SEM-EDS ANALYSIS OF SOIL AND PLANT (*CALOTROPIS GIGANTEA* LINN) COLLECTED FROM AN INDUSTRIAL VILLAGE, CUDDALORE DT, TAMIL NADU, INDIA

N. RAMAMURTHY, S. KANNAN***

*Department of Physics, Annamalai University, Annamalai nagar-608 002
Tamil Nadu, India, profram_phy@rediffmail.com
**Vel Tech Dr. R.R & Dr. S.R. Technical University, Avadi, Chennai-62, Tamil Nadu, India

Abstract. The scope of this study is to investigate the effects of the atmospheric emissions of heavy metals in soil and plants collected from an industrial area. In this connection the environmental pollution of the bioindicators (soil and plant) have been analysed by SEM-EDS method by estimating heavy metals like Na, Mg, Al, Si, Cl, K, Ca, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Pb and Cd. From this analysis, a perceptible variation in the trace element concentration of samples in different seasons is found.

Key words: SEM-EDS, industrial pollution, soil, plant.

INTRODUCTION

Heavy metals are important trace elements in nutrition of plants, animals or humans (e.g. Zn, Cu, Mn, Cr, Ni), while others are not known to have positive nutritional effects (e.g. Pb, Cd, As). However, all of these may cause toxic effects (some of them at a very low content level) if they occur excessively. The bioaccumulation of heavy metals over large territories and long time periods may result in the gradual damage of living organisms, which necessitates careful monitoring of the input, mobility and effects of these pollutants.

Heavy metals are emitted from many sources contributing to metal loads in terrestrial and aquatic food chains. These elements are released into the environment as a result of a wide range of industrial activities as well as combustion of fossil fuels. The total metal content in polluted soil needs to be known to assess the potential risk. But, knowing of total metal content in soil alone

Received: March 2008;
in final form September 2009

does not give information about the available fraction of metal, which can easily enter the biota [7].

Plants are good environmental quality indicators and respond directely to air, soil and water quality [8, 9]. Since the plants can naturally draw the pollutants from their local environment, their chemical composition can indicate the degree of disturbances when assessed against background values obtained from unpolluted vegetation [10]. Increased introduction of foreign elements to the plant or excessive presence of some essential and trace elements can result in the toxicity of plant and hence change of colour of leaves, inhibition to the germination of seeds and growth of plants or even death of the plants [1]. Other effects of pollution can be described as inhibitory effects, by the fact that the excessive presence of some elements can result in blocking the uptake of other elements and hence depriving the plant from absorbing essential elements from the soil [2].

The SIPCOT (State Industries Promotion Corporation of Tamil Nadu Limited) industries are playing an important role in the economic development of India. The effluents released by them produce a high degree of pollution in the air, soil and aquatic systems. SIPCOT has set up of a 200 hectare estate, 8 km away from Cuddalore town, South India and it consists of big and small units manufacturing pesticides, pharmaceuticals, chemicals, plastics, dyes and textiles.

The plant *Calotropis gigantea* (Linn.) belongs to the botanical family *Asclepiadaceae*. The importance of this plant in this study comes from the fact that this plant is abundantly found in the locations, the plant is not edible and no disturbance is caused to the plant either by man or animal.

The objective of this study was to analyse the effect of atmospheric emissions of heavy metals in soil and plant samples from few industrial locations of SIPCOT around Kudikadu village. SEM-EDS technique is used for the quantitative estimation of elements like Na, Mg, Al, Si, Cl, K, Ca, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Pb and Cd present in the samples.

MATERIALS AND METHODS

The leaves of *Calotropis gigantea* and soil samples were collected from SIPCOT area particularly in Kudikadu village Cuddalore district, Tamil Nadu, India. The samples were collected in both winter (W) and summer (S) seasons of the year 2006, at five different locations [Athangarai street (S_1), Mettu street (S_2), Uppannar river (S_3), Middle street (S_4) and Kudikadu pond (S_5)] and one control sample was collected from an unpolluted area, 60 km far from SIPCOT industries. The investigations were carried out both in winter and summer seasons. The control samples of soil and plant were collected only in winter season.

The leaves are thoroughly washed with ample water to remove clay, sands, dusts and associated algae. The soil samples and the cleaned leaves samples were shade dried and dried in oven at 60 ºC for four hours to remove moisture content. Dried samples were ground into fine powder using agate mortar. These samples are used for the SEM-EDS (Scanning Electron Microscope – Energy Dispersive Spectrometer) analysis.

The microphotographs were recorded using SEM JEOL model, JSE-5610LV with an accelerating voltage of 20 keV, at high vacuum (HV) mode and Secondary Electron Image (SEI). The maximum magnification possible in this equipment is 300000 times with a resolution of X 500 for all samples. The semi quantification elemental analysis to identify the weight percentage of major and minor elements present in the samples was done using the OXFORD INCA Energy Dispersive X-ray spectrometer (SEM-EDS). This technique is being used in numerous applications for environmental science and technology.

