Turk J Pharm Sci 2021;18(5):581-588
DOI: 10.4274/tjps.galenos.2021.45389

ORIGINAL ARTICLE

Trend Analysis of Lead Content in Roadside Plant and Soil Samples in Turkey

Türkiye’de Yol Kenarında Bulunan Bitki ve Toprak Örneklerinde Kurşun İçeriğinin Eğilim Analizi

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ABSTRACT

Objectives: Lead (Pb) is one of the most common heavy metals which contaminate the environment. People may be exposed to Pb by inhaling the contaminated air droplets and dust particles through drinking water or eating contaminated foods such as vegetables grown in lead-contaminated soils. This study aimed to examine the changes in Pb levels measured in roadside plant and soil samples that have been exposed to heavy traffic for years.

Materials and Methods: Sixty-three articles were searched using keywords from different databases. Twenty-five of the scanned articles were found to be relevant for the determined criteria. The Pb levels were evaluated according to the previously measured Pb levels in plant and soil samples collected from the roadside by years.

Results: In the data collected from databases over the years, it was observed that there was a decrease in Pb accumulation in both soil and plant samples. Pb levels were higher in industrial cities and metropolitan areas than in rural areas.

Conclusion: In ealier studies, Pb levels have often been found to exceed safety limits. This may be due to the Pb added to gasoline in the past, as well as the low sensitivity of analytical methods used for measurement. The decrease over the years has been interpreted as the use of unleaded gasoline after 2004, taking essential measures to improve air quality and at the same time increasing the sensitivity of analytical methods.

Key words: Heavy metal, herbal, plant, highway, roadside, lead

ÖZ

Amaç: Kurşun (Pb), çevreyi kirleten yaygın elementlerden birisidir. İnsanlar, kontamine olmuş hava damlacıklarını ve toz parçacıklarını soluma yoluyla, içme suyuyla veya Pb ile kirlenmiş topraklarda yetişen sebzeleri yiyerek Pb’ye maruz kalabilir. Trafik hareketliliğinin yoğun olduğu yol kenarlarında yetişen bitki ve topraklarda ölçülen Pb düzeylerinin yıllara göre değişiminin incelenmesi amaçlanmıştır.

Gereç ve Yöntemler: Farklı veri tabanlarından anahtar kelimeler kullanılarak 63 makale taranmıştır. Taranan makalelerin 25’i belirlenen kriterlere uygun bulunmuştur. Yol kenarında yaşayan bitki ve toprak örneklerinde ölçülen Pb düzeyleri yıllara göre değerlendirilmiştir.

Bulgular: Yıllar içinde toplanan verilerde hem toprak hem de bitki örneklerinde Pb birikiminde azalma olduğu görülmüştür. Sanayi şehirlerinden ve metropollerde Pb seviyeleri kırsal bölgelere göre daha yüksek bulunmuştur.

Sonuç: Daha önceki çalışmalarda, Pb seviyelerinin çoğunlukla güvenlik limitlerini aştığı tespit edilmiştir. Bu durum, önceki zamanlarda benzine katılan Pb nedeniyle olabileceği gibi aynı zamanda ölçüm için kullanılan analitik yöntemlerin hassasiyetlerinin düşük olmasıyla da ilişkilendirilebilmektedir. Yıllara göre azalmanın ise 2004 yılından sonra kurşunsuz benzin kullanılması, hava kalitesinin artırılması için önemli tedbirlerin alınması ve aynı zamanda analitik yöntemlerin hassasiyetinin yükselmesi olarak yorumlanmıştır.

