THE RELATION OF GEOGENIC AND ANTROPHOGENIC FACTORS WITH BLOOD AND HAIR LEAD AND ARSENIC LEVELS IN WOMEN LIVING IN ÇAN AND BAYRAMİÇ DISTRICTS OF ÇANAKKALE PROVINCE

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ABSTRACT

Objective: *Mining areas and associated industrial activities carry considerable risks for human health due to multi-pathway exposure of heavy metals such as arsenic and lead. The objective of this study was to compare arsenic and lead levels in human blood and hair samples in an industrial mining area in northwestern Turkey with that of a non-exposed group demonstrating similar sociocultural characteristics.*

Material and Method: *The population of the study consisted of 674 nonsmoker women over the age of 40 who were selected on a random basis from mine region and control area. Venous blood samples were taken and analyzed for blood lead and arsenic levels in all participants. Hair samples were later collected from 108 women with high levels in blood samples.*

Results: *The results showed that the highest prevalence of occurrences was found in district centers whereas relatively lower values were observed in the villages. Hair arsenic and lead levels were comparably higher in the industrialized area (Çan Region) where low-quality coal combustion used in power generation and residential heating were dominant.*

Conclusion: *Although high correlations were not found, blood and hair arsenic and lead levels in individuals living in industrial and agricultural areas were found to be high at levels influencing the human health. On the other hand, these results should be further supported and verified with advanced and long duration monitoring activities.*

Keywords: *Arsenic, lead, medical geology, human health, anthropogenic factors.* **Nobel Med 2019; 15(2): 25-34**

ÇANAKKALE İLİ ÇAN VE BAYRAMİÇ İLÇELERİNDE YAŞAYAN KADINLARDA KAN VE SAÇ KURŞUN VE ARSENİK DÜZEYLERİNİN JEOLOJİK VE ANTROPOJENİK FAKTÖRLERLE İLİŞKİSİ

ÖZET

Amaç: Maden bölgeleri ve bununla ilişkili endüstriyel alanlar arsenik ve kurşun gibi ağır metallerin çok yönlü maruziyetleri nedeniyle insan sağlığı için önemli riskleri barındırırlar. Bu araştırmanın amacı, Türkiye'nin kuzeybatısında bulunan endüstriyel maden alanında insanların kan ve saçlarındaki arsenik ve kurşun seviyelerinin benzer özelliklerdeki fakat maruziyetin olmadığı bir bölgedeki grup ile karşılaştırmaktır.

Materyal ve Metot: Araştırma popülasyonunu maden ve kontrol bölgesinden rastgele seçilen ve sigara içmeyen 40 yaş üstü 674 kadın oluşturmuştur. Tüm katılımcılardan venöz kan örnekleri alınarak kandaki kurşun ve arsenik düzeyleri analiz edilmiştir. Daha sonra aynı grup içinde kan örnekleri yüksek seviyelerde olan 108 kadından saç örnekleri alınmıştır.

Bulgular: Elde edilen sonuçlara göre en yüksek maruziyet ilçe merkezlerinde gözlenirken en düşük değerler köylerde tespit edilmiştir. Saç arsenik ve kurşun seviyeleri düşük kaliteli linyit kömürlerinin elektrik üretimi ve kentsel ısınma amaçlı yakıldığı endüstriyel alanda (Çan Bölgesi) göreceli olarak daha yüksek bulunmuştur.

Sonuç: Yüksek korelasyon değerleri elde edilmemiş olsa da, gerek endüstriyel alanda gerekse tarımsal üretimin yoğun olduğu kontrol bölgesinde kan ve saçtaki arsenik ve kurşun seviyelerinin insan sağlığını etkileyebilecek seviyelerde bulunduğu gözlenmiştir. Buna karşın elde edilen sonuçların daha ileri ve uzun süreli izleme çalışmaları ile desteklenmesi gerekmektedir.