Energy dispersive X-ray spectrometry is a popular method for the determination of trace elements in geological and environmental samples. With the morphological characters obtained from SEM, supported by Energy dispersive X-ray (EDS) micro analysis device, it is possible to identify elements like Na, Mg, Al, Si, Cl, K, Ca, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Pb and Cd in soil and plants.

The SEM photographs and corresponding EDS spectrum were taken for all samples and one typical microphotograph and spectrum of soil and plant sample are given in Figs. 1 and 2. The weight percentage of elements present in all sample locations with control sample for soil and plants obtained from EDS are given in Tables 1 and 2, respectively.

RESULTS AND DISCUSSION

From Tables 1 and 2 it is seen that the percentages of elements in control soil and plant samples are less than the permissible limit and hence, the control samples can be used as standard for comparison.

SOIL

The alkaline earth elements Na, Ca, Mg and K are higher than the control samples in all locations. The trace metals like Cu, Fe, Zn, Mn, etc. also show a slightly higher trend in almost all locations than the control samples, excepting in one or two locations. The toxic element Pb is only present in S1 while the other heavy toxic element Cd is present in almost all locations. In the control sample they are absent.

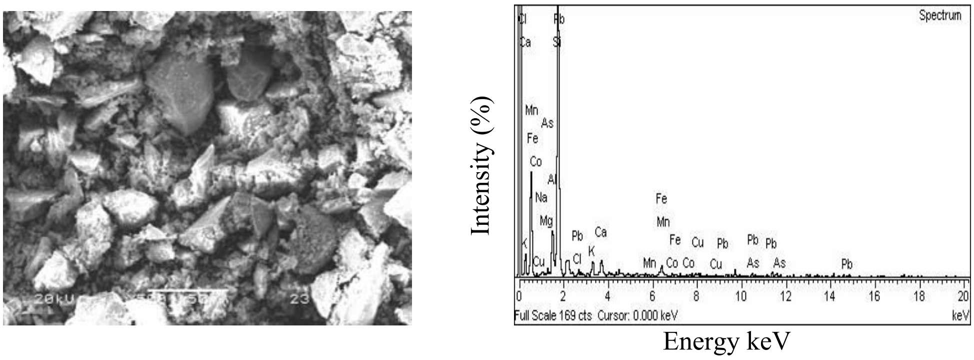

Fig. 1. Example of SEM and corresponding EDS spectrum of soil sample.

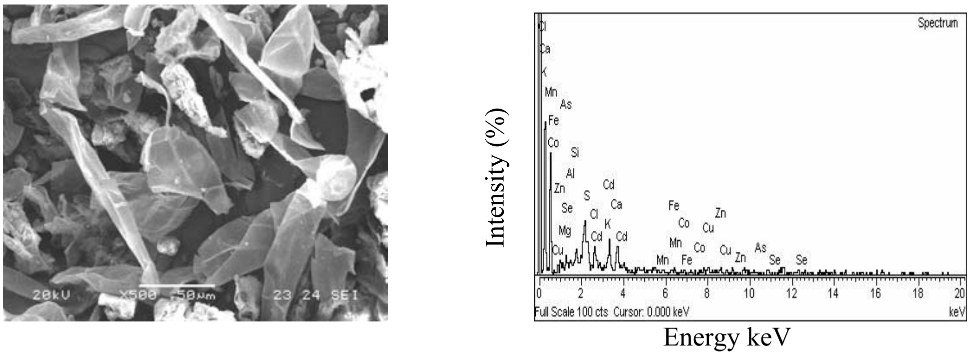

Fig. 2. Example of SEM and corresponding EDS spectrum of plant sample.

PLANT

The alkaline earth elements Na, Ca, Mg and K are very much higher than in the control plant sample in all locations. The other trace metals Cu, Fe, Zn, Mn, etc. also show the same trends. The heavy toxic elements Pb and Cd are present in almost all locations. In the control sample they are absent.

