A reprint from Journal of Environmental Science and Health

Part A
Environmental Science
and
Engineering
including
Toxic and Hazardous Substances Control

Part B
Pesticides, Food Contaminants
and
Agricultural Waste

Part C
Environmental Carcinogenesis Reviews

J. ENVIRON. SCI. HEALTH, A28(2), 269-283 (1993)

EFFECT OF FLY ASH FROM A FUEL OIL POWER STATION ON HEAVY METAL CONTENT OF WILD PLANTS AT TENERIFE ISLAND, THE CANARIAN ARCHIPELAGO, SPAIN.

Key Words: Iron, nickel, vanadium, pollution, heavy metal, power station.

Alvarez C.E.(*)[1], Fernández M.[1], Pérez N.[1,2], Iglesias E.[(1)], Snelling R.[3]

1. Instituto de Recursos Naturales y Agrobiología de Canarias, Apartado de Correos, 38208 La Laguna, Tenerife, Spain.
2. Departament of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana 70803. USA.
3. Environmental Science Institute. Louisiana State University, Baton Rouge, Louisiana 70803. USA.

ABSTRACT

Heavy metal analysis have been carried out in wild plants around a Power Station located at the southeastern area of Tenerife Island (Canary Islands, Spain). The concentrations of Fe, Ni, and V in the leaves and terminal stems of three wild plants (**Euphorbia obtusifolia**, Kleinia neriifolia, and Plocama **pendula**) which were collected during the spring of 1988 are reported from four different allotments. These

(*) Please correspond with this co-author.

sampling sites were located at distances of 0.4, 1, 1,25, and 34 km from the Electric Generating Facility, and at elevations of 60, 120, 180 and 60 m, respectively.

Results show a potential contamination of vanadium in **E. obtusifolia** and **P. pendula** plants located close to the Power Station, probably due to dry deposition on fly ash in the surrounding area. The levels of iron and nickel concentrations in the same type of plants did not show any geographical relationship with respect to the location of the Power Station.

INTRODUCTION

The increased combustion of oil has led in recent times to an increase in the emission of heavy metals in the environment. The most significant metals present in the residual oils used in power generation are iron, nickel and vanadium [1], although there is not much concern with high levels of Fe in ashes emitted from petroleum-fire facilities, as iron toxicity to plants has scarcely been reported, except for rice [2, 3, 4]. Yet nickel and vanadium are well known as potentially toxic elements to plants, animals and humans [5, 6, 7]. The average Ni concentration in petroleum is 10 ppm [6], but levels of 490 ppm of Ni have been found in fly ashes [8] from the combustion of its derivatives (e.g. fuel oil). As far as V is concerned, ash from petroleum-fired facilities may contain up to 38 % of vanadium, but the concentrations vary depending upon the source of the petroleum. Crude oils were found to contain as much as

1400 ppm V in the Venezuelan oils characteristically enriched in this metal [6].

Plant "accumulators", defined as plants that have dry-weight elemental concentrations greater than either the associated substrate or normal plants, have been widely used for assessing heavy metal pollution [6, 9]. In Tenerife island (Canary Islands, Spain), fly ash emissions from a Fuel Oil Power Station showed high levels of Fe (20 ppm), Ni (40 ppm) and V (250 ppm) [8], so research was undertaken to study their effect on wild plants growing in the surrounding area of the Power Station and to be able to detect plant accumulators which are sensitive to atmospheric metal contamination.

MATERIAL AND METHODS

The Fuel Oil Power Station is located in the South-East of Tenerife island, on the coast, near a range of mountains (Fig. 1). Three allotments were chosen for sampling purposes, at 60 m (A), 120 m (B) and 180 m (C) topographic levels along the direction of predominant winds from the coast line to the interior. These sampling locations were at distances of 375, 1000 and 1250 m away from the Electric Generating Facility, respectively. Another allotment which was located at 34 km away from the Power Station was included in this study. This sampling site was in the opposite direction of the predominant winds and in soils of the same typology (vertisols) as those near the Electric Generating Facility. The farthest geographical allotment from the Power Station was chosen due to the existence

