LEAD, CADMIUM AND COPPER CONCENTRATIONS IN LEAVES OF *Nerium oleander* L. AND *Robinia* pseudoacacia L. AS BIOMONITORS OF ATMOSPHERIC POLLUTION

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ABSTRACT

Pb, Cd and Cu concentrations in leaves of *Nerium oleander* L. and *Robinia pseudoacacia* L. plants collected from industrial areas in Gaziantep-Turkey were examined for biomonitoring of atmospheric pollution using flame atomic absorption spectrophotometry. The Pb levels in the leaves of *Nerium oleander* L. and *Robinia pseudoacacia* L. collected at a distance of 50 m from the battery plant were observed to be 2820 and 1860 mg kg^{-1}, respectively. The Pb, Cd, and Cu concentrations in the soils studied were in the range of 17-602, 0.142-0.656 and 12-38 mg kg^{-1}, respectively. Lead concentrations described above for plant leaves were found to be about 2000-fold higher than those in the same plants collected from the control area (1.0 mg Pb kg^{-1} for both plant species). Similarly, Cd levels in *Robinia pseudoacacia* L. collected from polluted area were observed to be about 40 times higher than those from control area. Consequently, it is observed that the leaves *of Nerium oleander* L. can be used for biomonitoring of Pb, and *Robinia pseudoacacia* L. for biomonitoring of both Pb and Cd pollution.

KEYWORDS:
Biomonitoring, trace metals, atomic absorption, *Nerium oleander* L., *Robinia pseudoacacia* L., environmental pollution

ABBREVIATIONS

ICP-MS: Inductively coupled plasma mass spectrometry
MW: Microwave
STAT: Slotted tube atom trap
F-AAS: Flame-atomic absorption spectrophotometer
NO: Nerium oleander L.
NE: North East
SE: South East
DW: dry weight

INTRODUCTION

The impact of metals on health and disease depends on their chemical species and concentration ranges. Interest in determination of lead and cadmium in biological matrices has been increasingly growing because both metals have toxic effects on brain, kidney, reproductive system and intellectual functions [1-3]. It was shown that lead exposures to school-aged children can significantly reduce the IQ, and have been associated with aggressive behavior, delinquency and attention disorders [1]. The frequently observed toxic effect of Cd in humans is the chronic nephropathy characterized by proximal tubular necrosis and proteinurea [2]. Furthermore, it was reported by the International Agency Research on Cancer (IARC) that inhalation of cadmium could cause lung cancer in humans and animals [4]. Lead has been used in hundreds of products, such as pipes, solders, brass fixtures, crystals, paints, cables, ceramics, and batteries, due to its malleability, low melting point, and ability to form compounds. As a result, the populations of, at least, 100 countries are still exposed to considerable lead levels owing to air pollution despite the banning of lead in gasoline. There are several sources of human exposure to Cd, including employment in primary metal industries, production of certain batteries, some electroplating processes, and use of tobacco products. Interest in Cu determination in environmental and biological samples has been originated from its necessity as a component of more than 30 enzymes as well as its adverse effects on human health at high concentrations. It is also stated that copper is a well-known pro-oxidant and may participate in metal-catalyzed peroxidation of lipids, similar to iron [3]. As a result, the World Health Organization (WHO) suggests a safe upper limit of 12 mg Cu day^{-1} for adults and 0.15 mg Cu day^{-1} for children, as well as the tolerable weekly intakes of 0.007 mg Cd kg^{-1} and 0.025 mg Pb kg^{-1} body weight for all human groups [5]. Briefly, the accumulation of Pb, Cd and Cu in human body can cause middle and long–term health risks and adversely affect the physiological functions [1-3]. Lead and cadmium absorption from food by ingestion are between 3-10% in humans, and their absorption increase depending on special conditions, such as low dietary Ca, low iron stores and iron deficiency during pregnancy. The absorption rates of Pb and Cd by inhalation are significantly higher (up to 50-60%) than those by ingestion described above [3].