Anahtar kelimeler: Arsenik, kurşun, tıbbi jeoloji, insan sağlığı, antropojenic faktörler. **Nobel Med 2019; 15(2): 25-34**

INTRODUCTION

Heavy metal pollution originating from mine extraction and associated industrial activities is the source for a number of important public health problems, particularly in developing countries. The quality of water, air and soil environment is negatively influenced by such actions, which eventually impact the well-being of the entire ecosystem including humans and animals.[1,2] Numerous research has revealed the presence of elevated levels of heavy metals in the surrounding areas of mine sites that can lead to high carcinogenic and non-carcinogenic risks for human-beings.[3-8] Furthermore, it is generally accepted that heavy metal pollution is covert, persistent and irreversible.[9]

In general, most heavy metals and trace elements are known to create serious health effects.[10] Among these, arsenic and lead are known carcinogens and are among the etiological factors for many diseases.[11-19] These toxic heavy metals come from different sources such as mining activities and agricultural production. The concentration of an element in geologic materials such as coal is commonly used as a gauge of the material's potential environmental and human health impacts. For potentially toxic elements such as arsenic and lead, it may seem logical that the higher their concentration, the greater the harmful environmental and human health impacts.[20] Apart from mining facilities, most agricultural production depends on the use of chemicals to sustain high crop incomes. The use of these chemicals in modern farming practices is viewed as an integral part of the success of the agricultural industry. However, most of the pesticides applied to agricultural lands may affect non-target organisms and contaminate soil and water resources.[21] The use of arsenic- and lead-contaminated water for drinking, food preparation and irrigation of edible crops pose significant threats to public health. In particular, long-term exposure to arsenic and lead through drinking water and food can cause cancers of skin, lung, stomach, liver etc. They are also associated with other health problems including but not limited to developmental defects, cardiovascular diseases, neurotoxicity and diabetes.[15, 22-29]

The Çan District of Çanakkale Province is located in northwestern Turkey on the Ida Mountain range. Widespread and intense zones of alteration and coal deposits are present in the Çan volcanic of Biga Peninsula, northwestern Turkey. Significant mining activities exist in the area that creates water and air quality problems as discussed by Baba and Gunduz[30] and Baba *et al.*[31] Consequently, human health complications are detected in the local population living in this area that necessitated a screening level study. Based on this motive, this study is aimed to compare the levels of arsenic and lead in blood and hair samples of randomly selected individuals living in two distinct regions where mining and associated industrial activities are dominant in one particular area (Çan region), creating numerous possible exposure pathways for arsenic and lead, whereas the other region (Bayramiç region) was selected as a area without any major anthropogenic activity except agriculture.

MATERIAL AND METHOD

Study Area

The study area is located about 60 km southeast of Çanakkale Province center and is situated within the district boundaries of Çan and Bayramiç on Biga Peninsula, northwestern Turkey (Figure 1). The study area encloses the mystic Ida Mountain, one of the most important natural parks in Turkey. Yet, it also contains a range of mining activities for the extraction of coal, gold and industrial minerals. The region has an approximate economical coal reserve over 100 million tons.[32] The coals of the area are typically considered to be low-quality lignites with an approximate composition of 6% (3-8 %) sulfur, 23% (14.7- 28.4 %) humidity and 24% (3.5-29.8 %) ash.[30] These coals contain elevated levels of arsenic that reach to levels as high as 932.9 ppm according to Baba *et al.*[33] and 117.5 ppm according to Gürdal.[34] Furthermore, arsenic levels in the fly ash of a coal fired power plant in the area had an average value of 3035.9 ppm Baba *et al.*[33] Similarly, average lead levels were 11.5 ppm and 245.9 ppm in coal and fly ash.[33] The distribution of coal containing Çan formation around Çan district center. Çan coals are primarily used for domestic heating in Çan district center and its vicinity as well as for power generation the 320 MW Çan Thermal Power Plant. Both the power plant and its stack areas of coal and fly ash emit noxious gases, toxic trace elements and some radioactive particles.

Type of Study

This study is a cross-sectional epidemiologic research for determining arsenic and lead levels in blood and hair samples of inhabitants living in Çan and Bayramiç regions, which are considered to be a mining and industrial area and an agricultural area, respectively.