Anahtar kelimeler: Ağır metal, bitkisel, bitki, otoyol, yol kenarı, kurşun

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Received: 30.10.2020, Accepted: 12.02.2021

INTRODUCTION

Chemical substances form the core of our world for both the living systems and the environment. When produced, used, and managed appropriately, the chemicals make things easy and benefit our everyday needs. However, chemicals may also be a significant threat to the living systems and the ecosystem in some circumstances. In 2010, the World Health Organization (WHO) published a report on ten chemicals or groups considered major public health concerns. WHO listed them as air pollution, arsenic, asbestos, benzene, cadmium, dioxin, and dioxin-like substances, inadequate or excess fluoride, lead (Pb), mercury, and highly hazardous pesticides. There are several heavy metals on the list, including Pb.[1]

Environmental pollution has been a primary global health concern since the early phases of the industry. This issue is getting more threatening and becoming much more critical day by day. Heavy metals are accepted as one of the primary sources of environmental pollution. Thanks to technological developments, actions are being taken to diminish the hazardous effects of these pollutants using environmentally-friendly solutions, such as abandoning the use of Pb in gasoline.[2] Due to the high usage of heavy metals in technological equipment, their existence in living systems is inevitable. When the amount exceeds the acceptable ranges, heavy metals can be accumulated in organisms.

Heavy metal accumulation has become a predominant problem for the world, especially in developing countries, and it may cause several harmful effects on humans, animals, plant species, and the environment itself.[3] Contaminated soil can be a critical source for heavy metal exposure due to farming, agriculture, horticulture, and animal breeding. Roadside soils should also be a focus because many people, especially in the rural regions, collect, and consume plant substances growing on the roadside. Therefore, it is necessary to estimate harmful substances' qualitative and quantitative content, particularly heavy metals in the soil.[4]

Heavy metal can be considered the naturally occurring metallic elements with densities higher than 5 g/cm^3, equal to more than five times that of water, and relatively high atomic numbers.[2,5] Several definitions had been proposed for heavy metals. The Oxford English Dictionary indicates that the oldest definition in the scientific literature of heavy metal is "those metals with an elemental density above 7 g/cm^3".[6] More specific definitions have been published, but none of these have been widely accepted. Ali and Khan[6] defined heavy metals as naturally occurring metals having an atomic number greater than 20 and an elemental density greater than 5 g/cm^3.

Heavy metal exposure results in toxicities and tissue damages with various symptoms. Toxic effects vary depending on the amount and route of exposure and personal characteristics like age, gender, hereditary characteristics, and eating habits of the exposed individual.[2,5]

Heavy metal contamination is caused by exhaust gases from industrial activities, motor vehicles, chemical and pharmaceutical manufacturings, and fertilizers and pesticides used for agricultural purposes, eventually leaking into the soil. The contamination of heavy metals in the soil is harmful because of their non-biodegradable nature; they may persist and accumulate in the soil for many years. Additionally, as the soil's heavy metal content increases, the amount is taken up by the plant also rises.[2,3] The United States Environmental Protection Agency (US EPA) and the International Agency for Research on Cancer classify arsenic, cadmium, chromium, Pb, and mercury as probable or known human carcinogens.

This study focused on the Pb accumulation levels throughout the years because of their high content in the roadside plants and soils.[5] Pb is naturally occurring in the environment and is one of the most important and commonly contaminated heavy metals. It has an atomic number of 82 and a molecular weight of 207.2 u.[5] According to the US EPA, Pb is a naturally occurring element found in small amounts in the earth's crust. It causes severe toxicities besides some beneficial impacts.[7]

People may be exposed to Pb by inhaling the contaminated air droplets and dust particles, exhaling the household paintings, drinking contaminated water, or ingesting contaminated food such as vegetables grown in Pb-contaminated soils.[5]

Pb shows its toxic effects by particular mechanisms after entering the systemic circulation in the body. It may interfere with the enzymes by binding their amide and sulfhydryl groups and inhibiting their action. It competitively binds to the sites of some essential elements like calcium and alters their activities. Also, it induces oxidative stress generating reactive oxygen species. Oxidative stress is a widely known toxicity mechanism for its role in cellular damage.[5]

The central nervous system is the primary target for Pb toxicity, which results in headaches, memory deficits, attention deficits, or hallucinations. In addition, studies report that Pb poisoning causes neurobehavioural and intelligence-related damages in children. Furthermore, Pb exposure is a significant problem for pregnant women, including possible preterm labor and post-natal complications in the child because it may cross the placental barrier.[5]

In this study, a literature review was conducted by collecting data from 25 studies regarding the Pb accumulation in the roadside plants and soils from several different regions in Turkey between 2001 and 2020. Then, Pb levels' changes throughout the years were examined, and possible reasons beneath them were discussed.