Biomonitoring is one of the indicating methods for environmental pollution, and it includes trace element analysis of plant parts and similar biological matrices. Proper selection of plant species for biomonitoring plays an important role in the determination of the extent of toxic metal pollution in environmental media, such as soil, water and air. The advantages of using biomonitors for environmental surveillance lie in the lower cost as compared to direct methods of pollution measurement, since no collecting or measuring equipment has to be installed and protected against vandalism. If biomonitors are widely distributed and occur frequently enough, they can be used over large areas for recording and evaluating heavy-metal inputs. Furthermore, they make it possible to identify sources of emissions and verify the overland transportation of individual elements [6-8]. Some naturally occurring plants from polluted environments can accumulate trace metals in their harvestable biomass up to 10–500-times higher levels than in those from non-polluted environments. These plants, termed metallic biomonitors (or hyperaccumulators in state of excess uptake), grow on metal-rich soils. Moreover, they can also accumulate metals in their aboveground tissues up to concentrations between one and three orders of magnitude higher than in those normal (non-accumulator species) plants grown at the same site [9-11].

Nerium (N.) oleander L., among the higher plants, is commonly used for biomonitoring of atmospheric pollution [12-17]. In the industrialized areas of the southwestern Spain (Huelva), Pb and Cu concentrations (as mg kg^{-1}) in leaves of *N. oleander* L. depending on wind direction were found to be 2.4 and 21.5 (NE) and 18.7 and 408 (SE), respectively [12]. Similarly, Pb and Cu concentrations were described to be in ranges of 0.27-0.91 mg kg^{-1} for *N. oleander* L. leaves taken from Seville city (the most densely populated city) of Southern Spain [13]. To assess urban pollution in Palermo city (Sicily, Italy), Mingorance and Rossini Oliva [14] determined Pb and Cu levels in leaves of *N. oleander* L. plant ranging between 2.8-5.5 and 5-12 mg kg^{-1}, resp. In another study [15], Pb and Cu concentrations in *N. oleander* L. plants grown in contaminated sites were found to be 2.15 and 23.66, respectively, and these levels were 5- and 3-fold higher than in background sites (0.43 and 7.3 mg kg^{-1}). The influence of washing on metal concentrations in some plants including *N. oleander* L. in Palermo city in Sicily was studied by Rossini Oliva and Valdes [16]. Pb, Cd and Cu concentrations in washed and non-washed (in parenthesis) *N. oleander* L. plants were found to be 3.14 (3.3), 0.18 (0.15) and 9.32 (9.36) mg kg^{-1}, respectively. Cadmium concentration in unwashed leaves of *Robinia (R.) pseudoacacia* L. plant grown in an area with large coal-fired plants in Macedonia was found to be up to 1.25 mg kg^{-1} [17].

Although intensive industrial activities and rapid urbanization in the past three decades caused dramatic increase in the emission of pollutants in Gaziantep city, there are fewer studies to monitor atmospheric pollution in this region [18, 19]. The aim of this study is as follows: (1) to determine the Pb, Cd and Cu contents of plant leaves *(N. oleander* L. and *R. pseudoacacia* L.*)* collected from industrial areas in Gaziantep-Turkey and from the control areas (far from urban and industry), and (2) to examine biomonitor and hyperaccumulator plants. For this purpose, the amounts of those metals were FAAS-analyzed in soils and leaves of the interesting plants.

MATERIALS AND METHODS

Apparatus and reagents

The concentrations of Pb, Cd, and Cu were determined using a Model ATI UNICAM 929 FAAS (Unicam Ltd., Cambridge, England). The optimum conditions in FAAS were applied as described in the manufacturer's handbook. A domestic microwave oven (Kenwood) was used for digestion of the leaves. A slotted tube atom trap (STAT) made of quartz (Quarzschmelze Ilmenau, GmbH, Germany) was used to enhance the sensitivity of FAAS. The applied conditions for the quartz tube were taken from elsewhere [19, 20]. Thus, Pb, Cd and Cu concentrations as low as 50, 4 and 50 ng ml^{-1} could be determined, respectively. All chemicals used were of analytical reagent grade. Double-distilled water was used for all preparations.