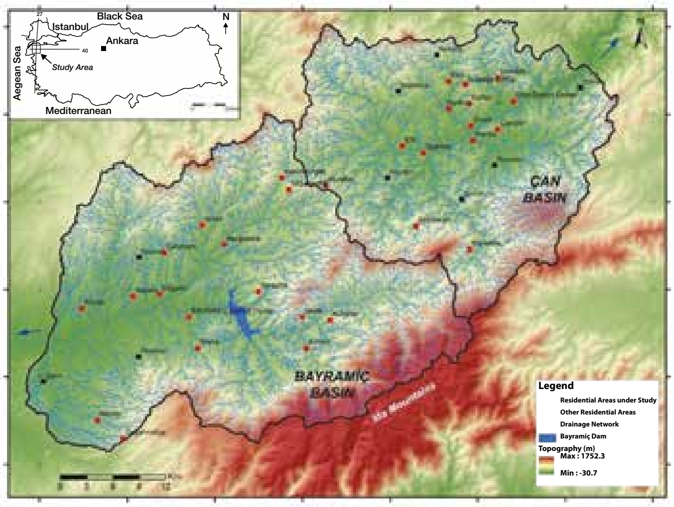

Figure 1. Location map of study area

Population, Sample Size and Field Surveys

This study is focused on rural and urban areas of Çan and Bayramiç districts. The total populations of Çan and Bayramiç during fieldwork were 52929 and 32314, respectively. A total of 674 women living in the districts centers and villages of Çan and Bayramiç districts were selected to participate in this research. The names of the streets in villages and in district centers were obtained from local administrators and participants were selected on a random basis to reach a total of 25% ratio. Human blood and hair samples were then collected from the selected women starting with Çan district center. The number of participants to be sampled from each street was determined by dividing the total number of participants to the total number of streets in that particular district. These number were found to be 7 women per street in Çan district center and 4 women per street in Bayramiç district center.

The study was formulated such that all houses in a selected street were visited and women living in these dwellings, who are (i) above the age of 40, (ii) have never smoked before or quitted smoking 5 years ago, (iii) have not consumed sea food within the last three days, (iv) reside in the area for the last 10 years and (v) don't work in an industrial workplace, were selected for interviews. In each street, one in every four houses were sampled and if more than one candidate was suitable for sampling in a house, the decision was made on a random basis (i.e., coin toss). If the selected individual from a house did not want to participate in the study, someone from the next house was sampled. When the desired total number of samples was reached in a street, the field teams proceeded to the next street in the neighborhood. Once an individual was selected, a face to face interview was conducted and samples of blood and hair were collected.

Since the project area is mostly rural, reliable health information was missing and, face-to-face questionnaires were conducted for determining socio-demographical variables, health status, disease history and causes of all previous cases of death within the past five years. Directed questions were also used to reveal the history of smoking, exposure to second-hand smoke, use of alcohol and primary sources of drinking water for possible correlation with health status and death causes.

In order to prevent the possibility of the false declaration with regards to smoking in individuals who donated blood samples, cotinine levels were also measured in the collected blood samples to determine any potential influence from the environmental smoke. Since the cotinine levels of all individuals were found to be low, none of the individuals were excluded from the study. Furthermore, individuals were also asked whether she was exposed to environmental smoke to verify the blood cotinine results.

In addition to blood samples, hair samples were also collected from individuals to determine the level of chronic exposure to arsenic and lead. A total of six villages were sub-sampled for hair in each region. Hair samples were collected from all individuals who gave blood samples. In all villages except Söğütalan and Doğancı, hair samples were collected randomly. In these two villages, however, hair samples were collected from all blood sample donors.

Laboratory Analysis

Six hundred seventy-five blood samples were collected according to the international standards by using Vacutainer Systems® tubes. The tubes used in this study were EDTA-preserved blood sampling tubes that were under vacuum and had single-use sterile needles. The sample volume was 4.5 mL. They were placed in isothermal boxes (4°C) and transferred to the laboratories for chemical analysis. Full blood count was conducted in the blood sample within 12 h after sampling. Collected samples were mixed with proteinase enzyme and centrifuged for 30 min. Centrifuged samples were then mixed with sample triton-x to increase surface tension and were later taken into analysis. For lead analysis, 2.5 mL of stock solution (Merck standart asidic solution) was added to the collected blood samples and mixed thoroughly. The samples were centrifuged for 20 min at 3000 rpm and were later taken into analysis. The total arsenic and lead levels in samples were then determined by atomic absorption spectrometer (SHIMADZU AA-6300 GFA - EX7I) in a SİSTEM TIP accredited biochemistry laboratory.

