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Research Note

Determination of Airborne Lead Contamination in *Cichorium intybus* L. in an Urban Environment

Dilmaç YAKUPOĞLU[1], Tülin GÜRAY[1], Deniz YURTSEVER SARICA[2], Zeki KAYA[1,*]

[1]Department of Biological Sciences, Middle East Technical University, 06531 Ankara - TURKEY

[2]Ankara Test and Analysis Laboratory, The Scientific and Technical Research Council of Turkey (TÜBİTAK), Konya Yolu No: 67 06100 Beşevler, Ankara - TURKEY

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Abstract: The major source of environmental lead (Pb) is the combustion of leaded gasoline. After emission as exhaust, lead in the air falls to earth and contaminates soil and plants. Seventeen wild chicory (*Cichorium intybus* L.) plant samples were collected from each of 2 urban sites in Ankara, one is located at the road side of major intercity road (heavy traffic) and the other one is located in relatively less traffic area that is about 1 km away from the first location. Lead content of chicory plants were analyzed by a flame atomic absorption spectrophotometer. The mean lead concentrations in the heavy traffic site was 8.3 ± 2.8 mg/L with the range of 3.88 ± 1.8 - 14.18 ± 1.76 mg/L. For the low traffic site, the mean was 9.76 ± 6.01 mg/L and the range was from 4.39±1.5 to 19.19 ± 7.8 mg/L. From the statistical analysis, significant differences were not found between the low and heavy traffic influenced sites, indicating that plants from areas away from roads and motor traffic were not free of lead so the consumption of these plants could bring high amounts of lead into food chain.

Key Words: Lead exposure, *Cichorium intybus*, urban environment, edible wild plants.

Kent Ortamında Yetişen *Cichorium intybus* L.'de Atmosferik Kurşun Kirliliğinin Belirlenmesi

Özet: Çevresel kurşunun (Pb) ana kaynağı kurşunlu benzinin yanmasıdır. Eksoz gazı olarak salınan havadaki kurşun yer yüzeyine geri dönerek bitki ve toprakları kirletmektedir. Birbirine 1 km yakınlıkta birisi trafiğin yoğun olduğu şehirler arası yol kenarından diğeri de trafiğin daha az olduğu iki kentsel çevreden olmak üzere 17 yabani hindiba (*Cichorium intybus* L.) bitkisi örneklenmiştir. "Flame Atomic Absorption Spectrophotometer" kullanılarak yabani hindiba bitkilerinde kurşun oranları analiz edilmiştir. Bitkilerdeki kurşun oranı trafiğin yoğun olduğu çevrede 3,88 ± 1,8 ile 14,18 ± 1,76 mg/L arasında olup, ortalama 8,3±2,8 mg/L'dir. Trafiğin daha az olduğu çevrede ise değerler 4,39±1,5 ile 19,19 ± 7,8 mg/L arasında olup ortalama 9,76 ± 6,01 mg/L'dır. Yapılan istatistik analizler sonucu, trafiğin yoğun olduğu çevre ile az olduğu çevre arasında bitkilerin kurşun oranı bakımından anlamlı farklılıklar bulunmamıştır. Bununla beraber, yoğun trafikten uzakta bulunan çevredeki bitkilerin bile yüksek kurşun içermesi, sözkonusu bitkilerin tüketilmesi sonucu besin zincirne yüksek oranda kurşun girmesine neden olacaktır.

Anahtar Sözcükler: Kurşun kirliliği, *Cichorium intybus*, kentsel çevre, yenebilir yabani bitkiler

Introduction

In the first half of the century, lead has been emitted into the environment as it is used as an efficient anti-knock additive in gasoline. According to Olendrzynski et al. (1995), about 70% of the total emissions in Europe were related to road traffic, 15% to industrial production, 5%-10% to power generation, and 2% to waste incineration; lead in gasoline being the most significant emission source of lead in the atmosphere.