To assess the reliability of measurements, some samples were analyzed by ICP-MS (PerkinElmer SCIEX ELAN® 9000, Concord, Ontario, Canada). The operation conditions for this instrument were applied as recommended by the manufacturers.

Sampling and sample preparation

Representative locations, in surrounding areas of lead battery-production plant, cement factory and textile industry around Gaziantep city (1.200,000 inhabitants) in SE of Turkey were chosen for this study. The samples were also taken from control area (far from the urban and industrial areas). The sampling sites around the battery plant are displayed in Fig. 1. The sampling was conducted in summer of 2006. Two plant species, *N. oleander* L. and *R. pseudoacacia* L. were examined. *Armeniaca* sp. and *Cydonia oblonga* Miller values were also obtained, only from one site, for comparing. The healthy looking leaves (about 100 g of fresh plant) were taken from 3 trees per site. The soil samples were also obtained (depth of 10 cm, distance of 2 m) around the sampled trees. The plants were transferred to the laboratory in plastic bags, washed with tap water, and then rinsed with distilled water. After drying at 70 ºC, the samples were ground with agate mortar, and then homogenously mixed.

Digestion of plant and soil samples

0.2-1.0 g of the dried samples was transferred into flasks (Pyrex) and digested by dry and/or microwave (MW)