A total of 108 hair samples were collected from the suboccipital region with a total length of 3-5 cm and about 3 g by cutting at a distance of 1 cm from the scalp. The samples were obtained by using stainless steel scissors and placed them in metal-free plastic containers. Hair samples were stored in polyethylene bags and transported to the laboratory. Hair samples were washed with distilled water to remove contamination prior to analysis. The samples were then dried in an electric oven and then subjected to a microwave-assisted closed wet digestion (by using approximately 1 g sample and 2000 mL supra-pure HNO_3). Calibration curves were obtained using standard solutions subjected to the same digestion procedure. The total arsenic and lead concentrations were then determined by atomic absorption spectrometer (SHIMADZU AA-6300 GFA - EX7I) in a SİSTEM TIP accredited biochemistry laboratory.

Data Analysis

The data obtained from the field and laboratory studies were statistically assessed by the SPSS v11.0 program. In this analysis, continuous variables were presented as average ± standard deviation when the associated distribution was normal and was presented as median and quantiles when the associated distribution was not normal. Regional differences were analyzed by Man Whitney U, Kruskall Wallis ANOVA methods or by their parametric counterparts such as independent samples t-test or ANOVA test. Correlation analyses were conducted by Spearman's Rank method.

The ethical approval for this study was issued by the Research Ethical Committee of Marmara University with the document dated 28/03/2008 and numbered B.30.2.MAR.0.01.02/AEK/151.

RESULTS

The demographic characteristics of individuals participating the study are given in Table 1. The average age of participants was calculated as 59.8±10.3 (min-max: 40-88). The average age in Çan region (58.6±9.9) was found to be lower than the average age in Bayramiç region (60.9±10.6) (p=0.03). The participants living in Bayramiç region was found to be a member of the lower socioeconomic level when compared to the participants living in Çan region. In addition, Bayramiç was also found to have a disadvantage with regards to the education level of participants and their spouses. These differences between the two groups were found to be statistically significant (p<0.05).

Face-to-face interviews were conducted with 238 individuals in Çan center and 184 blood samples (77%) were collected. The remaining 54 individuals refused to participate in the study. In addition, 12 villages of Çan Region were also included in the study and interviews were conducted with 157 individuals. A total of 150 blood samples (96%) were obtained from these individuals and 7 people refused to give blood samples. The distribution of villages where blood and hair sampling was conducted are shown in Figure 1.

Also, 132 individuals were interviewed in Bayramiç center where 121 blood samples (92%) were collected. The remaining 11 individuals refused to participate in the study. In addition, 16 villages of Bayramiç Region were also included in the study and interviews were conducted with 226 individuals. A total of 219 blood samples (97%) were obtained from these individuals and 7 people refused to give blood samples. No statistically significant differences (p>0.05) were observed between the two groups with regards to age, profession, marital status, the school graduated, spouse's school graduated, social security type, the source of drinking water supply and presence of diseases.

Female non-smokers were particularly important for the study as their blood biochemical parameters are not influenced by the chemicals exposed to cigarette smoking. Blood cotinine levels were measured to detect participants exposure extends to tobacco smoke. Levels representing acute exposure were not observed in the study area. Statistically significant differences between Çan region with intense mining activities and in the Bayramiç region without mining activities were not detected (p>0.05). Nevertheless, when the same relation was investigated with regards to settlement areas, cotinine levels in Çan villages were found to be significantly higher than their corresponding levels in Çan district center (p=0.0003), Bayramiç district center (p=0.003) and Bayramiç villages (p<0.001).

Table 1. Distribution of demographical characteristics of individuals participating the study

