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Studies on some trace element accumulation in Terminalia bellerica growing on a Cu and Mn mine waste dump

Madhuri Singhal[1]; Rishikant Asati[1] ; Anjali Jijhotiya[1]& Mohini Saxena[2]
[1]Department of Chemistry, Govt. S.G.S. Post Graduate College, Ganjbasoda (India),
[2]Advanced Materials and Processes Research Institute (CSIR) Bhopal-462026 (India)

Abstract
The article draws on the search of Indian medicinal plant Terminalia bellerica Roxb of Combretaceae family able to grow in metal-contaminated soil. Malajkhand and Ukwas are famous highland places of Balaghat district of Madhya Pradesh state, India for their copper (Cu) and managanese (Mn) mining activities respectively. This plant is naturally growing on the copper and manganese mine waste dump in these places. Copper and manganese content in dump soil, root, heartwood, bark, green leaves and fruits of the plant was determined. Values were compared with similar samples collected from normal vegetation. Copper and manganese distribution in samples collected from the dump site revealed that Terminalia bellerica has a special ability to grow in the contaminated soil with high amounts of cooper and manganese. It was concluded that the average concentration of Cu, Mn and Zn in different plant parts were found under permissible limits in all plant samples collected from all three above mentioned sites.

Keywords : Terminalia bellerica; Manganese; Copper; mine waste dump.

1. Introduction :

Terminalia bellerica is cultivated throughout India in the plains and lower hills, chiefly in the deciduous forests, at 900 m elevation where the climate is not very dry. This species was also observed naturally growing on coal mine spoils[1]. Terminalai bellerica is also regenerating naturally on the mine waste-dumps of Cr, Ni and Fe of Sukinda chromite mines (TISCO sector) were investigated[2]. The fruits of Terminalia bellerica is used in the treatment of piles, dropsy, leprosy, diarrhea, biliousness, dyspepsia and headache and this is the important ingredient of a herbal preparation Triphala.

It is now well established that many trace elements play a vital role for general well doing as well as in curing of diseases[3]. Several attempts have been made in determination of the metal contents of herbal, medicinal, and aromatic plants from other parts of the world[4]. All plants have the ability to accumulate heavy metals from soil and water which are essential for their growth and development. Element, such as Cu, Mn and Zn are essential micro-nutrients that the plants require for their proper growth[5]. These essential elements also constitute a small fraction of human diet and play an important role in metabolic processes. However, excessive accumulation of these heavy metals can be toxic to most plants.

In the present investigation, naturally growing medicinal plant, Terminalia bellerica were identified on a copper and manganese mine dump. The aim of the present study was to show the tolerance level of the Terminalia bellerica in heavy metal stress conditions.

2. Materials and methods :

2.1 Sampling of soil and plant materials:

The study was carried out in the fruiting period of Terminalia bellerica in March 2006. The copper and manganese mines are located in Malajkhand and Ukwa respectively in the district Balaghat, Madhya Pradesh India. It was identified that Terminalia bellerica is growing naturally in the copper and manganese mine waste dump .An experiment was conducted to generate information on Cu, Mn and Zn accumulation and distribution in the different parts of this plant. The data were compared with those generated from samples collected from the plant growing naturally in contamination free soil.

Each site was divided into three locations and soil (from surface to the respective root length) was collected at each location and prepared by adopting conventional quartering and coning method from the root zone of Terminalia bellerica plant species. Similarly plant samples (Root, heartwood, bark, leaves and fruits) were also collected at each location. All samples were packed properly to avoid contamination and then labelled.

At the laboratory, accumulated dust on the surface of the plant samples were removed by washing thoroughly with tap water. This was followed by thorough washing of the samples with deionized water. The samples were then dried on a filter paper to eliminate adhering moisture from the surface. The same process was repeated for the plant samples or control area. These samples were oven dried at 70°C then powdered by mortar and pestle and passed through 2 mm sieve for analysis.