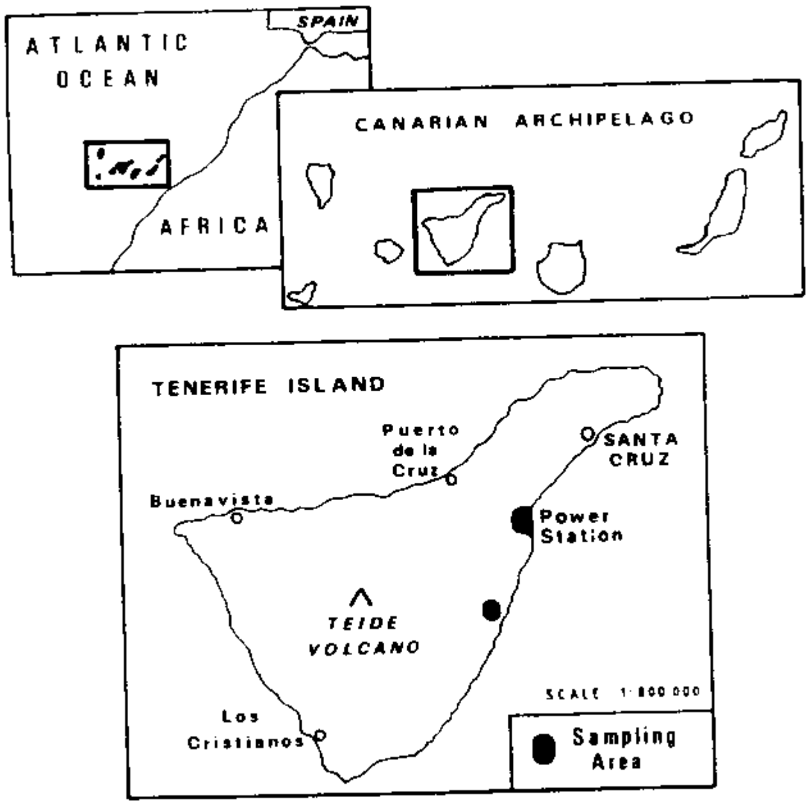


FIG. 1

Map showing Power Station placement and locations of sampling (circled).

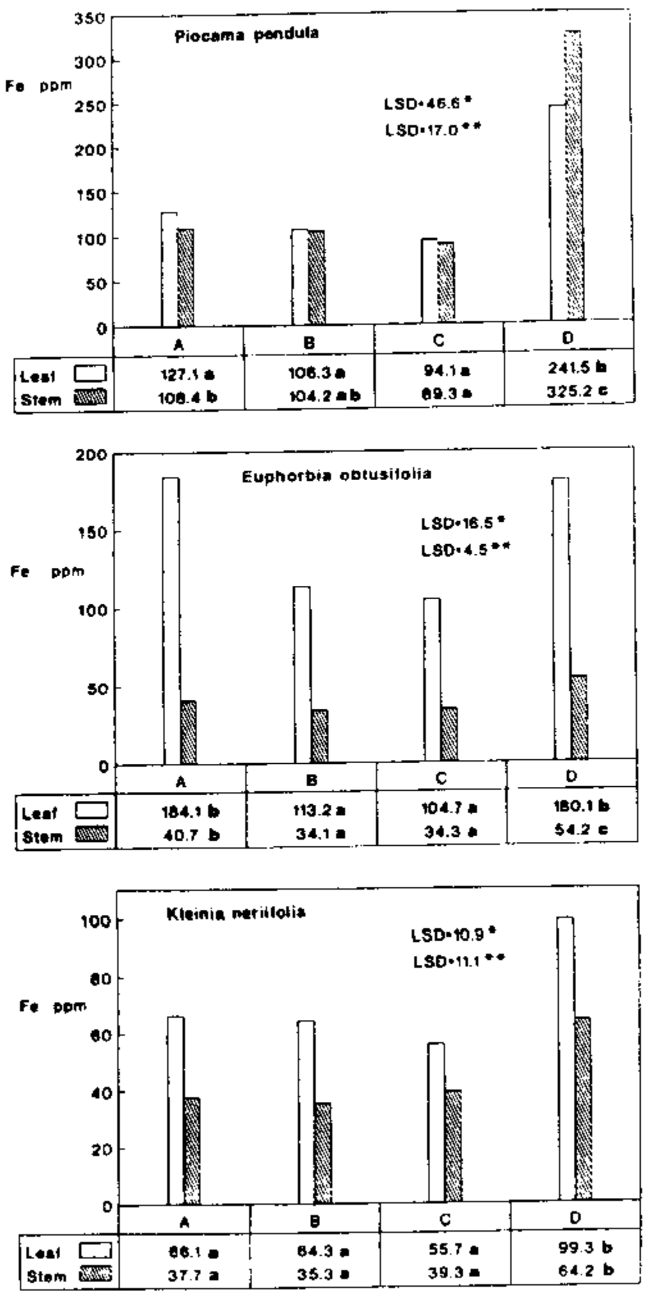
of data on results of heavy metal pollution as far as 16 up to 30 km from the contaminant source [1, 10].