	Total	Çan Region Center		Çan Villages		Bayramiç Region Center		Bayramiç Villages		
	n	n	%	n	%	n	%	n	%	p
Age										
40-49	130	45	24.5	29	19.3	20	16.5	36	16.4	<0.01
50-59	219	76	41.3	39	26.0	43	35.5	61	27.9	
60-69	190	45	24.5	48	32.0	35	28.9	62	28.3	
70-79	107	14	7.6	29	19.3	15	12.4	49	22.4	
80 and above	28	4	2.2	5	3.3	8	6.6	11	5.0	
Profession										
Housewife	355	153	83.2	53	35.3	68	56.2	81	37.0	<0.01
Unpaid family worker	247	2	1.1	76	50.7	33	27.3	136	62.1	
On salary	72	29	15.8	21	14.0	20	16.5	2	0.9	
Marital Status										
Married	513	150	81.5	110	73.3	87	71.9	166	75.8	0.18
Separated	161	34	18.5	40	26.7	34	28.1	53	24.2	
School Graduated										
None	170	28	15.2	33	22.0	33	27.3	76	34.7	<0.01
Primary school and higher	504	156	84.8	117	78.0	88	72.7	143	67.3	
Spouse's School Graduated										
None	80	20	10.9	15	10.0	12	9.9	33	15.1	0.11
Primary school	383	103	56.0	92	61.3	60	49.6	128	58.4	
Secondary school and higher	211	61	33.2	43	28.7	49	40.5	58	26.5	
Home Ownership										
Home owner	625	167	90.8	147	98.0	97	80.2	214	97.7	<0.01
Rental without payment	29	17	9.2	3	2.0	24	19.8	5	2.3	
Social Security Institution										
Pension Fund	48	15	8.2	4	2.7	18	14.9	11	5.0	<0.01
SSK	377	152	82.6	100	66.7	63	52.1	62	28.3	
Bağ-Kur	170	13	7.1	27	18.0	29	24.0	101	46.1	
Other	79	4	2.2	19	12.7	11	9.1	45	20.5	
Socieconomic Status										
Low	476	83	45.1	112	74.7	84	69.4	197	90.0	<0.01
Middle Low	168	81	44.0	36	24.8	29	24.0	22	10.0	
Upper Middle	30	20	10.9	2	1.3	8	6.6	-		
Total	674	184	27.4	150	22.2	121	17.9	219	32.4	

***p*:** Chi-Square test

The statistical summary of blood arsenic levels of participants is given in Table 2. Accordingly, the median blood arsenic level in Çan district center

Table 2. Statistical summary of arsenic and lead levels in blood samples

		n	Median	1-3 quartiles	Min	Max
Blood arsenic level (mg/dL)	Çan district center	183	9.9	6.3-14.0	183	183
	Çan villages	149	13.5	9.0-20.4	149	149
	Bayramiç district center	116	14.2	10.3-18.7	116	116
	Bayramiç villages	218	15.8	12.0-21.0	218	218
	Kruskal Wallis p= 0.0001					
Blood lead levels (µg/dL)	Çan district center	185	3.4	1.6-9.0	185	185
	Çan villages	149	1.1	0.6-2.2	149	149
	Bayramiç district center	115	1.0	0.5-2.1	115	115
	Bayramiç villages	218	1.9	1.2-2.7	218	218
	Kruskal Wallis p<0,001					

Table 3. Statistical summary of arsenic and lead levels in hair samples

		n	Median	1-3 quartiles	Min	Max
Hair arsenic level (µg/gr)	Çan district center	14	0.27	0.16-0.56	0.1	0.9
	Çan villages	35	0.46	0.17-0.84	0.1	1.9
	Bayramiç district center	12	0.15	0.14-0.21	0.1	0.5
	Bayramiç villages	47	0.17	0.13-0.21	0.1	0.4
	Kruskal Wallis p=0.0004					
Hair lead levels (µg/gr)	Çan district center	14	4.0	3.1-17.1	1.9	97.0
	Çan villages	35	4.8	3.4-19.6	1.2	72.0
	Bayramiç district center	12	2.5	1.9-4.0	0.8	6.0
	Bayramiç villages	47	1.9	1.9-3.2	1.2	9.2
	Kruskal Wallis p<0,001					

and Çan villages were found to be 9.9 mg/dL and 13.5 mg/dL, respectively. In Bayramiç district and Bayramiç villages, on the other hand, the median values were found to be 14.2 mg/dL and 15.8 mg/dL, respectively. There were statistically significant differences between the two regions (p<0.001) and