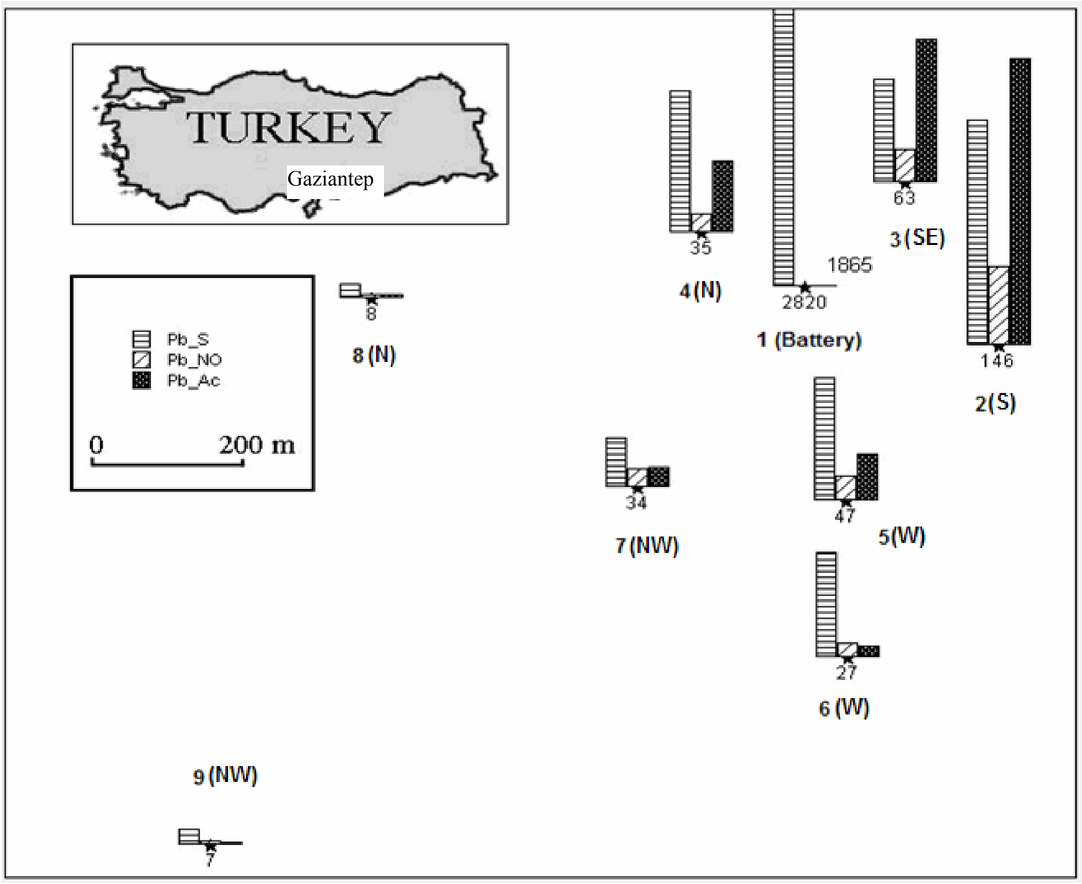

FIGURE 1 - The positions of sampling sites and Pb concentrations in these points. The positions and abbreviations are as follows: (S): south, (N): north, (W): west, (E): east, (SE): south east, (NW): north west, Pb_S: soil lead, Pb_NO: *N. oleander* L. - lead, Pb_Ac: *R. pseudoacacia* L. - lead. The Pb concentrations in *N. oleander* L. for all points and *R. pseudoacacia* L. for point 1 are given as numericals because these values are extremely high.

TABLE 1 - Pb, Cd and Cu concentrations in plant leaves taken from different points (n=3). The values are mg kg^{-1} for Pb and Cu, but ng g^{-1} for Cd.

No. in Fig. 1	Sampling point, direction	Soil			*N. oleander* L. (ICP-MS)			*R. pseudoacacia* L. (ICP-MS)		
		Pb	Cd	Cu	Pb	Cd	Cu	Pb	Cd	Cu
1	Area of 50 m around battery	602±65	444±45	37±5	2820±345	84±12	5.4±1	1865±234	63±8	9.3±1
2	200 m far from Battery, South	415±36	623±58	38±6	146±24 (170±22)	79±16 (88±13)	7.5±1 (8.3±0.9)	527±62 (546±53)	81±11 (90±17)	9.5±1 (10±2)
3	200 m far from Battery, South east	191±23	344±32	24±4	63±8	77±9	6.5±1	263±29	93±12	10±1
4	200 m far from Battery, North	261±22	142±6	31±4	35±5	92±12	5.9±1	131±17	69±9	7.3±1
5	200 m far from Battery, West	227±25	156±14	27±3	47±7	172±25	12±1	85±10	74±7	8.2±1
6	300 m far from Battery, West	193±20	172±16	24±4	27±5	165±30	14±2	21±2	367±25	8.1±1
7	300 m far from Battery, North west	92±9	284±25	20±4	34±6	95±21	4.7±0.7	37±4	101±14	9.2±1
8	800 m far from Battery, North	27±3	656±69	21±2	8±1 (8.2±1)	97±19 (100±18)	12±1 (13±2)	7±1 (7.3±1)	69±9 (71±110)	7.8±1 (8.0±1)
9	1500 m far from Battery, North west	29±3	236±20	23±2	7±1	85±10	7.6±1	6±1	64±8	9.7±1
	400 m far from cement plant	42±5	323±29	20±3	2±0.4 (2±0.3)	66±8 (60±5)	8.2±1 (9.0±1.0)	3±0.5	57±7	6.9±1
	Control (far from the polluted sites)	17±2	268±26	12±1	1±0.2	72±9	5±0.6	1±0.2 (1±0.2)	40±6 (50±7)	4.3±0.6 (5±0.5)

Pb, Cd and Cu concentrations in leaves of *Armeniaca* sp. plant taken from point 1 were found to be 97, 0.020 and 5 mg kg^{-1}, respectively. Pb, Cd and Cu concentrations in leaves of *Cydonia oblonga* Miller plant taken from point 6 were found to be 12, 0.012 and 4.9 mg kg^{-1}, respectively.