MATERIALS AND METHODS

In this study, 63 articles about heavy metal accumulation in plants and soil were searched. All studies about heavy metal accumulation included Pb but other heavy metals were varied. The study targeted the roadside plants and soil. Heavy metal, herbal, plant, highway, and roadside keywords were used while searching the articles. Initially, articles throughout the world were read, then narrowed down to studies from Turkey. The articles that did not examine Pb, not collected samples at the roadside, and were not studied in Turkey were eliminated. Twenty-five articles were left to be put on the tables. Table 1 shows Pb accumulation in plants (fruit and leaves).

Table 1. Lead content and its safe limit in different plant samples of different regions in Turkey

Year	Sample	Pb level (ppm)	Pb in portion (100 g)	Safe limits (ppm)	Proportion of safe limit	Location	Reference
2001	*Robinia pseudo-acacia* (leaves)	72.69	7.27	2	36.34	Denizli	Celik et al.[13]
2002	Apple	180	18.0	2	90.00	Elazığ	Bakirdere and Yaman[14]
2002	Grape	213	21.3	2	106.50	Elazığ	Bakirdere and Yaman[14]
2002	Apple (leaves)	866	86.6	2	433.00	Elazığ	Bakirdere and Yaman[14]
2002	Grape (leaves)	547	54.7	2	273.50	Elazığ	Bakirdere and Yaman[14]
2002	Tomato	175	17.5	2	87.50	Elazığ	Bakirdere and Yaman[14]
2002	Bell pepper	139	13.9	2	69.50	Elazığ	Bakirdere and Yaman[14]
2002	Parsley	585	58.5	2	11.70	Elazığ	Bakirdere and Yaman[14]
2003	Grass	1.75	0.175	2	0.875	Konya	Onder et al.[15]
2003	Lavender (flowers)	0.5	0.05	2	0.25	Western Anatolia	Divrikli et al.[16]
2003	Laurel (root)	0.1	0.01	2	0.05	Western Anatolia	Divrikli et al.[16]
2003	Chard (leaves)	0.2	0.02	2	0.10	Western Anatolia	Divrikli et al.[16]
2003	Chard (root)	2.8	0.28	2	14.0	Western Anatolia	Divrikli et al.[16]
2003	Lavender (leaves)	0.8	0.08	2	0.40	Western Anatolia	Divrikli et al.[16]
2006	Parsley	9.9	0.99	2	4.95	Kayseri	Demirezen and Aksoy[17]
2006	Tomato	9.7	0.97	2	4.85	Kayseri	Demirezen and Aksoy[17]
2007	Cabbage	0.91	0.091	2	0.455	İstanbul	Osma et al.[18]
2007	Parsley	0.95	0.095	2	0.475	İstanbul	Osma et al.[18]
2007	Chard	0.99	0.099	2	0.495	İstanbul	Osma et al.[18]
2007	*Rosmarinus officinalis*	6.9	0.690	2	3.45	Mersin	Koc and Sari[19]
2008	Apple	2.21	0.221	2	1.10	Konya	Hamurcu et al.[20]
2008	Cornelian	2.65	0.265	2	1.32	Konya	Hamurcu et al.[20]
2008	Plum	2.82	0.282	2	1.41	Konya	Hamurcu et al.[20]
2008	Rose	2.86	0.286	2	1.34	Konya	Hamurcu et al.[20]
2009	*Pinus nigra*	0.35	0.035	2	0.175	Denizli	Keskin and Ili[21]
2010	*Pinus nigra*	0.00	0	2	0	Denizli	Keskin and Ili[21]
2012	Sweet cherry (leaves)	8.74	0.874	2	4.37	Aras valley	Pehluvan et al.[22]
2012	Sweet cherry (fruits)	1.75	0.175	2	0.875	Aras valley	Pehluvan et al.[22]
2012	Black mullberry (leaves)	3.48	0.348	2	1.74	Aras valley	Pehluvan et al.[22]
2012	Black mullberry (fruits)	1.62	0.162	2	0.81	Aras valley	Pehluvan et al.[22]
2012	White mullberry (leaves)	4.15	0.415	2	2.07	Aras valley	Pehluvan et al.[22]
2012	White mullberry (fruits)	2.15	0.215	2	1.07	Aras valley	Pehluvan et al.[22]
2012	Apricot (leaves)	10.23	10.23	2	5.11	Aras valley	Pehluvan et al.[22]
2012	Apricot (fruits)	3.15	0.315	2	1.57	Aras valley	Pehluvan et al.[22]