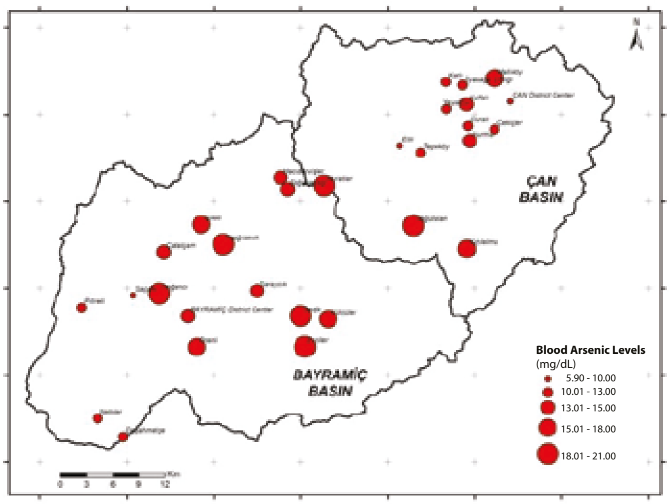

Figure 2. Spatial distribution of blood arsenic levels

the blood arsenic levels were significantly higher in Bayramiç region, which was mainly an agricultural production area where pesticide application was significant. The spatial distributions of blood arsenic levels are presented in Figure 2.

The statistical summary of hair arsenic levels is given in Table 3. The median hair arsenic levels in Çan district and Çan villages were found to be 0.27 and 0.46 µg/g hair with the first and third quartiles being 0.16-0.56 and 0.17-0.84 µg/g hair, respectively. On the other hand, median arsenic levels in Bayramiç district and Bayramiç villages were found to be 0.15 µg/g and 0.17 µg/g hairs with the first and third quartiles being 0.14-0.21 µg/g and 0.13-0.21 µg/g hair, respectively. The spatial distributions of hair arsenic levels are presented in Figure 3.

The statistical summary of blood lead levels is given in Table 2. The median blood lead level in Çan district and Çan villages were found to be 3.4 µg/dL and 1.1 µg/dL, respectively. In Bayramiç district and Bayramiç villages, on the other hand, the median value was found to be 1.0 µg/dL and 1.9 µg/dL, respectively. There were statistically significant differences between the two regions (p<0.001) and the blood lead levels were significantly higher in Çan region. Highest blood lead levels were found in Çan region center (3.4 µg/dL), which was followed by Bayramiç villages (1.9 µg/dL). The difference was statistically significant (p<0.001). The spatial distributions of blood lead levels are presented in Figure 4.

The statistical summary of hair lead levels is given in Table 3. The differences between residential areas were found to be statistically significant. The median lead levels in Çan district and Çan village was found to be 4.0 µg/g and 4.8 µg/g hair with the first and third quartiles being 3.1-17.1 µg/g hair and 3.4-19.6 µg/g hair, respectively. On the other hand, median lead levels in Bayramiç district and Bayramiç villages were found to be 2.5 µg/g and 1.9 µg/g hair, respectively. The differences between these two regions were statistically significant (p=0.0005). The highest hair lead level was found in Çan villages (4.8 µg/g) and in Çan region center (4.0 µg/g). Bayramiç region center had a relatively lower value (2.5 µg/g). The difference was statistically significant (p<0.001). The spatial distributions of hair lead levels are presented in Figure 5.

DISCUSSION

The results showed that the highest prevalence of occurrences was found in district centers whereas relatively lower values were observed in the villages. Hair arsenic and lead levels were comparably higher in the industrialized area (Çan Region) where low-quality coal combustion used in power generation and residential heating were dominant (As median level Çan district:0.27, Çan villages:0.46, Bayramiç district:0.15, Bayramiç villages:0.17, *p*:0.0004; Pb median level Çan district:4.0, Çan villages:4.8, Bayramiç district:2.5, Bayramiç villages:1.9, *p*<0.001). On the other hand, blood arsenic and lead levels were higher in the Bayramiç Region where agricultural activities with significant pesticide and fertilizer consumption were extensive (As median level Çan district:9.9, Çan villages:13.5, Bayramiç district:14.2, Bayramiç villages:15.8, *p*:0.0001; Pb median level Çan district:3.4, Çan villages:1.1, Bayramiç district:1.0, Bayramiç villages:1.9, *p*<0.001).