A study of the type of wild plants in the surrounding area of the Power Station was performed before the sampling. The following wild plants were found to occur most frequently in the zone: **Euphorbia obtusifolia** (Poiret), **Kleinia neriifolia** (How.) and **Plocama pendula** (Aiton). As there was no previous criterion of the organs to be sampled, we selected terminal leaves (from now on referred to as leaves) and tips (5 to 7 cm long) of the stems (from now on referred to as stems). Three samples from ten plants each of leaves and stems of the three above mentioned plants were taken in every location.

To asses the accumulative capacity of these plants, previous sampling and analysis of the selected parts were performed during the winter of 1987. The data obtained supported the proposed sampling method. We collected samples again during the spring of 1988 rather than Winter because the effects of the washing off and removing of ashes from plants by rainfall was much less. It was nos possible to collect samples during the summer season for two reasons: (a) **E. obtusifolia** loses its leaves, and (b) **P. pendula** comes into bloom. Additional inconveniences occur during the fall season as the leaves of **E. obtusifolia** and **K. neriifolia** are too young to be sampled.

Techniques of Foliar Analysis

The samples were washed in deionized water, and dried in an oven at 80°C, after which they were ground to powder. 2 g of each sample were mineralized by wet



ashing [11] with a 5:1:2 mixture of concentrated HNO_3, concentrated H_2SO_4, and 60 % $HClO_4$ acids, respectively. Fe, Ni, and V were analyzed in posterior dilutions of this acid attack by ICP Mode 6500 Perkin-Elmer.

Statistical Analysis

SPSS/PC statistical program was used for processing data that were subjected to Analysis of Variance (ANOVA) and LSD test was used to determine differences among allotments as the p=0.05 probability level whenever the Analysis of Variance F value was significant [12].

RESULTS AND DISCUSSION

Iron

The average Fe content in leaves and stems from the three samples wild plants is indicated in Fig. 2. The concentration levels of Fe were significantly higher in both leaves and stems of **E. obtusifolia** from the allotment A, as compared to those from locations B and C. No differences were observed in both leaves and stems for the **K. neriifolia** among allotments. In the case of **P. pendula** no differences were found for the leaves, but

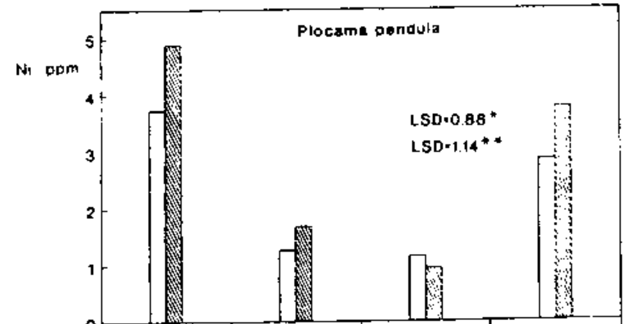
---

FIG. 2

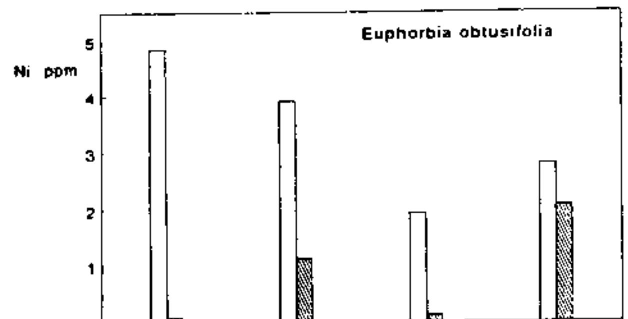
Analysis of Variance and LSD test (0.05 level) of Fe content (ppm) of leaves and stems of **E. obtusifolia**, **K. neriifolia** and **P. pendula**. Values in each row followed by the same letter are not significantly different at the 0.05 level.