Normally, lead is a natural, but minor, component of soils and plants. Contamination of environment with high concentrations of heavy metals including lead, mainly emitted from automobiles, were investigated by various researchers (Roth & Hornung, 1977; Foner, 1987;

* E-mail: kayaz@metu.edu.tr

Gratani et al., 1992; Bahemuka & Mubofu, 1999; Renberg et al., 2000; Yaman et al., 2000; Andrews & Sutherland, 2004; Finster et al., 2004). Increasing interest in heavy metal contamination of vegetation especially growing near roadsides in urban areas are mainly due to the lead content of roadside plants and also because vegetation is a sensitive indicator of lead pollution. Ingestion is a possible route of lead exposure and consuming plants grown near roadsides is a way that lead reaches humans (Andrews & Sutherland, 2004; Finster et al., 2004).

Wild chicory (or common chicory) is a perennial that resembles dandelion when in the rosette stage and produces an attractive blue or purple flower when mature. Plants initially develop as a basal rosette of leaves that are 3 to 10 inches long by 1/2 to 3 inches wide. Stems are branched and produce blue or purple flowers during the latter part of the growing season. Leaves that occur on the flowering stalks are much smaller than the rosette leaves and also have leaf bases surrounding or clasping the stem. Wild chicory is native to Europe and Asia and introduced to North America. Typical habitats include pastures, abandoned fields, areas along roadsides and railroads, grassy areas that are not mowed regularly, undeveloped real estate lots, and other waste areas. Occasionally, common chicory invades disturbed areas of natural habitats, but it is not a serious invader of such natural areas in the long run (Sanderson et al., 2003, Labreveux et al., 2006). Although, wild chicory is not sold in common markets, it is widely consumed in Turkey, as people pick them up from roadsides and use its leaves commonly in salads or cook it as a special dish. Sometimes, picked ones from wild are sold in local small markets, too. Furthermore, chicory is used as a folk remedy, believed to cure many liver diseases, tumours, and some types of cancer. As it is grown mainly near roadsides, it is subjected to many toxic materials mainly lead from motor exhaust (unleaded gasoline), which is an important source of lead in Turkey.

Leafy vegetables have potentials for high mineral uptake and a tendency to accumulate heavy metals. Wild chicory is a leafy vegetable and because of its worldwide cosmopolitan distribution, ability to grow as a weed, and ability to tolerate a broad range of climatic and soil conditions, it can be used as a biological indicator of heavy metal contamination (Simon et al., 1984). Additionally, wild chicory is a perennial plant that could be another convenient characteristic for biomonitoring purposes.

Numerous studies on the uptake of heavy metals by various plant species have been reported (Peterson et al., 1979; Lepp, 1981; Page et al., 1981; Nasu & Kugimoto, 1984; De Temmerman & Hoenig, 2004; Finster et al., 2004). Despite its high consumption, there are only few data available on heavy metal accumulation of wild chicory in contaminated areas (Simon et al., 1984; Turkan, 1986; Del Rio-Celestino et al., 2006).

The objectives of this study were (i) to find out the lead contamination level sampled in urban sites of Ankara using wild chicory plants, (ii) to test the genotypic abilities of wild chicory plant in accumulation of lead, (iii) to evaluate the possible health effects of lead contaminated wild chicory consumptions.

Materials and Methods

Since it was a pilot study, the leaves of wild chicory were obtained from only 2 sites. The first site is located at the major intercity roadside of Ankara and will be referred to as "*heavy traffic site*" (HT) throughout the study. The second site is located in a relatively less traffic area of the city and it will be referred to as "*low traffic site*" (LT).

Ideally, sampling of soil and different parts of plants is useful to determine the source and location of lead contamination (Aksoy & Sahin, 1999). However, considering that mainly leaves are consumed by animals and humans, leaf sampling without a wash should be satisfactory to meet the objectives of this pilot study. Thus, initially, 18 plants from each of the above regions were selected, but 1 plant from LT site was not useful for lead determination. Then, leaves were harvested and dried. Plant samples, approximately 0.2-0.3 g, were digested in a mixture of HNO_3, H_2O_2, and HF (12:2:1) and analyzed for lead content using a flame atomic absorption (FAA) spectrophotometer (ATI UNICAM Model 229 at TÜBİTAK - Ankara Test and Analysis Laboratory with a sensitivity and detection limit of 0.239 mg/L and 0.04 mg/L (N = 30, k = 3), respectively. Five readings were taken and results were recorded. Pb standard metal solution (1000 ppm, mg/L) was supplied from Fison Scientific Equipment, Loughborough, UK.