2.2 Chemical analysis of soil :

Soil sample (15 gm each) from each site were collected and dried at 70°C for 3 days for analysis. Now 1gm of dried soil sample from each site were taken in a platinum crucible and 3-4 drops of water, 5ml. HF, 0.5 ml $HCIO_4$ and 3 ml Conc. HNO_3 were added in it. After this, the sample was digested on a hot plate till the fumes of HClO4 starts appearing. After cooling the crucible, 5ml HF was added then the crucible was covered with lead and the mixture was heated in a sand bath to 200 to 250°c. This mixture was evaporated to dryness. After cooling the crucible, solution was mixed with 2ml water and 2-3 drops or $HClO_4$. Now solution was heated on sand bath till dryness. After cooling the crucible 5ml 6N HCI and 5ml water was added. The crucible was heated on the hot plate till solution starts boiling. When the residue gets completely dissolved, the sample was transferred to 50 ml volumetric flask and the content was diluted to volume by washing the filter paper with distilled water. Now samples were ready for the analyzing the concentration of Cu, Mn and Zn in all the three study site samples by Atomic Absorption. Spectrophotometer (A AS-Model Hitnchi Z-5000).

2.3 Chemical analysis of plant material :

Oven dried 1 gm. of powdered samples were digested in 10 ml aqua regia upto dryness on the hot plate and then after complete digestion it is diluted upto 100 ml. Now the samples were ready for trace element analysis using AAS.

3. Results and discussion :

The average values of heavy metals present in soil and plant samples for the fruiting period are given in Tables 1, 2 and 3 and discussed.

It was found that Cu content was present in soil and all parts of the plant collected from each location. The permissible concentrations of Cu in drinking water, soil and food as per the Indian Standards (IS) are 0.05 mg/L. 135-270 mg/kg and 30 mg/kg respectively[5], On the capper mine waste dump the average values of Cu has been found 428 μ g/g in the soil above permissible limit than the manganese and controlled conditions. Also it is accumulated in the plant parts specially in the medicinally important part fruit (16.61 μ g/g) under permissible limit. This shows the ability of this plantt to survive in the heavy metal stress condition (See Table I).

The Concentration of Mn in normal soil is 20-10000 mg/kg[3] and in plant is 20-1000 mg/kg[3]. Some other reported that Mn Values below 20 parts per million (ppm) are usually considered deficient readings of 30 to 200 ppm are normal, and those over 300 ppm are considered excessive or toxic[7]. Average Mn content in the soil on manganese mine waste dump was 1410.33 μ g/g. This is approximately 14 times higher than the control soil (See Table 2 and 3). Uptake of Mn by different parts Terminalia bellerica in the Mn dump site as well as in the controlled site were not high and it was found under permissible limit as mentioned above. This shows the tolerance and growing capacity of plant under heavy metal stress condition without increasing toxicity of metals in the plant parts.

The permissible concentrations of Zn in drinking water, soil and food according to IS are 5.0 mg/L, 300-600 mg/ kg and 50 mg/kg respectively[5]. The average values of Zn were found under permissible limits in the soil and plant samples on all three sites. Some higher plant species have developed heavy metal tolerance strategies which enable them to survive and reproduce in highly metal-contaminated soils[8]. Trace element are essential for human nutrition at low doses but may also be to toxic for human, animal and plant at higher doses. Cu, Mn and Zn are essential for plant growth and activation of many enzymes. According to National Institute of Nutrition, Hyderabad, copper is an essential element and it plays an important role in iron absorption. The essential intake of copper in a typical Indian diet is around 2mg/day. Manganese is also established as an essential element as it participates in a number of reactions as a component of metal enzyme or as enzyme co-factor. Manganese content of diets consumed in India varies from 4-10 mg/day. Zinc is an important element performing a range of function in the body as it is a co-factor for a number of enzymes[9]. Therefore, the determination of elemental content in plants, especially herbal products, should be the part of the quality control process to ensure their purity, safety and efficacy.