washing methods described elsewhere [18, 19]. As a result, each of the samples was analyzed in triplicate and the average of 3 values was used as mean value. The soil samples were dried at 100 ºC in an oven up to constant weight. A 0.2-g portion of dried soil was transferred into a flask (Pyrex) and 2 ml of HNO_3/H_2O_2 (1/1) mixture was added. The mixture was heated up near to dryness on a hot place (below the boiling point of hydrogen peroxide, 130 °C), with occasional stirring. This procedure was repeated. After cooling, 3 ml of 1-M HNO_3 was added and centrifuged. The clear solution was measured by FAAS for metal determinations. Blank digests were carried out using the same procedures.

RESULTS AND DISCUSSION

Analytical Performance

It is known that there are three methods to check the reliability of the results obtained. These are (1) the usage of Standard Reference Material (SRM), (2) comparison of the results with those obtained by independent method for the same samples, and (3) the recovery test. In this study, all 3 methods were applied to check the accuracy of the results obtained. From Table 1, it is observed that there was no significant difference between the data obtained from FAAS and those from ICP-MS using the *t*-test at a confidence level of 90%. The accuracy of the method was also checked by examining the Standard Reference Material Tomato Leaves-1573a. The recoveries for Cd and Cu in Tomato Leaves-1573a were found to be, at least, 96 and 98%, respectively (Table 2). Furthermore, the recoveries of Pb, Cd, and Cu from the plant leaves fortified with these metals were also used to test the accuracy. The concentrations of Pb, Cd, and Cu added to the samples were in the range of 5-20, 0.05-0.1, and 1-2 mg kg^{-1}, respectively. It was found that, at least, 94% of Pb, Cd, and Cu added to the plant leaves were recovered. The effects of contamination were eliminated by subtracting the obtained values from the blank. In order to overcome the enhancement or suppression due to the presence of major components, such as calcium and magnesium of the matrices, calibration solutions were performed within the sample matrix itself. On the other hand, the standard addition method for Pb, Cd, and Cu was also applied to figure out possible matrix interferences. The slopes of the calibration curves were compared with those obtained from the standard addition method. The results indicated the absence of chemical interferences because there was no difference in the slopes of both methods. Therefore, the calibration graphs were used to determine the metal concentrations in the samples. The calibration curves were linear in concentration (in parenthesis for STAT-FAAS) ranges of 0.20-5.0 (0.05-0.5) mg L^{-1} for Pb, 50-500 (4-80) ng ml^{-1} for Cd, and 0.1-3.0 (0.05-0.3) mg L^{-1} for Cu.

As related to determination of the best digestion procedure, it was found that there was no significant difference between the data obtained from both methods, namely, dry ashing and microwave digestion (considering *t*-test at a confidence level of 90%) as shown in Table 2. Although losses of Pb and Cd in dry ashing were reported for some matrices, such as fruits and vegetables [21], no losses of Pb and Cd in this study by using dry ashing could be attributed to differences in matrices. As a result, dry ashing method for sample digestion was chosen and used throughout the study. In other words, all results were obtained by using dry-ashing, unless stated otherwise.

Trace metal concentrations in plants and soils

Lead, Cd and Cu concentrations in the studied samples are summarized in Tables 1 and 2. It can be seen that the Pb concentrations are in range of 1.0–2,820 µg/g (DW) for *N. oleander* L. and 1.0-1,865 µg/g (DW) for *R. pseudoacacia* L., depending on the studied locations. This large variation may be attributed to uncontaminated and the highly polluted areas from the lead-battery factory as well as plant species. In the literature, it was described that lead might enter into the leaves through translocation of precipitated atmospheric lead along with accumulation through urban air, particularly in summer season [7]. As a result, the authors generally determined the metal concentrations in plants to evaluate environmental pollution [7-9, 22-32].