* Least Significant Difference for leaf Fe means.

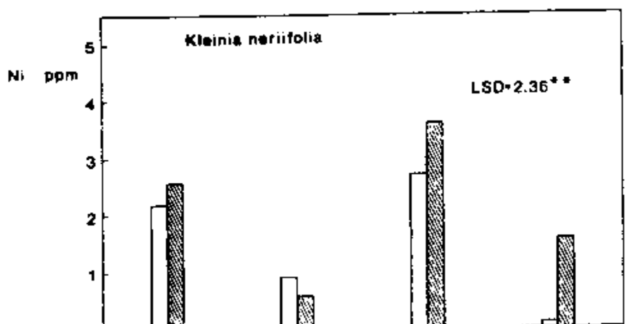
** Least Significant Difference for stem Fe means.



	A	B	C	D
Leaf	3.72 b	1.27 a	1.15 a	2.84 b
Stem	4.89 b	1.69 a	0.95 a	3.76 b



	A	B	C	D
Leaf	4.86	3.91	1.93	2.78
Stem	0.11	1.12	0.12	2.06



	A	B	C	D
Leaf	2.19	0.91	2.71	0.11
Stem	2.56 a b	0.59 a	3.59 b	1.57 a b

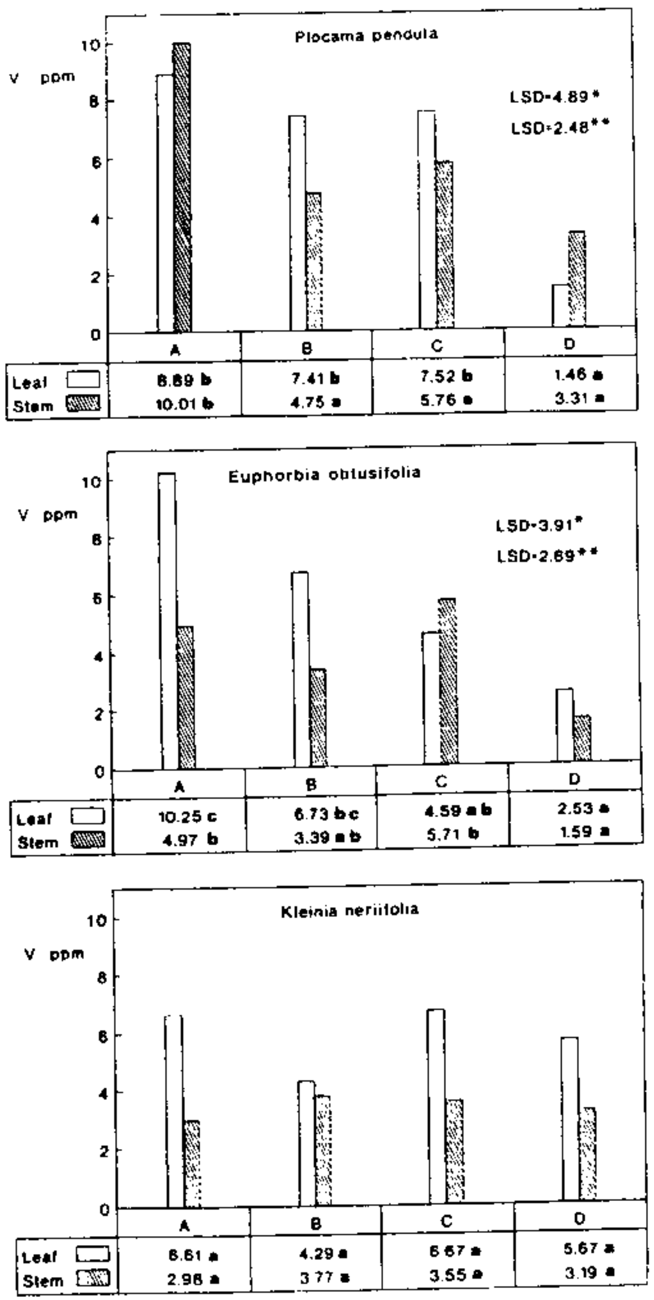
we detected higher concentrations of Fe in the stems from the sampling location A than from the allotment C. These results seemed to suggest an indirect relationship between iron concentrations and the distance of the wild plants from the Power Station. On the contrary, the Fe contents in leaves and stems for the K. neriifolia and P. **pendula** in the sampling location D were significantly higher than those from the other allotments. The same observation was detected for the iron levels in the stems of the **E. obtusifolia**, but the iron leaf levels in the sampling locations D and A were not significantly different.