From the study, it was revealed that Cu, Mn and Zn were accumulated to greater or lesser extents under permissible limits by different parts of Terminalia bellerica (Table. 1-3). It can be estimated that uptake of Cu, Mn and Zn were dependent on their concentration in the soil. It seems that Teminalia bellercia have heavy metal tolerance to survive in contaminated soil without much high accumulation of heavy metals in its parts. It can be suggested that the concentration levels of Cu and Mn in Terminalia bellerica are strongly affected by characteristics of soil and climatic conditions. The important thing is that concentration of Cu, Mn and were found under permissible limits. The concentration of Cu, Mn and Zn in Teminalia bellerica fruit samples was found to be 8.3 μ g/g, 22.9 μ g/g and 32.6 μ g/ g respectively which was procured from the Ayurvedic medicine shop and analyzed from well known manufacturers around the India[10]. It is clear that the concentration of Cu, Mn and Zn were found in this fruit part of this plant under permissible limit. So fruit can be used for herbal preparation collected from these sites and it can be planted in heavy metal contaminated soil.

Because of mining activities in Malajkhand and Ukwas, a large number of plants as well as medicinal plants are destroying. It can be suggested that medicinal plants like Terminalia bellerica can be planted on mine waste dumps due to its huge medicinal value. Hence, it becomes necessary that the medicinal plant should be properly cultivated for the future generation. Plantation of Terminalia belerica in the mining area would help for the survival of this variety of plants.

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Table 1

Distribution of Cu, Mn and Zn (ug/g) in terminalia belerica growing on the copper mine waste dump (malajkhand)

Parameter	Location A			Location B			Location C			Average		
	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn
Soil	465	160	65	397	158	72	422	161	56	428±34.39	159.6±1.52	64.3±8.02
Root	30	9	10	36	9	12	26	13	15	30.6±5.03	10.3±2.30	12.31±2.51
Heartwoord	28	19	15	21	15	26	33	25	19	27.3±6.02	19.61±5.03	20.1±5.56
Bark	31	17	12	41	21	14	34	19	13	35.3±5.13	19.1±2.0	15.1±1.0
Leaves	24	8	9	29	16	33	36	13	24	29.61±6.02	12.31±4.04	22.1±12.12
Fruit	20	13	18	13	15	21	17	11	27	16.61±3.51	13.1±2.0	22.1±4.58

Table 2

Distribution of Cu, Mn and Zn (ug/g) in terminalia belerica growing on the manganese mine waste dump (Ukwa)

Parameter	Location A			Location B			Location C			Average		
	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn
Soil	261	1410	42	249	1274	56	234	1337	53	248±1352	1340.31±68.06	50.31±7.37
Root	19	99	8	23	102	13	26	73	11	22.61±3.51	91.31±15.94	10.61±2.51
Heartwoord	24	107	14	34	113	27	33	97	31	30.31±5.50	105.61±8.08	24.1±8.88
Bark	33	61	7	41	83	12	34	86	24	36.1±4.35	76.61±13.65	14.31±8.73
Leaves	29	160	10	24	147	19	36	149	26	29.61±6.02	152.1±7.0	18.31±8.02
Fruit	14	161	17	5	123	21	17	108	29	12.1±6.24	130.6±27.31	22.31±6.1

Table 3

Distribution of Cu, Mn and Zn (ug/g) in terminalia belerica in controlled region

Parameter	Location A			Location B			Location C			Average		
	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn	Cu	Mn	Zn
Soil	97	86	97	67	74	85	82	58	112	82.1+15	72.61+14.04	98.1+13.52
Root	4	14	29	6	9	35	13	15	38	7.61+4.7	12.6+3.21	3.41+4.58
Heartwoord	13	19	25	21	15	32	16	11	42	16.61+4.04	154	33.1+8.5
Bark	19	23	20	13	21	27	19	23	35	17.1+3.46	22.3+1.14	27.31+7.50
Leaves	9	27	23	14	16	37	11	32	41	11.31+2.51	25+8.18	32.61+9.07
Fruit	6	21	32	13	15	41	15.5	28	49	11.51+4.92	21.3+6.50	40.61+8.50