Table 1. continued

Year	Sample	Pb level (ppm)	Pb in portion (100 g)	Safe limits (ppm)	Proportion of safe limit	Location	Reference
2012	Plum (leaves)	15.47	1547	2	7.73	Aras valley	Pehluvan et al.[22]
2012	Plum (fruits)	3.42	0.342	2	1.71	Aras valley	Pehluvan et al.[22]
2012	Peach (leaves)	7.69	0.769	2	3.84	Aras valley	Pehluvan et al.[22]
2012	Peach (fruits)	3.15	0.315	2	1.57	Aras valley	Pehluvan et al.[22]
2012	Pear (leaves)	10.43	1043	2	0.52	Aras valley	Pehluvan et al.[22]
2012	Pear (fruits)	2.15	0.215	2	1.07	Aras valley	Pehluvan et al.[22]
2012	Hawthorn (leaves	8.67	0.867	2	4.33	Aras valley	Pehluvan et al.[22]
2012	Hawthorn (fruis)	3.1	0.31	2	1.55	Aras valley	Pehluvan et al.[22]
2012	Rosehip (leaves)	10.36	1.36	2	5.18	Aras valley	Pehluvan et al.[22]
2012	Rosehip (fruits)	2.85	0.285	2	1.42	Aras valley	Pehluvan et al.[22]
2012	Sweet cherry (leaves)	47.83806947	4.784	2	23.92	Aras valley	Pehluvan et al.[22]
2012	*Rosmarinus officinalis (leaves)*	1.19	0.119	2	0.595	İzmir	Colak Esetlili et al.[23]
2012	Parsley	1.14	0.114	2	0.57	İzmir	Colak Esetlili et al.[23]
2014	*Passiflora coccinea*	8.94	0.894	2	4.47	Adana-Gaziantep highway	Kirpik et al.[24]
2014	Nerium oleander	4.86	0.486	2	2.43	Adana-Gaziantep highway	Kirpik et al.[24]
2014	*Rosmarinus officinalis*	8.16	0.816	2	4.08	Adana-Gaziantep highway	Kirpik et al.[24]
2014	*Rosmarinus officinalis* (refuge-stem)	9.48	0.948	2	4.74	Hatay	Bozdogan Sert et al.[25]
2014	*Rosmarinus officinalis* (refuge-leaves)	9.70	0.97	2	4.85	Hatay	Bozdogan Sert et al.[25]
2014	*Rosmarinus officinalis* (slope-stem)	11.21	1.121	2	5.60	Hatay	Bozdogan Sert et al.[25]
2014	*Rosmarinus officinalis* (slope-leaves)	10.01	1.00	2	5.00	Hatay	Bozdogan Sert et al.[25]
2016	*Celtis australis* (leaves)	34	3.4	2	17.00	İstanbul	Ozturk et al.[26]
2017	Hollyhock (leaves)	2.59	0.26	2	1.29	Lake Van	Kaya and Gülser[27]
2020	Pomegranate (fruits)	0.375	0.0375	2	0.1875	Pirinçli village-Siirt	Demirhan Aydın and Pakyürek[2]
2020	Pomegranate (fruits)	0.351	0.0351	2	0.1755	Kapılı village-Siirt	Demirhan Aydın and Pakyürek[2]
2020	Pomegranate (leaves)	0.614	0.0614	2	0.307	Pirinçli village-Siirt	Demirhan Aydın and Pakyürek[2]
2020	Pomegranate (leaves)	0.625	0.0625	2	0.3125	Kapılı village-Siirt	Demirhan Aydın and Pakyürek[2]