The plant *Calotropis gigantea* is sensitive to dust pollution [4]. The dust and carbon monoxide could be factors involved in addition to lead pollution to cause reduction in growth and pigments. The reduced growth of this species can be considered as an indicator of pollution along the industrial side particularly the leaf area can be treated as easily visible biomonitor for the presence of levels of industrial pollution. The environmental pollution affects the size and texture of leaf, thickness, number and branching of veins, loop formation [6]. Pollutants usually affect the plants as they are introduced into the plant via deposited contaminants in the soil or via ingestion through leaves [3]. In the study locations, it is observed that the plants have small leaves, a lesser number of leaves compared to the control plant area where the plants are noticed to contain healthy and large

Table 1

The percentage of trace elements present in the soil samples at various locations in two seasons with control sample

Elements	Elemental concentration (%)											Permissible limit		References
	S_1		S_2		S_3		S_4		S_5		Control sample	ppm	%	
	W	S	W	S	W	S	W	S	W	S				
Na	1.65	2.28	4.99	3.06	2.29	3.51	1.05	2.99	8.09	3.10	2.59	25000	2.5	Adriano.,1986
Mg	0.57	1.20	1.81	1.03	2.72	1.28	0	1.21	0.16	0.79	0.87	9000	0.9	"
Al	10.10	11.74	9.90	9.89	13.01	12.24	10.93	10.77	8.91	9.28	9.40	200000	20	"
Si	71.25	69.76	65.79	70.13	67.86	67.73	74.25	70.86	62.56	75.04	75.69	–	–	"
Cl	1.30	0.20	0	0.27	1.14	0.39	–	0.04	0.83	0.09	0.24	–	–	"
K	2.84	2.22	0.96	2.76	2.27	2.82	2.35	2.58	3.34	3.33	2.47	37000	3.7	"
Ca	4.00	3.05	3.84	2.90	3.05	3.36	2.77	3.00	6.83	2.71	2.37	52000	5.02	Pueyo et al., 2005
Mn	0.19	0.14	0	0	0	0.01	0	0.01	0	0.04	0	1000	0.1	Adriano.,1986
Fe	4.25	4.86	5.73	4.73	2.87	4.25	4.58	4.60	4.57	2.45	2.43	129000	12.9	Pueyo et al., 2005
Cr	0	0.12	0.45	0.08	0.41	0.05	0.35	0	0.07	0	0	1000	0.1	Adriano.,1986
Co	1.03	0	0.66	0.02	0	0	0	0.18	0.44	0	0	40	0.004	"
Ni	0	0	0.05	0.06	1.24	0.17	0	0	0	0	0.17	500	0.005	"
Cu	1.72	2.09	2.57	2.06	2.67	1.79	1.07	1.20	0	1.45	2.01	100	0.01	"
Zn	0	1.14	0.23	1.33	0	1.19	2.65	0.94	3.95	0.89	1.30	300	0.03	"
As	0.91	0	0	0.19	0.20	0	0	0	0	0	0	40	0.004	"
Se	0	0	0	0	0.12	0	0	0	0	0	0	2	0.0002	"
Pb	0.20	0	0	0	0	0	0	0	0	0	0	200	0.02	"
Cd	0	0.11	0	0.10	0.15	0	0	0.13	0.24	0.08	0	2	0.00002	"

Table 2

The percentage of trace elements present in the plant (*Calotropis gigantea*) samples at various locations in two seasons with control sample

Elements	Elemental concentration (%)											Permissible limit		References
	S_1		S_2		S_3		S_4		S_5		Control sample	ppm	%	
	W	S	W	S	W	S	w	S	w	S				
Na	0	20.38	24.81	7.31	14.99	0.87	9.46	6.37	15.64	7.61	7.13	–	–	–
Mg	7.25	6.66	0	11.34	12.91	7.00	10.79	10.30	5.49	10.21	0	–	–	–
Al	7.28	5.17	8.95	10.58	1.42	7.10	3.38	8.10	8.35	5.49	7.41	–	–	–
Si	11.56	15.67	11.15	20.63	11.90	17.56	16.80	17.31	23.77	20.51	0	–	–	–
S	8.34	2.06	0	0	0	3.44	0.21	0	0	0	0	–	–	–
Cl	7.58	20.84	10.79	12.28	17.75	13.21	19.83	10.60	20.23	6.84	0	–	–	–
K	11.49	9.52	10.23	10.23	11.40	10.47	5.64	11.98	4.27	5.89	42.34	–	–	–
Ca	17.02	8.69	6.85	12.61	14.91	21.75	10.97	19.63	17.45	12.47	7.09	–	–	–
Mn	2.46	0	3.53	0	4.11	0.13	0.72	0	0	0	0	500	0.05	Abbasi et al., 1998
Fe	1.25	2.38	0	2.60	0	1.44	0.26	2.12	0.80	0.92	0	–		–
Cr	0	0.04	0	0	0	0.60	0.82	0	0	0	14.30	79	0.0079	Abbasi et al., 1998
Co	0.96	0	0	0.96	0	0	0	0	0	0	0	2	0.0002	"
Ni	0	0.23	0	0.07	0	0.06	2.87	0	0.20	0	11.45	340	0.034	"
Cu	8.84	4.35	8.42	7.07	1.06	10.01	5.86	7.08	2.77	16.63	5.83	50	0.005	"
Zn	6.81	3.58	10.55	3.15	3.28	4.04	0.78	4.67	1.04	9.40	0	50	0.005	"
As	5.62	0	1.64	0.32	0	0.82	5.35	0.66	0	0	0	–		–
Se	3.07	0	0	0.12	2.74	1.20	5.15	0.76	0	0.41	4.46	5	0.0005	Abbasi et al., 1998
Pb	0	0.05	0	0.33	1.76	0	0.22	0.09	0	0.12	0	8000	0.8	"
Cd	0.47	0.38	3.08	0.19	2.02	0.29	0.86	0.31	0	0	0	2	0.0002	"