TABLE 2 - Metal levels in *R. pseudoacacia* L. and *N. oleander* L. taken from relatively uncontaminated (around textile industry) sites. The values are mg kg^{-1} for Pb and Cu, but ng g^{-1} for Cd, N=3.

Sample No	Soil			Plant		
	Pb	Cd	Cu	Pb	Cd	Cu
1- *R. pseudoacacia* L.	6±0.5	525±57	11±1	1.2±0.2	48±6	2.6±0.3
2- *R. pseudoacacia* L.	5±0.4	265±30	10±1	1.3±0.2	15±2	2.0±0.2
3- *R. pseudoacacia* L.	9±0.6	489±40	15±1	1.9±0.3 (2.0±0.3)	31±3 (32±3)	3.7±0.4 (3.8±0.4)
4- *R. pseudoacacia* L.	18±2	403±38	17±2	4.1±0.4	19±3	5.3±0.6
5- *R. pseudoacacia* L.	15±1.6	578±57	20±2	3.4±0.4 (3.5±0.4)	63±8 (60±7)	6.9±1 (7.1±0.8)
6-*N. oleander* L.	13±1.0	556±53	14±1	2.1±0.2 (2.5±0.2)	56±7 (60±6)	3.7±0.5 (4.1±0.5)
SRM-Tomato leaves (1573a)	Certified value, mg kg^{-1}			-	1.52±0.04	4.70±0.14
	Found			-	1.46±0.05	4.6±0.18

The values in parentheses were obtained by using microwave (MW) digestion method.

Onianwa and Fakayode [23] investigated the extent of contamination in the vicinity of a lead-battery manufacturing plant located in Ibadan (largest city) in Nigeria. For this purpose, they determined trace metal levels in topsoil and vegetation (plant *Cromonolina odorata*, a composite). They found Pb about 2000 mg kg^{-1} in soil around the factory (1450 mg kg^{-1} about 500 m far from the factory and 50 mg kg^{-1} about 750 m far from the factory). In addition, they observed that Pb levels in soils and plants around the factory varied significantly depending on wind direction (the values in parenthesis are for the plant); NW: 2010 (1350), SW: 4100 (970), NE: 950 (3640) and W: 3010 (1710). As it can be seen from these values, Pb levels in the plants are not depending on soil-Pb concentration. They attributed their results to the wind direction and aerial pollution. In their study, mean Pb concentration in plant samples taken from control site was found to be 10 mg kg^{-1}. So, the bioindication index can be estimated to be 364 for their study. Moreover, they found Cd and Cu concentrations in plants grown around factory and control site (in parenthesis) as mg kg^{-1}; 1.5 (0.4) and 19 (9.5), resp. They deduced that higher Cd and Cu concentrations in plants grown around the factory can be attributed to impurities in the alloys of Pb used, or as trace additive in molding and casting processes of the industry.