Arsenic and lead are toxic elements that lead to chronic and acute health problems. Agriculture, industrial production, mining activities and energy production can result in human exposure to arsenic and lead. In particular, arsenic is a chemical agent that can enter the human body through numerous pathways and can create several systemic diseases. It can trigger chronic diseases due to widespread and inconvenient pesticide use in agricultural fields. Based on data obtained from International Labor Organization (ILO), respiratory system cancers were observed in increased numbers in workers who work in the production of lead arsenate and calcium arsenate containing insecticides, in grape farmers who spray insecticides that contain inorganic lead and arsenic compounds and in smelter workers who were exposed to arsenic and its several inorganic compounds.[35,36] Arsenic levels in humans are typically determined by urine tests. However, this test only gives information on imminent exposure and is deemed to be unsuccessful in indicating past and long termed exposure. Other methods such as toe nail, hair, and blood sampling can also be used in determining the level of arsenic exposure.[37] Lead follows a similar mechanism in causing acute toxicity in humans. It is typically deposited in humans living in mining areas and industrial zones. Chronic lead exposure is mostly traced by assessing the blood lead levels.[35] Therefore, the display of lead and arsenic exposure in people living in agricultural and industrial areas is an important indicator of the health problems that may arise due to these factors.

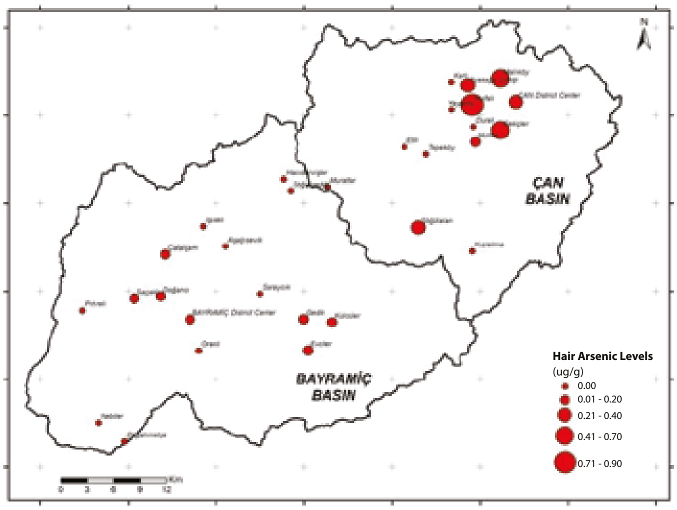

Figure 3. Spatial distribution of hair arsenic levels

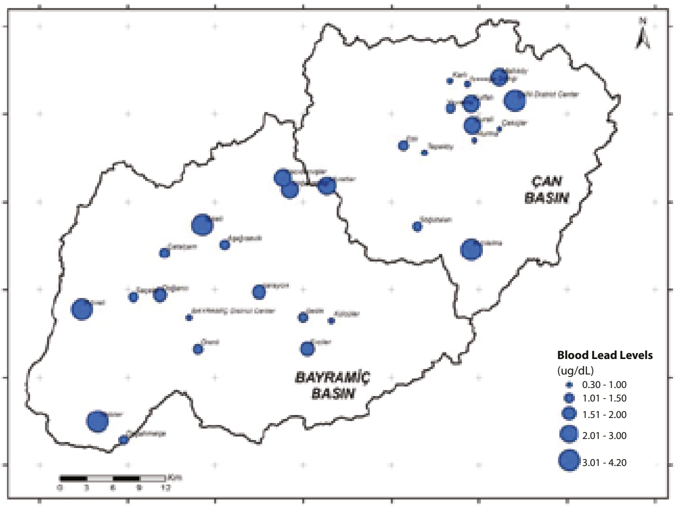

Figure 4. Spatial distribution of blood lead levels

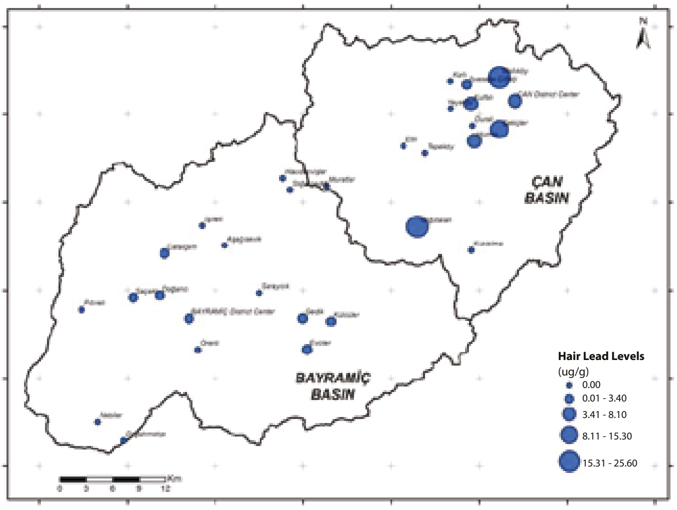

Figure 5. Spatial distribution of hair lead levels

When the blood arsenic levels of the participants were compared with regards to urban and rural residential areas, it was observed that individuals living in Bayramiç villages with dense agriculture activity, had the highest blood arsenic levels. These were followed by individuals living in Bayramiç district center and individuals living in Çan villages. These differences with regards to residential areas were statistically significant (p=0.0001).

The hair arsenic levels that demonstrate chronic exposure to arsenic were found to be higher in Çan which was different from blood arsenic levels that demonstrate acute exposure to arsenic. The differences between these two regions were statistically significant (p=0.002). The higher hair arsenic levels in Çan district center was mostly associated with the high arsenic content of the coals extracted from the nearby Çan Lignite deposit area. The extracted coals from the region are used for power production in the 320 MW Çan Thermal Power Plant. The coal and fly ash storage areas are at the boundary of the residential area and emissions from these open stack storage areas directly influence the district center. In addition, the air pollution associated with residential heating via regional coals are also believed to be responsible for the elevated hair arsenic levels.