Pb: Lead

Table 2 shows Pb accumulation in soil. Tables 3 and 4 show Pb accumulation in parsley and rosemary (*Rosmarinus officinalis*). These two plants were used because they have more data available. We have to compare the same plants to make a correct comparison since each plant species has different bioaccumulation factors. Parsley and rosemary data were listed in different tables to achieve a more accurate comparison. Table 5 shows the exposure limits of five different national and international authorities for Pb, including Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH), WHO, European Chemicals Agency (ECHA), and the Ministry of Family, Labor and Social Services of Turkey. The permissible exposure limit of Pb according to OSHA and NIOSH is 0.00005 ppm.[8] The safety limit of Pb for soil and plants according to WHO are 85 and 2 ppm, respectively.[9] Occupational exposure limits of Pb according to the Ministry of Family, Labour and Social Services of Turkey and ECHA are 0.00015 and 0.00003 ppm, respectively.[10-12]

Statistical analysis was not used in this manuscript due to the meta-analysis of published studies.

RESULTS

Pb accumulation in roadside plants

From the research, 60 results from different plants and places were collected. All plant data are listed in Table1 according to the year. The safe level of Pb in plants is 2 ppm, according to WHO. However, the results vary ranging from 0.00 to 866.0 ppm; 30% of plants were safe according to their Pb level. The Pb levels were higher in studies conducted in the early years than the recent years' results. Before 2003, all data were higher than the safe limit. The highest values were found in a study in 2002 in Elazığ, Turkey, and apple leaves had the most Pb accumulated. The second and third highest values were found in grape leaves and parsley, respectively, in the same study. The lowest values were found in Denizli, Turkey, in 2010. In that study, researchers found no Pb accumulation in *Pinus nigra*.

Table 2. Lead level and its safe limit in various soil samples of different places in Turkey

Year	Sample	Pb level (ppm)	Pb level in portion (100 g)	Safe limit	Proportion of safe limit	Location	Reference
2001	Soil	336.55	33.66	85	3.959	Denizli	Celik et al.[13]
2002	Soil	73	7.3	85	0.8588	Tokat	Tüzen[28]
2002	Soil	26	2.6	85	0.3059	Elazığ	Bakirdere and Yaman[14]
2002	Soil	13.28	1.328	85	0.1562	Elazığ	Bakirdere and Yaman[14]
2003	Soil	2.66	0.266	85	0.0313	Konya	Onder et al.[15]
2006-2007	Soil	1.55	0.16	85	0.0182	Edirne	Aktaş and Kocabaş[29]
2007	Soil	235.1	23.51	85	2.766	Bursa-İzmir highway	Aydinalp[30]
2008	Soil	191	19.1	85	2.247	İstanbul	Guney et al.[31]
2009	Soil	31.50	3.15	85	0.3705	Eskişehir	Malkoc et al.[32]
2009	Soil	1.72	0.172	85	0.0202	Fatsa	Özkutlu et al.[33]
2010	Central soil	401	40.1	85	4.7176	Ankara	Akbulut and Çevik[34]
2010	Highway soil	567	56.7	85	6.6705	Ankara	Akbulut and Çevik[34]
2010	Central soil	442	44.2	85	5.20	Bursa	Akbulut and Çevik[34]
2010	Highway soil	405	40.5	85	4.7647	Bursa	Akbulut and Çevik[34]
2012	Soil	124.36	12.436	85	1.4631	Gümüşhane	Vural[35]
2013	Soil	102.8514	10.285	85	1.21	Sakarya	Çelenk and Kızıloğlu[36]
2014	*Passiflora coccinea (soil)*	33.70	3.37	85	0.3965	Adana-Gaziantep highway	Kirpik et al.[24]
2014	*Nerium oleander (soil)*	25.56	2.556	85	0.3007	Adana-Gaziantep highway	Kirpik et al.[24]
2014	*Rosmarinus officinalis (soil)*	35.76	3.576	85	0.4207	Adana-Gaziantep highway	Kirpik et al.[24]
2016	Soil	27.4-51.55	2.74-5.155	85	0.3224 - 0.6065	İstanbul	Ozturk et al.[26]

Pb: Lead

The lethal dose of Pb is 450 ppm in the lowest published data. Three of the 60 results collected were higher than the lethal dose. The Pb values are mostly higher than 2 ppm but lower than the lethal dose.