Even though some relations has been observed between the iron concentrations in the wild plants with respect to their distance from the power station, the high iron content detected in wild plants far away from the source of potential contamination suggested that there is not an association between the iron concentration levels in the wild plants and the emission of contaminants from the power station. Freedman and Hutchinson [1] reported that the ecological effects of the high emissions of F_2O_3 from different sources were minimal due to the highly unreactive nature of iron oxides which are insoluble except in strong acids. The chemical reactivity behavior of these iron compounds is

---

FIG. 3

Analysis of Variance and LSD test (0.05 level) of Ni content (ppm) of leaves and stems of **E. obtusifolia**, **K. neriifolia** and **P. pendula**. Values in each row followed by the same letter are not significantly different at the 0.05 level.
* Least Significant Difference for leaf Ni means.
** Least Significant Difference for stem Ni means.



the main reason for their being non-bioavailable for the plants. We may conclude that the Fe contents in the wild plants did not exceed normal levels of concentration [13].

Nickel

No relationship was detected between the levels of Ni concentration in both leaves and stems of E. **obtusifolia** and K. **neriifolia** and the distance from their geographical locations to the power station (Fig. 3). The Ni content in both leaves and stems of P. **pendula** was significantly higher in plants from location A than those from allotments B and C. We should have thought of an accumulative effect of Ni from fly ashes from the Electric Plant if the Ni concentration in both parts of the plants from location D had not been similar to those from allotment A. Besides, the concentration of Ni found in all the leaf samples were within the normal range reported in the bibliography [14, 15, 16].

Vanadium

The results of our study indicate that the leaves of the E. **obtusifolia** plants in the allotment A contain higher vanadium concentrations levels than those detected in the sampling locations C and D. This

---

FIG. 4

Analysis of Variance and LSD test (0.05 level) of V content (ppm) of leaves and stems of **E. obtusifolia**, **K. neriifolia** and **P. pendula**. Values in each row followed by the same letter are not significantly different at the 0.05 level.
* Least Significant Difference for leaf V means.
** Least Significant Difference for stem V means.

observation suggests and indirect relationship between the vanadium concentrations levels in **E. obtusifolia** and its distance from the location of the power station (Fig. 4). This relationship was not so clear in the stems, because its contents of vanadium in the plants from location B was similar to those from A and D sites.

No significant differences in the V content of the **K. neriifolia** sampled organs were observed among the locations.

According to V data obtained from leaves of **P. pendula**, there seems to be a general pollution effect of the power station on the surrounding area for this type of wild plant (Fig. 3). All the measurements of vanadium content in the **P. pendula** show significantly higher concentrations form the sampling locations A, B and C than those form location D. This pollution effect is only observed in the sampled stems from allotment A, possibly because of a lower V absorption capacity due to their smaller stomatal surface, so that vanadium contamination could only be detectable in the place of heavier fly ash deposition (location A).

The V concentrations detected in the leaves of **E. obtusifolia** which were sampled close to the Power Station, and in the leaves of **P. pendula** from the locations A, B and C exceeded the background level of vanadium contents in plants (non detectable to 6.6 ppm) reported in the literature [6, 17, 18]. The same was observed in the stems of **P. pendula** which were collected in allotment A. In addition, the vanadium concentration levels in the soils from the same study area [8] showed background values and did not show a geographical relationship with respect to the Power Station. As V is

an environmental pollutant [19], these results denote an aerial V contamination, probably due to the emissions of fly ash from the Fuel Oil Power Station.

CONCLUSIONS

The Fe and Ni contents in the three species did not show any relation between the geographical locations of the wild plants and their distances to the Power Station. Vanadium concentrations were significantly higher in the **P. pendula** and **E. obtusifolia** plants in the sampling locations close to the Power Station than those growing far away from the Electric Generating Facility, but no difference was detected in the V content of **K. neriifolia**.

The vanadium concentrations in the leaves of **E. obtusifolia** showed a progressive decrease with distance from the Power Station, while this trend was not so clear in the stems. The leaves of **P. pendula** seemed to be a better bio-ecological indicator for the vanadium air pollution than the stems; therefore, they appeared to be accumulator plant organs that could be used for monitoring vanadium environmental pollution from fly ash.

