greening of the land and in reducing pollution (Pulford and Dickinson, 2006). The aim of the present study is to determine the Cr accumulation and distribution pattern in the plant species growing on chromite mine and to asses these plants for their ability to uptake and accumulates the Cr in different organs of the plants.

Study Area

The study area, Thagadur (Lat.13^{0}01'50" to 13^{0}04'30"E, Long.76^{0}26'40" to 76^0 27'30"N) is located in Chhanarayapatana Taluka, Hassan district, Karnataka and is included in survey of India toposheet No. 57 C/8. The Thagadur chromite mine is a part of Nuggihalli schist belt received considerable attention in view of the chromite, and vanadiferrous titanomagnetite mineralization. This mine has other mineral deposits include titaniferrous magnetite, quartz, dunite and serpentinite. Thagadur chromite mineralized zone comes under Nuggihalli schist belt, one of the ultramafics rich belts in the Dharwar craton (Bidyananda et al 2003). Sporadic occurrence of sulphide mineralization has also been known from this belt (Radhadkrishna et al 1973).Earlier workers have studied on mineralogy of chromites from Nuggihalli schist belt (Perumal et al 2011).The surrounding area of the mining the important cultivation is of coconut, sugar cane and seasonal crops such as maize. The area receives a moderate rainfall. The study area is part of tropical climate with hot summer, moderately cool winter and moderate monsoon during June to August.

Methodology

After a preliminary geobotanical survey in Thagadur chromite mining area, among the several plants occurring, four naturally growing dominant plant species, viz., Cassia ariculata, Tephrosia purpurea, Hyptis suaveolens and Acacia arabica are identified. To know the chroimium (Cr) accumulation and distribution pattern in these different plant species an experiment is conducted and the data obtained is compared with the data of similar plants growing in natural vegetation in non-mining zone. Composite samples of the fresh leaves and stems of the six samples of plants per species (C. ariculata, T.purpurea, H.suaveolens and A.arabica) and soil samples are collected from the mine. Similarly, the leaves and stems, and soil samples are collected from the same plant species growing on non-mineralized zone to determine the plant-soil relationship and also to study the indicator characteristics of the plants if any. Leaves and stems are collected separately at different points around the

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circumference of the plant and these are made into a composite sample. The sample preparation of the plant material for the laboratory study is made as suggested by Brooks (1983). Dust, soil particles accumulated on the surface of the plant samples i.e leaves and stems/twigs removed by washing thoroughly with tap water. This is followed by thorough washing of the samples with deionized water and air dried. The moisture was eliminated by keeping these samples in a hot air oven at 110^{o}C. The oven dried material is ignited into ash in a muffle furnace at 500^{o}C for six hours, and digested in 2M HCl. Samples of soils are oven dried at 110^{o}C, and lightly disintegrated in a porcelain mortar. Finally, 2mm sieved samples are powdered and ignited at 500^{o}C in a muffle furnace for six hours and then digested in aquaregia. All samples are analyzed for Cr content by atomic absorption spectrophotometry and the data is presented in Table 1.Chromium concentration in stems and leaves of four different plant families of mining and non-mining areas are diagrammatically shown in Fig 1 and 2.