Pb accumulation in roadside soil

During the research, 20 results were collected. All soil data are listed in Table 2 according to the year. The safe level of Pb in the soil is 85 ppm, according to WHO. Results were varied in the range of 1.55 to 567.00 ppm, whereas 55% of the samples were within the safe limit. The highest results were obtained in 2010 in Ankara, Turkey, while the lowest was in 2006 in Edirne, Turkey.

Comparison of Pb values in parsley

In Table 3, Pb accumulation in parsley from various locations are listed according to year. Four values were found. The values varied in the range of 0.95 to 585 ppm. Fifty percent of these results are under the safe limit. After 2007, the values are within safe limits even though the results are from metropolises. The highest accumulation, where Pb accumulation was higher than the lethal dose, was seen in 2002 in Elazığ, Turkey.

Comparison of Pb accumulation in R. officinalis

In Table 4, Pb accumulation in *R. officinalis* leaves from different areas are listed according to year. Four values were found, and two of them were from the same study where they investigated differences in Pb accumulation according to place (slope or refuge). Values vary from 1.19 to 10.01 ppm, in which 25% of the collected data were within the safe limit. Additionally, none of the reported values were above lethal dose. The highest value was seen in 2014 in Hatay, Turkey, in slope.

DISCUSSION

Heavy metal accumulation is one of the primary health concerns worldwide, affecting millions of people and ecosystems. Pb is a naturally occurring heavy metal that may accumulate through waste products and exhaust gases in the soils plants.

Initially, articles on heavy metal accumulation in plants and soil were searched. Then, the search was limited to the Pb accumulation of roadside plants and soil. After finding the Pb levels in plants and soil from diverse articles, the safe limit values of Turkish and International authorities were examined. The Pb levels were evaluated base on the WHO data. More data were obtained from plants, thus, making separate tables for

Table 3. Lead level and its safe limit in parsley samples of different places in Turkey

Year	Pb level (ppm)	Pb level in portion (100 g)	Safe limit	Proportion of safe limit	Location	Reference
2002	585	58.5	2	11.70	Elazığ	Bakirdere and Yaman[14]
2006	9.9	0.99	2	4.95	Kayseri	Demirezen and Aksoy[17]
2007	0.95	0.095	2	0.475	İstanbul	Osma et al.[18]
2012	1.14	0.114	2	0.57	İzmir	Colak Esetlili et al.[23]

Pb: Lead

Table 4. Lead level and its safe limit in *Rosmarinus officinalis* samples of various places in Turkey

Year	Pb level (ppm)	Pb level in portion (100 g)	Safe limit	Proportion of safe limit	Location	Reference
2007	6.9	0.690	2	3.45	Mersin	Koc and Sari[19]
2012	1.19	0.119	2	0.595	İzmir	Colak Esetlili et al.[23]
2014	9.70	0.97	2	4.85	Hatay-refugee	Bozdogan et al.[25]
2014	10.01	1.001	2	5.005	Hatay-slope	Bozdogan et al.[25]

Pb: Lead

Table 5. Exposure limits of lead according to different national and international authorities

Exposure limits of lead (ppm)					
OSHA PEL	NIOSH REL	WHO		Ministery of Family, Labour and Social Services	ECHA
		Soil	Plant		
0.0005[a]	0.0005[b]	85[c]	2[d]	0.00015[e]	0.00003[f]

[a]Permisible exposure limit of lead according to OSHA, [b]Recommended exposure limit of lead according to, NIOSH, [c]Safety limit of lead for soil according to WHO, [d]Safety limit of lead for plants according to WHO, [e]Occupational exposure limit of lead according to the Ministry of Family, Labour and Social Services of Turkey, [f]Occupational exposure limit of lead according to ECHA. OSHA: Occupational Safety and Health Administration, NIOSH: National Institute for Occupational Safety and Health, WHO: World Health Organization, ECHA: European Chemicals Agency

a more accurate comparison regarding their bioaccumulation factors.