Accuracy of the method was found as 98.46% with 0.55% relative standard deviation (RSD). Prior to analyses, a calibration curve was plotted and the standard addition technique and salt interference tests were carried out.

A microwave system with PMD cooling unit was used for destruction of solid sample matrix. A domestic microwave oven (High Performance Microwave Digestion Unit MLS 1200 Mega), with time setting and power levels ranging between 70 and 900 W, was used to induce the acid leaching process (Bermejo-Barrera et al., 2000).

Analysis of variances (ANOVA) was carried out according to the following described models using VARCOMP Procedure of SAS (SAS Inst., 1991):

$$Z_{ijl} = \mu + B_i + S_j + e_{ijl} \qquad \text{(Model 1)}$$

Where μ is the experimental mean, Z_{ijl} is the lead concentration of *l*th experimental plant in *j*th site and *i*th replication. Site in the model was considered as fixed effect while the rest were treated as random effects. The F-test for lead concentration at the site level was performed at 0.01 probability level. In addition, the component of variance attributed to the sites was estimated according to the above model (Model 1).

$$Z_{ijl} = \mu + S_i + P_{j(i)} + e_{ijl} \qquad \text{(Model 2)}$$

where μ is the experimental mean, Z_{ijl} is the lead concentration of the *i*th experimental plant within the *j*th site and the *l*th sample from a plant. Site in the model was considered as fixed effect while the rest were treated as random effects. The F-tests for lead concentration at plant within site and site were performed at 0.01 probability level. Furthermore, components of variance attributed to sites and plants within site were estimated according to the above model (*Model 2*).

Results

Site means and ranges for lead concentration of chicory plants are given in Table 1.

As seen from the Table 1, LT site is located away from traffic, though it is only 1 km from main road, it was found to be as polluted as HT in terms of lead contamination. When the minimum and maximum values of experimental plants were examined, there was a great variation between pollution levels of individual plants within as well as between sites (data not presented here).

The ANOVA results given in Table 2A indicated that source of variance among sites covered only 3.52% of total variance in Pb contamination in wild chicory. F-test confirmed that there was no significant statistical difference between the 2 sites ($P < 0.01$), but there was a significant difference between plants in a given particular site. The components of variance provided some indication of the difference between lead-concentration of plants of the 2 examined sites. For instance, the percentage of variance due to plants within sites for lead concentration made up as high as 89% of the total variance (Table 2B).

Discussion

Western European countries introduced unleaded fuel in the late 1980s, and a number of countries now market only unleaded gasoline though there are many other countries, including Turkey, that have switched to unleaded gasoline without completely eliminating the sale of leaded gasoline. Therefore, lead pollution due to leaded gasoline still occurs in these countries. The major source of human lead accumulation in developing countries was found to be airborne lead, 90 percent of which comes from leaded gasoline ((MECA, 2003)

Based on the results of a previous study carried out by Aksoy and Şahin (1999), our estimate for lead concentration in leaves is around 50% higher than what it should be if the leaf-samples had been washed before lead concentration was measured. Nevertheless, the

Table 1. Mean lead concentration of wild chicory plants in low traffic (LT) and heavy traffic (HT) sites.

	LOW TRAFFIC SITE	HEAVY TRAFFIC SITE
MEAN	9.76 ± 6.01	8.30 ± 2.80
Range	(4.39±1.5)-(19.19 ± 7.8)	(3.88 ± 1.80)-(14.18 ± 1.76)

Table 2. Analysis of variance for lead concentration in wild chicory. A) Testing the site differences for lead contamination. B) Testing the site and the plants within the site for lead contamination.