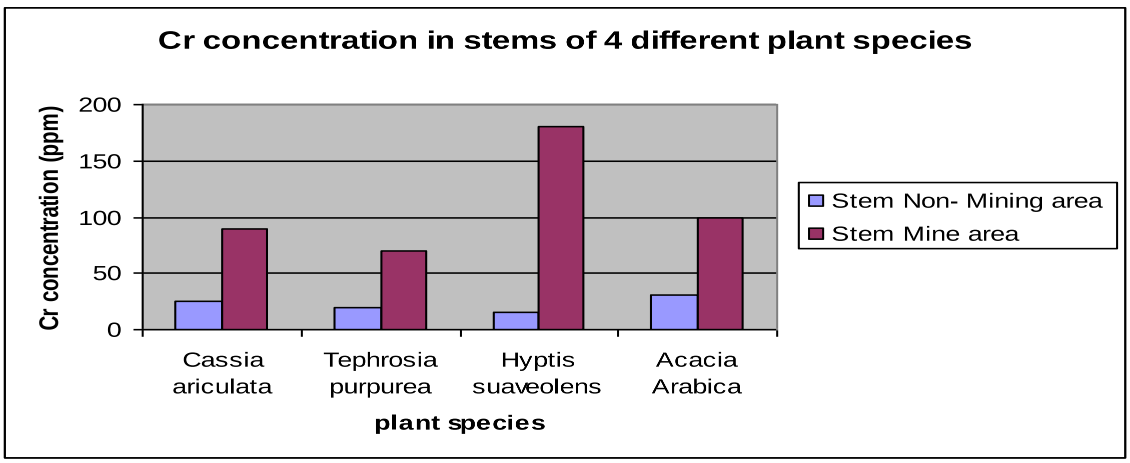

Fig 1. Chromium concentration in stems of four different plant families

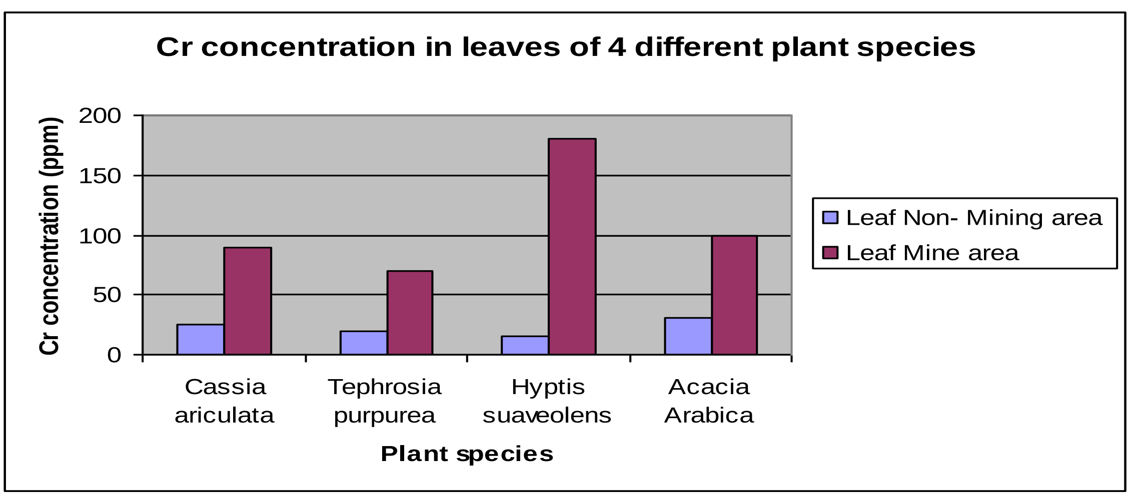

Fig 2. Chromium concentration in leaves of four different plant families

p-ISSN: 2348-6848
e-ISSN: 2348-795X
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Table 1. Distribution of chromium (ppm) in plant organs and soils from mining and non-mining area

Plant species	Leaf			Stem			Soil		
	Non-Mining area (N)	Mine area (M)	Ratio of N&M	Non-Mining area (N)	Mine area (M)	Ratio of N&M	Non-Mining area (N)	Mine area (M)	Ratio of N&M
Cassia ariculata	25	90	1:3.6	15	60	1:4	8	155	1:19.3
Tephrosia purpurea	20	70	1:3.5	12	54	1:4.5	8	155	1:19.3
Hyptis suaveolens	16	180	1:11.25	10	135	1:13.5	8	155	1:19.3
Acacia arabica	31	100	1:3.2	18	88	1:4.8	8	155	1:19.3