In Table 1, accumulated Pb values (ppm) for several plant samples from different locations are listed throughout the years with their safe limits and percentages.

All the Pb values from the studies before 2003 exceed the safe limits. This findings gave rise to the thought that this is probably resulted from the low sensitivity of the analytical methods used back then due to the lack of the quality parameters of measurements. Analytical methods used for determining the heavy metal content in the plants were not precise enough to give a correct measurement, which led to inaccurate results.

On the other hand, banning the use of Pb in gasoline in 2004 positively decreased the accumulation rates. The Pb content in the plants generally diminished. This change may have resulted from a more proper and accurate analytical system and the ban of Pb in gasoline. However, the reported values were still high in metropolises and industrial cities.

By examining studies conducted from various cities with different economic backgrounds and means of livings, it can be concluded that, in the industrially-developed cities, Pb levels exceed the safe limits because of exhaust gases, heavy industry factories, waste products, and heavy traffic.

In addition, the differences in plants' bioaccumulation factors affect the results, such as different accumulation rates of perennial and annual plants.

In Table 2, the Pb contents in soil samples from the different regions in Turkey are listed by the year. Once again, the Pb content determined from the studies of earlier years is high, probably also because of the inaccuracy in the analytical methods and measurement systems. Furthermore, most industrialized cities had exceeded the safe limits.

According to a study conducted in 2010, Pb accumulation in the highway soil is higher in Ankara than in Bursa, the central soil's Pb content is more elevated in Bursa than in Ankara.[30] This contrast could be due to the heavier traffic on the highways of Ankara and intense industrial activity in Bursa. As a capital city, Ankara is the center of several routes, and Pb can be quickly accumulated in the plants and soils near the highway. In contrast, Bursa is known for its heavy industrial activity, especially the machinery industry. This industrialization is in the city center, which may release high exhaust gases containing Pb from the factories and cause accumulation in the central soil.

For Istanbul, Pb contents were measured in 2008 and 2016, and a significant decrease was found when comparing the results. Although the population has risen from 2008 to 2016 in İstanbul, which directly affect the traffic's heaviness, the Pb content in the soil reduced from 191 ppm to 27.4-51.55 ppm. This change probably is due to the banning of Pb in gasoline in 2004. Even after the ban, Pb levels in the given data did not decrease immediately but took some time, as shown in the results. The results indicated that it requires time to reduce the accumulation of Pb in the soil.

In Table 3, Pb levels in parsley samples determined from the different regions in Turkey are listed. The earlier years results seem to be much higher; this can be caused by improved measurement technologies and increased environmental awareness in the later years. For instance, the value measured in Elazığ in 2002 is within the lethal range. The cause of this high level may be explained by the technical problem, or low sensitivity of methods or a high metal level.

According to data from 2006 and 2007, although samples were collected within almost the same year in Kayseri and İstanbul, Pb accumulation in Istanbul is nearly one-tenth of Kayseri. Probably resulted from different industrial activities in those cities where Kayseri has many heavy metal industrial applications releasing a high amount of solid waste to the environment.

In Table 4, Hatay has the highest values, although it is long after the ban of Pb in gasoline. Air pollution can be the reason for this high amount. Besides, the slope had a higher accumulation than the refuge in Hatay. Mersin and Hatay are close cities geographically, and the accumulation rate decreased from 2007 to 2014, which may be the result of unleaded gasoline use since 2004.

CONCLUSION

In conclusion, Pb accumulation is a global concern, including in Turkey. Although the soil and plants' Pb contents generally decrease with time, the environmental and health risks are still present. The banning of gasoline is one of the primary causes of reduced concentrations.

The studies conducted by far provide us an insight into the contamination status of Pb in Turkey. The methods used for analyses can be more problematic in the earlier years due to the lack of quality parameters of measurements in published studies; however, more accurate and precise results are given in recent studies. For a better analysis, further studies must be done. The concentration levels of Pb should be followed more closely for different purposes, and research can be widen for different areas.

Conflict of interest: No conflict of interest was declared by the authors. The authors are solely responsible for the content and writing of this paper.

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