W – Winter, S – Summer, S_1 – Athangarai street, S_2 – Mettu Street, S_3 – Uppannar River, S_4 – Middle Street, S_5 – Kudikadu pond.

leaves with bushy growth. This indicates that the plant is affected by pollution. Also, that is evident from Table 2, the plants absorb the heavy toxic elements Cd and Pb from the atmosphere rather than from the soil, since we notice from Table 1 that in soil Cd and Pb are absent in few locations.

CONCLUSION

It is noticed that the estimation of pollutants in soil and plants, the soil is less affected by the pollution of elements (toxic) Cd and Pb, compared to the plants, which are highly affected. The plants have an exclusion mechanism [5], by which they preferably absorb only lighter elements like Na, Mg, Al, Si, Cl, K, Ca, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Pb and Cd, while they reject the heavy elements like Cd and Pb through roots. This aspect was also verified by Ramamurthy and Thillaivelavan (2003) [11]. Here, we noticed that the leaves of the plant have more Cd and Pb than we expected which infer that the area is affected by air pollution by the atmospheric emission from industries. The plants seem to have no exclusion mechanism in leaf structure unlike root structure, and hence, they seem to absorb Pb and Cd from atmosphere during the photosynthesis process. This phenomenon also has support from the visual evidence that the plants in the study area suffer due to small leaves, lesser number of leaves and stunted growth of plants.

Hence, it may be concluded that the SIPCOT area we studied suffers more from air pollution than from the soil pollution. If the atmospheric emissions from chimneys are governed by the standard pollution norms, the area may be saved from future pollution problems.

REFERENCES

1. ABBASI, S.A., T. KUNHAHAMED, K. MADHAVAN, P.C. NIPANEY, R. SONI, Environmental management of chromium, copper and zinc with respect to impact on growth and germination of gram (*Cicear ariatinium*), *J. Inst. Public Hlth. Engrs*., India, 1992, **12**(1), 12–23.
2. ALTAF, W.J., Effect of motorway traffic emission on roadside wild plants in Saudi Arabia, *J. Radioanal. Nucl. Chem*., 1997**, 217**(1), 91–94.
3. ALTAF, W.J., Response of *Calotropis procera* for urban, suburban, and sewage pollution, *Umm Al-Qura Univ. J. Sci. Med. Eng.*, 2006, **18**(1), 31–40.
4. BHATNAGAR, A.R., A.B. VORA., T.S. PATEL., Measurement of dust fall on leaves in Ahmedabad and its effect on chlorophyll. Indian, *J. Air. Pollut. Control*, 1985, **6**, 77–90.
5. BROOKS, R.R., *Geobotany and Geochemistry in Mineral Exploration*, Harper&Row, New York, 1972.
6. CHAUDHARI, G.S., N.V. RAO, J.A. INAMDAR, Effect of air pollution on leaf epidermis and architecture of *Lycopersicon lycopersicum* var. *Angurlata*, *Indian J. Environ. Health*, 1984, **26**(3), 238–243.

7. CHAUDHARY, S., D.K. BANERJEE, Metal phase association of chromium in contaminated soils from an industrial area in Delhi, *Chemical Speciation and Bioavailability*, 2004, **16**(4), 145-151.
8. DÍAZ, E., A. MASSOL-DEYÁ, Trace elements composition in forage samples from various anthropogenically impacted areas in Puerto Rico, *Carib. J. Sci*., 2003, **39***,* 215–220.
9. KABATA-PENDIAS, A., *Trace Elements in Soils and Plants*, Third Edition, CRC Press: New York, 2000, p. 432.
10. MASSOL-DEYÁ, A., D. PÉREZ, E. PÉREZ, M. BERRIOS, E. DÍAZ, Trace elements analysis in forage samples from a US Navy bombing range (Vieques, Puerto Rico), *Int. J. Environ. Res. Public Health*, 2005, **2**(2), 263–266.
11. RAMAMURTHY, N., K. THILLAIVELAVAN, Accumulation of elements in plants and soil and around Neyveli, Tamil Nadu, *National Conference on Biological Treatment of Waste Water and Waste Air*, Regional Research Laboratory, Council of Scientific and Industrial Research, Thiruvanthapuram, India, August, 2003.