Results and Discussion

In the study area, the concentration of chromium in the leaves of cassia ariculata, tephrosia purpurea, hyptis suaveolens and acacia arabica in non-mining area is recorded as 25ppm, 20ppm,16ppm, and 31ppm respectively; while in stems the concentration is 15ppm, 12ppm,10ppm, and 18ppm respectively. Similarly the concentration of chromium in the leaves of C.ariculata, T.purpurea, H.suaveolens and A.arabica in mining area is recorded as 90ppm, 70ppm, 180ppm, and 100ppm respectively; while in stems it is 60ppm, 54ppm, 135ppm and 88ppm respectively. The concentration of Cr in the soils of non-mining and mining area is 8ppm and 155ppm respectively (Table 1). From the data (Table 1) it may be seen that generally, chromium concentration is considerably high in the leaves than in the stems of all the four plant species irrespective of location of the plant developed. Hence there may be maintaining a kind of grade in these organs i.e leaves and stems. This might be possible due to deposition of chromium in the leaves. The concentration of chromium is higher in various plant samples of leaves and stems collected from the chromite mining area, than that of the same plant species of the non-mining area i.e normal vegetation. Even though all these four plants are growing under identical conditions, chromium concentrations in their organs are varied. Therefore this reveals that the mechanism of chromium uptake in these plant species may be different. All the four plant species in this study are growing in the high chromium-containing zone for many years, but the chromium is not uniformly distributed in these plant organs. Hence, there is a need for detailed investigation to know the process of transfer of chromium from the stems to the leaves to maintain the gradient. The sequence of individual parts of four plant species is arranged in the deceasing order based on the elemental concentration both in mining and non-mining area and is shown in Table 2. From the data (Table 2) it may be seen that in mining area, Cr concentration is high in stems and leaves of H. suaveolens while in non-mining area, Cr concentration is high in stems and leaves of A. arabica. Concentration of chromium is varied in four different plant species which were collected from non-mining/normal vegetation. Concentration of chromium in non-mining soil is 8 ppm. In non-mining area the plant, A.arabica shows highest chromium concentration in leaves (31 ppm) and in stems/twigs (18 ppm) followed by C.ariculata, T.purpurea and H.suaveolens. The values are higher than the concentration of the chromium in the soil (8ppm). Hence, further studies are essential to determine whether these are the required concentrations in the plant organs for their regular functioning. Thus the varying amounts of chromium in the organs of the four various plants species under identical conditions indicate that the ability of a plant to uptake and accumulate chromium differs from species to species. Under study amongst the selected four plants growing in chromite mining area, the concentration of chromium is high in the leaves (180 ppm) of H.suaveolens. Then this is followed by A.arabica, C.ariculata and T.purpurea. In H.suaveolens, the ratio of Cr in leaf samples of non-mining and mining area is 1:11.25 whereas in stems, the ratio is 1:13.5. Therefore it reveals that the uptake of chromium by H.suaveolens is more. The optimum capacity of this plant to uptake and accumulate Cr needs to be determined by other suitable experiments. Long et al (2002) have the opinion that some plants that grow on naturally metal-contaminated soils may adapt and develop to survive and accumulate greater concentration of heavy metals on their shoots than other plant species.

Table 2. The sequence of four plants based on the elemental concentration

Location	Plant organs	Sequence
Mining Area	Stems	H.suaveolens >A.arabica>C.ariculata> T.purpurea
	Leaves	H.suaveolens >A.arabica>C.ariculata> T.purpurea
Non-mining Area	Stems	A.arabica>C.ariculata> T.purpurea> H.suaveolens
	Leaves	A.arabica>C.ariculata> T.purpurea> H.suaveolens