Acknowledgements. The authors express their gratitude to the staff of the Instituto de Productos Naturales y Agrobiología de Canarias (CSIC) for providing important support in the field and laboratory work, and to the Basin Research Institute for providing access to the ICP instrumentation. This research has been supported by the

Environmental Departement Grants of the Autonomic Government of the Canary Islands.

REFERENCES

1. Freedman B., Hutchinson TC. Sources of metal and elemental contamination of terrestrial environment. In: Lepp NW. ed. **Effect of Heavy Metal Pollution on Plants. Vol. 2.** London, New Jersey: Applied Science Publishers Ltd. 1981: 35-94.

2. Ottow JCG., Benckiser G., Watanabe I., Santiago S. Multiple nutritional soil stress as the prerequisite for iron toxicity of wetland rice (Oriza sativa L.). Tropical Agriculture (Trinidad) 1983; 60: 102-106.

3. Ponnamperuma FN. Genotypic adaptability as a substitute for amendments on toxic and nutrient-deficient soils. In: Scaife A. ed. **Proceedings of the Ninth International Plant Nutrition Colloquium, Warwick, England.** Farnham Royal, Bucks: Conmomwealth Agricultural Bureau 1982: 467-473.

4. Yoshida S., Tadano T. Adaptations of plants to submerged soils. ASA Special Publication 1978; 32: 233-256.

5. Nickel. Review of Environmental Contamination and Toxicology 1989; 107: 103-115.

6. Adriano DC. **Trace Elements in the Terrestrial Environment**, New York, Berlin, Heidelberg, Tokio: Springer-Verlag, 1986.

7. Peterson PJ., Girling CA. Vanadium. In: Lepp NW. ed. **Effect of Heavy Metal Pollution on Plants. Vol. 1.** London, New Jersey: Applied Science Publishers Ltd. 1981: 256-261.

8. Carracedo JC. Geoquímica ambiental: determinación y distribución de metales pesados y radionucleidos en el medio natural del area ubana-industrial de Santa Cruz de Tenerife. Informe a la Dirección General de Medio Ambiente, Islas Canarias, Spain, 1988. Unpublished data.

9. Brooks RR., Wither ED., Zepernick B. Cobalt and Nickel. Plant and Soil 1977; 47: 707-712.

10. Gignac LD., Beckett PJ. The effec of smelting operations on peatlands near Sudbury, Ontario, Canada. Canadian Journal of Botany 1986; 64: 1138-1147.

11. Chapman HD., Pratt PF. **Methods of Analysis for Soils, Plants and Waters.** Riverside: University of California, Division of Agricultural Sciences, Riverside, 1961.

12. Snedecor GW., Cochran WG. **Statistical Methods.** Ames: The Iowa State Univesity Press 1967 (6th ed.).

13. Mengel K., Kirkby A. Iron. In: **Principles of Plant Nutrition.** Bern: International Potash Institute 1987(4th ed.): 493-511.

14. Hutchinson TC. Nickel. In: Lepp NW. ed. **Effect of Heavy Metal Pollution on Plants. Vol. 1.** London, New Jersey: Applied Science Publishers Ltd. 1981: 171-211.

15. Freedman B., Hutchinson TC. Pollutants inputs from the atmosphere and accumulations in soils and vegetations near nickel-copper smelter at Sudbury, Ontario, Canada. Canadian Journal of Botany 1980; 58: 108-132.

16. Freedman B., Hutchinson TC. Effects of smelter on forest litter decomposition near a nickel-copper smelter at Sudbury, Ontario, Canada. Canadian Journal of Botany 1980; 58: 1722-1736.

17. Macnicol RD., Beckett PHT. Critical tissue concentrations of potentially toxic elements. Plant and Soil 1985; 85: 107-129.

18. Davis RD., Beckett PH., Wolland E. Critical levels of twenty potantially toxic elements in young spring barley. Plant and Soil 1978; 49: 395-408.

19. Patel B., Chan KH., Haswell SJ., Grzeskowiak R. Importance of calibration for accurate determination of vanadium in soil samples. Analyst 1989; 114: 133-136.

Date Received: 08/07/92
Date Accepted: 09/24/92