The differences between residential areas were found to be statistically significant. The highest hair arsenic levels were detected in Çan villages (particularly near the coal mine and power plant), which were followed by Çan region center, Bayramiç villages and Bayramiç region center. The results showed that hair arsenic level in Çan Region was higher than Bayramiç Region, on the other hand, median blood arsenic levels in Bayramiç Region was higher than Çan Region. The spatial distributions of blood and hair arsenic levels are presented in Figure 2 and Figure 3, respectively. Based on these results, it can be concluded that blood arsenic levels were measured to be higher in Bayramiç region where intense agricultural activity was present compared to Çan region. Orchards are widespread in Bayramiç region where various pesticides and artificial fertilizers are heavily used.

Blood lead levels are typically strongly correlated to smoking and to the number of cigarettes smoked.[38] However, since all blood samples were collected from non-smoker females in the study area, the blood lead levels were not influenced from smoking and any possible anomaly in blood lead values was related to factors other than smoking. The relatively low blood cotinine levels were thus not attributed to chronic exposure to tobacco smoke and further supported the statements of participants who mentioned that no one smoked within the household (i.e., smokers in the household smoked outside the house). When compared to their corresponding levels in Bayramiç Region, hair arsenic and lead levels were found to be significantly higher in Çan Region, which was most likely related to mining activities and air pollution in this particular area.

The two regions compared in this study have similar characteristics excluding the mining activities that are dominant in Çan region. Thus, this comparative study was conducted to minimize the influence of other factors and only focused on the influence of mining and mining-related industrial activities. The blood and hair arsenic levels were not found to create a major health concern for the inhabitants of the study area. Nevertheless, there is a considerable heavy metal exposure in the region. Although this exposure did not yet reach the limits that could influence the human health, it is likely that continued exposure and accumulation in the body can create health problems in the future. This exposure is also likely to create more significant health concerns in males with smoking habits. Considering the high levels of blood lead values in the vicinity of residential areas with mining practices, human health risks are deemed to be more significant for the Çan region when compared to Bayramiç region.

Statistically significant differences were observed in hair lead levels between the two regions for ages 50 and above. The hair lead levels in Çan region were found to be significantly higher than the Bayramiç region. This finding demonstrates the necessity for conducting detailed research on the effect of geogenic factors on human activity. In addition, blood arsenic levels were measured to be higher in Bayramiç region where intense agricultural activity was present compared to mining region. Consequently, the evaluation of the data obtained in this study indicates that further monitoring studies should be planned to focus more on the mining and agricultural activities on human health.

The ethical approval for this study was issued by the Research Ethical Committee of Marmara University with the document dated 28/03/2008 and numbered B.30.2.MAR.0.01.02/AEK/151.

*The authors declare that there are no conflicts of interest.

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