In this study, the observed metal concentrations in plant samples collected from different points are given in Tables 1-2 as well as Fig. 1. Statistically significant relationships were observed between lead concentrations in leaves of both *N. oleander* L. and *R. pseudoacacia* L. plants and distance and/or wind direction. Dramatically high Pb concentrations up to 2,820 and 1,860 mg kg^{-1} were found in *N. oleander* L. and *R. pseudoacacia* L. plants taken at a distance of 50 m around the battery plant, respectively. These concentrations are extremely high when compared to the values described above for similar plants, and the levels obtained for plants growing around the cement factory and textile industry in this study. These data can be attributed to aerial accumulation of Pb by the plants. These high values decreased sharply to 150 mg kg^{-1} for *N. oleander* L. and 500 mg kg^{-1} for *R. pseudoacacia* L. plants collected at a distance of 200 m from battery. The decrease in Pb concentration of plant leaves depends not only on the distance of sampling point from the contaminated area but also seems to be related to the wind direction. It is observed that Pb absorption by *N. oleander* L. and *R. pseudoacacia* L. varied significantly depending on wind direction. In the study area, the predominant wind direction is mainly in NS directions. As a result, significantly higher Pb concentrations were found in all samples (including soil, *N. oleander* L. and *R. pseudoacacia* L. plants) when sampled from southern direction rather than the northern. Furthermore, it was observed that Pb levels in *R. pseudoacacia* L. leaves taken from all distances around the battery were higher than in *N. oleander* L. leaves unlike in those taken at a distance of 50 m around the battery. Briefly, the accumulation of Pb in *N. oleander* L. and *R. pseudoacacia* L. leaves are not only related to soil pollution but also to air pollution. Mertens et al. [24] also concluded that foliage sampling and analysis is a useful tool for studying the effects of metals on ecosystems and for monitoring atmospheric pollution, but it has only little value for the straightforward biomonitoring of soil pollution. It can be seen that Pb levels emitted from the battery plant can influence the plants far beyond 300 m because being higher than phytotoxic limit (30 mg kg^{-1}) (Table 1). Pb concentrations in leaves of *N. oleander* L. and *R. pseudoacacia* L. plants taken from control site (far from the urban and industrial areas) were found to be 1.0 mg kg^{-1} for both plants, and the corresponding values for the cement factory were observed to be 2 and 3 mg kg^{-1}, respectively. Thus, bioindication indices were estimated to be 2,820 and 1,860. To consider the biomonitor/hyperaccumulator potential of *N. oleander* and *R. pseudoacacia* plants, the leaves of *Armeniaca* sp. and *Cydonia oblonga* Miller plants taken from the same point sites 1 and 6, respectively, were examined. In respect to the first view of biomonitoring definition: "10-times higher metal concentrations in biomonitoring plants with regard to other plants taken from the same sampling point", *N. oleander* and *R. pseudoacacia* plants can be used as biomonitors of atmospheric Pb pollution because Pb levels in these plants were found to be, at least, 19 times higher than in *Armeniaca* sp. leaves (97 mg Pb kg^{-1}) grown in the same site 1 (Table 1). It was observed that Cd concentrations in *N. oleander* L. and *R. pseudoacacia* L. plants taken from site 6 were found, at least, 36-fold those of *Cydonia oblonga* Miller plants taken from the same site (site 6). Therefore, *N. oleander* L. and *R. pseudoacacia* L. plants can be used as biomonitor plants.

The results obtained for lead concentrations in soil samples are given in Table 1 and Fig 1. Lead concentrations in soil samples collected at a distance of 300 m from the battery were found to be higher than the limit levels (70 mg kg^{-1}) for agricultural purposes. On the other hand, the observed Pb concentrations in soil samples collected from the surrounding of textile industry were in the range of 5-18 mg kg^{-1}. The observed Cd and Cu levels in the studied soil and plant samples were found to be lower than the allowable limit values as not any industrial source emitted these 2 metals in these regions. However, Cu in plant leaves taken from battery area are higher than those from cement plant and textile industry. This increase can be attributed to the incineration of tires and personal metallic activities in the studied area. No correlations between the contents of Pb, Cd and Cu in soil and plant samples were observed. In respect to the second view of biomonitoring definition that "metal concentration in biomonitor plant grown in polluted media is, at least, 10-times higher than in the same plant grown in an unpolluted medium", it is observed that the leaves of *N. oleander* L. and *R. pseudoacacia* L. for Pb as well as those of *R. pseudoacacia* L. for Cd can also be used as biomonitors. Aksoy and Ozturk [25] reported Pb, Cd and Cu concentrations in washed *N. oleander* L. plants collected from rural and urban roads in ranges of 0.3-16, 0.24-0.5 and 3.2-4.5 mg kg^{-1}, respectively. Baycu et al. [26] reported Pb concentrations of 0.0-34.4 mg kg^{-1} in *Robinia* plants taken from the vicinity of Istanbul city, depending on season and traffic density. Aksoy et al. [27] determined Pb, Cd and Cu in washed leaves of *R. pseudoacacia* L. taken from vicinity of Kayseri city ranging between 14.89-62.42, 0.44-1.22 and 7.32-14.04 mg kg^{-1}, respectively, depending on rural and industrial sites [27]. Kartal et al. [28] reported Pb, Cd and Cu concentrations in soil samples taken around a zinc-production factory of 0.5-1648, 0.1-4.9 and 5.0-47 mg kg^{-1}, respectively, depending on distances (50-2000 m) from the factory [28].