In the mining are uptake of chromium in leaves of A.arabica is high (100 ppm) when compared non-mining (31ppm) area but it is not as high as in H.suaveolens. However, the ratio of Cr concentration of the non-mining and mining area soil sample is 1:19.3, where as the ratio of the non-mining and mining area samples of leaves and stems of A.arabica are only 1:3.2 and 1:4.8 respectively. Hence the amount of Cr accumulated in leaves and stems of A.arabica may be the optimum for this plant. The mechanism of chromium tolerance in A.arabica may be different from that of H.suaveolens. In non-mining area chromium content is recorded as high in leaf (20 ppm) and stem/twig (12 ppm) samples of tephrosia purpurea than in hyptis suaveolens; where as the chromium concentration in the organs of T.purpurea in the mine area is less (70 ppm in leaves, and 54 ppm in stems) than in H. suaveolens(180 ppm in leaves, and 135 ppm in stems). Hence it seams to be that the amount of chromium detected in the organs of T.purpurea in non-mining soil is required for their normal functioning and growth. Generally in the chromium-rich soil, uptake of the metal in each plant is according to its own specific ability. In the mine location uptake of chromium in leaves of C.ariculata is recorded 90 ppm and in stem it is recorded 60ppm. In C.ariculata, the ratio of Cr in leaf samples of normal vegetation and mine location is 1:3.6; while in twigs/stems, the ratio is 1:4. However, the ratio of Cr content between the normal vegetation soil sample and mining area soil sample is 1:19.3. Hence the amount of chromium accumulated in the two organs of C.ariculata may be the optimum for this plant. The distribution of elemental concentrations and the metal uptake in different organs of plant varies widely due to complex process of metabolism. The differential concentrations of an element in a particular horizon of a soil profile is determined by biogeochemical cycling of elements involving progressive differentiation of sol horizons, and differential migration of elements in vertical and lateral directions (Rose et al 1979). Each plant species has its own requirements and tolerance to elemental uptake and retention. Thus the composition of an individual plant varies substantially among its various tissues types, i.e. roots, wood, bark, twigs, needles-leaves and flowers (Dunn et al 1993).

From this study it is clear that among the four plant species growing on the mine location reveals that hyptis suaveolens has a special ability to accumulate higher amounts of chromium under pressure circumstances. Therefore, further studies will reveal more information on its optimum ability to accumulate Cr and also other associated metals. The amount of Cr detected in the organs of plants consisting of acacia arabica, cassia ariculata and tephrosia purpurea in the non-mining soil is required for their normal functioning and growth. Uptake of the plant mechanism normally restricts the nonessential elemental concentration to a constant level in spite of the higher metal abundance of such metals in the soil (Brooks, 1972). Generally the plants take up metals to varying degree from the substrates in which they are developed (Baker et al 2000), and the level of tolerance developed can often be related to the amount of metal in the soil (Foy et al 1978). The high concentration of an element in one particular organ does not imply that this is the best part of the plant to sample for biogeochemical prospecting (Brooks, 1983).

Conclusion

In the study area wide variations in the concentrations of chromium in four different families of plant species may be attributed to their habitational environmental conditions. The differential accumulation of chromium in these four plant species demands further studies to determine the mechanism of Cr tolerance in them. The different plant organs show wide variations in respect of accumulation of different elements (Tiagi, 1990). In view of the high concentration of chromium in hyptis suaveolens than other plants in the study area, the hyptis suaveolens may serve a better purpose than other three plants in biogeochemistry involved in mineral exploration. As hyptis suaveolens has the capability to take up more metal when compared to other three plant species, this plant is more suitable for removal of chromium metal from the soil. Further studies are required to determine whether hyptis suaveolens is a hyper accumulator.

Several workers have studied accumulation of element in plants and reported various plant species as acculators of heavy metals (Brooks,1983;). Prasad and Vijayasaradhi (1985) found O.adscendens as an accumulator for chromium. Hence in the study area these plants serve as an ideal indicator in regional geochemical and reconnaissance survey and monitoring of pollution levels of the terrestrial environment. These plant species can also be used in reclamation and revegetation of the adversely affected areas, and also suitable for restoration of chromium contaminated sites. This study has given greater scope on the plant-soil relationship in the mining/mineralized areas and their significance in biogeochemical orientation surveys, environmental studies and in mineral exploration.

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