A)

Trait	MEAN SQUARES					
	Replication (degree of freedom (df) = 4)	Variance component (VC) (%)	Site (df = 1)	VC%	Error (df = 174)	VC%
Lead Concentration. (mg/L)	15.95	2.35 ns	96.58	0.2 ns	118.52	97.44

B)

Trait	MEAN SQUARES					
	Site (df = 1)	VC%	Plant (Site) (df = 34)	VC%	Error (df = 144)	VC%
Lead Concentration (mg/L)	197.31	3.51 ns	651.043	89.442*	10.093	7.042

*: Significant at P<0.01; ns : not significant; df: degrees of freedom; VC: Component of total variance.

results of the present study showed that plants from areas away from roads and motor traffic were not free of lead contamination. At the beginning of our study, it was expected to find lower lead concentrations at the LT sites compared to HT sites. However, the results indicated that there was no significant difference in plant lead concentration between the 2 sites. On the other hand, there were drastic differences between lead concentration levels of plants within each site, which may be explained by several reasons. Basically, there are 2 routes whereby vegetation got contaminated by lead, one from soil sources via root uptake (Yaman et al., 2000; Finster et al., 2004; Wong & Li, 2004; Del Rio-Celestino et al., 2006), and the other from aerial deposition onto plant leaves (Aydınalp & Marinova, 2004). Different lead pollution levels among plants were due to the different deposition levels of airborne lead. After emission as exhaust, lead can travel up to 100 km, therefore, it is very difficult to find lead free plants. When airborne lead precipitates, it accumulates on soil and plants. Consequently, high pollution levels of plants in LT sites are more likely due to the deposition of airborne lead.

Each plant has a different level of lead concentration ranging from low 2.4-2.5 mg/L to high 28 mg/L. Some researchers (Burguera & Burguera, 1988) suggest that plants may have some endogenous lead-concentrating mechanism in the inner surface of leaves that is not affected by atmospheric pollution. There can be an alternative mechanism of surface accumulation of lead in plant bodies mostly determined by the ambient lead level. This exogenous route of lead accumulation is to a great extent responsible for high concentration surface lead values whose relationship to the endogenous lead-concentrating mechanism is not clear. Nasralla and Ali (1985) studied lead concentration levels of crops grown near high traffic density regions, they found out that lead concentration levels in tomato leaves were 17-124 mg/L and similarly in pepper leaves 15.7 – 127 mg/L. Since there is a great range of lead contamination among plants within a site, genetic ability of plants to uptake lead can be different. Basco et al. (1984) determined lead contamination in plants like dandelion and rye grass and reported as 23.3 mg/L and 48.5 mg/L, respectively. Our maximum finding in LT region, which was 28 mg/L, is comparable to their findings. However, the future studies dealing with wild chicory should consider other variables, such as the season of collection, number of vehicles passing from the highway, and distance from the road.

Since collections of wild chicory plants from road sides and grazing of animals along road sides in urban areas are common practice in Turkey, consumption of wild chicory can bring directly or indirectly high amount of lead into human food chain and in turn will cause acute to chronic health effects at even low dosages (Lanphear et al., 2002). Our results indicated that plants within a given site, regardless of how close to motor traffic, had wide range of lead concentration - as high as 28.62 mg/L. In order to avoid the exposure of lead from plants, wild plant collectors and consumers have to be informed on possible toxic effect of lead contaminated wild chicory. Consuming or grazing plants that are not only grown near roadsides, but also in areas close to motor traffic should be avoided in urban as well rural areas. As the highest emission of lead to the environment comes from leaded gasoline, use of unleaded gasoline has to be encouraged more to reduce the lead emission into atmosphere. The reports of US-Environmental Pollution Agency about lead states that the only cure for lead exposure is to prevent the exposure (US-EPA, 1988).

Conclusion

Lead contamination of wild chicory as well as other edible wild plants needs to be explored further by considering wider areas and variables. Lead pollution, mainly from automobile exhausts in urban areas, regardless of proximity to main roads, can affect human health through collection and consumption of edible wild plants like chicory by low socioeconomic groups. Since grazing of sheep and cows along banks of highway are also common practice in most part of the country, an additional lead could be transferred indirectly to human food chain with consumption of such animal products.

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