The enrichment coefficient (EC) or bioaccumulation factor (BF) (the ratio of element concentration in above-ground tissues of plant to element concentration in soil) must be higher than 1 for hyperaccumulator plants. The ECs for Pb in the studied plants were found to be 4.68 for *N. oleander* L. and 3.1 for *R. pseudoacacia* L. taken around the battery plant (Fig. 2). The observed ECs for *R. pseudoacacia* L. plant were higher than 1.0 up to 200 m far from the battery. As a result, *N. oleander* L. and *R. pseudoacacia* L. can be used as hyperaccumulator plants considering both ECs and BFs.

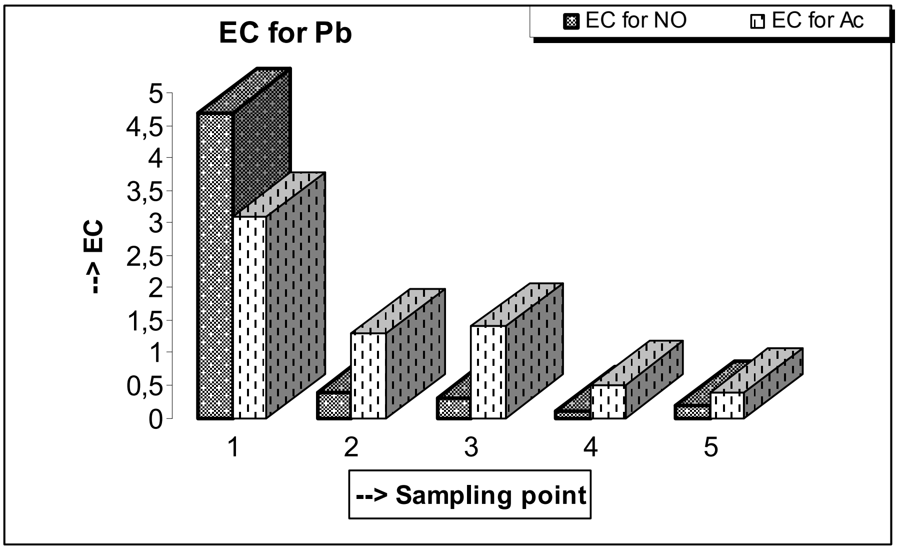

FIGURE 2 - Enrichment factor (EC) for Pb depending on different distances (sampling points from Table 2) around lead-battery. NO: *N. oleander* L. and Ac: *R. pseudoacacia* L.

CONCLUSION

Lead concentrations higher than 1000 mg kg^{-1} were found in leaves of *N. oleander* L. and *R. pseudoacacia* L. plants taken from n 50-m distance around a lead battery-manufacturing plant. Furthermore, *R. pseudoacacia* has a potential for biomonitoring of Cd pollution because Cd concentration (367 ng g^{-1}) in this plant was, at least, 36-fold higher than in *Cydonia oblonga* Miller (12 ng g^{-1}) grown at the same sampling point 6. Although the studied battery area is unpopulated, the employers are working in this region. As a result, it is concluded that there is a hazardous risk from the lead-battery plant far beyond at a distance of 300 m because higher Pb levels than the phytotoxic limit (30 mg kg^{-1}) were found in plants taken at these distances. The results reconfirmed applicability of higher plants for assessing the degree of atmospheric pollution around point sources as well as trace element atmospheric deposition on large geographical areas.

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