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Assessment of the pollution level, microscopic structure, and health risk of heavy metals in surface dusts in a sports field

Bir spor sahasında yüzey tozlarındaki ağır metallerin kirlilik seviyesinin, mikroskobik yapısının ve sağlık riskinin değerlendirilmesi

Kadir ULUTAŞ[1,2*]

[1]Department of Health Management, Faculty of Health Sciences, İstanbul Medeniyet University, Istanbul, Turkey.
kadir.ulutas@medeniyet.edu.tr

[2]Department of Environmental Engineering, Engineering Faculty, Karabuk University, Karabuk, Turkey.
kadirulutas@karabuk.edu.tr

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Abstract

In urban areas, dust accumulated on the surface is one of the most used sampling methods used to evaluate environmental pollution, due to the effectiveness of meteorology and topography in the transport and accumulation of atmospheric pollution. The heavy metal concentration of surface dust collected from stadium seats was examined in this study. 22 different heavy metals namely Si, Fe, Al, Ti, Mn, Zn, Sr, Ba, Cr, Pb, Co, V, Ni, Sn, Sc, Bi, Sb, Ag, As, Mo, Hg and Cd concentrations were determined by ICP-MS and ICP-OES techniques, and SEM image was examined to determine its morphological structure. Heavy metal concentrations, except Zn and Bi, were found to be lower than those found in the earth crust. The shape and size of the particles indicated that the environment could be influenced by the natural soil source and anthropogenic sources. In addition, two separate assessments were conducted in terms of exposure to dust toxicity for normal daily activity and sporting activity coupled with normal daily activity. The results were considered acceptable because the health risk and cancer risk assessments were below the limit values.

Keywords: Dust, Air pollution, Health risk, Sportive activity, Health management.

Öz

Kentsel alanlarda, meteoroloji ve topografyanın atmosferik kirliliğin taşınması ve birikmesindeki etkinliği nedeniyle, yüzeyde biriken tozlar çevre kirliliğini değerlendirmek için en çok kullanılan örnekleme yöntemlerinden biridir. Bu çalışmada, stadyum koltuklarından toplanan yüzey tozları ağır metal içeriği açısından araştırılmıştır. Si, Fe, Al, Ti, Mn, Zn, Sr, Ba, Cr, Pb, Co, V, Ni, Sn, Sc, Bi, Sb, Ag, As, Mo, Hg ve Cd olmak üzere 22 farklı ağır metal konsantrasyonu ICP-MS ve ICP-OES tekniği ile belirlenmiş ve morfolojik yapısını belirlemek için SEM görüntüsü incelenmiştir. Zn and Bi hariç diğer ağır metal konsantrasyonlarının yer kabuğu konsantrasyonlarından düşük olduğu belirlenmiştir. Parçacıkların şekli ve boyutu, ortamın doğal toprak kaynağından ve antropojenik kaynaklardan etkilenebileceğini göstermiştir. Ayrıca normal günlük aktivite ve normal günlük aktivite ile birlikte sportif aktivite için tozdaki toksitiye maruz kalmaları açısından iki farklı değerlenme yapılmıştır. Sonuçlar sağlık riski ve kanser riski değerlendirmeleri sınır değerlerin altında olduğu için kabul edilebilir olarak belirlenmiştir.

Anahtar kelimeler: Toz, Hava kirliliği, Sağlık riski, Sportif aktivite, Sağlık yönetimi.

1 Introduction

Environmental quality and health risk can be assessed using surface dust samples due to its suspension and exposure [1]. The transport and accumulation process of air pollutants such as gases and particles on terrestrial and aquatic surfaces is affected not only by the sources of pollution, but also by the climatic and geographical structure of the region, and the physical and chemical properties of the pollutants in the atmospheric accumulation process [2],[3]. Therefore, identifying the sources and composition of dust particles on surfaces is important to develop appropriate pollution reduction plans [4] for both public health.

Traffic and industrial processes, soil contaminated by accumulation, and the use of fossil fuels are the main sources of pollution [5]. Particles larger than 50 µm in diameter can fall rapidly, while smaller particles can remain suspended for a long time and be transported long distances by wind or diffusion forces [6]. The mineral part (60%) in street dust consists of quartz (40-50%), albite, microcline, chlorite and muscovite clay (the remainder). Organic materials constitute about 2% of the street salt, while the rate of possible toxic pollutants is 30% [4].

Heavy metal pollution in atmosphere, one of the most important environmental pollutions, is basically seen in particulate form. Heavy metals have natural properties of persistence in the environment and non-biodegradable [7],[8]. The first step of atmospheric heavy metal deposition is the transfer of metal particles to another surface by dry, wet, or deposition [9]. Thus, there may be a variety of sources of atmospheric heavy metal deposition depending on the nature of the sampling site and urbanized areas impacted by anthropogenic activities such as industry and traffic.

Trace amount of Al, As, Cr, Ni and Se, which enter the body in various pathways, may play a role in the formation of cancer stem cells depending on genetic and epigenetic changes in different cancers [10]. They can cause serious damage to the main metabolic process of the human body. For example, free radicals, which are formed as a result of redox reactions caused by carcinogenic metal ions Ni and As in the environment in biological systems, are the sources of damage to protein and

*Corresponding author/Yazışılan Yazar

DNA. The accumulation of heavy metals can finally lead to various diseases [11]. Exposure to Pb pollution has effects on the immune system [12]. As a result of Pb toxicity, neurotransmitter levels are affected, and serious health problems can be seen due to organ damage [13]. Comparing Cr(VI) and Cr(III), Cr(VI) is carcinogenic. In addition to all toxic effects, it sometimes causes asthmatic responses when exposed through inhalation. Some genetic changes that are harmful to human health also occur due to exposure to Cr [14].

Sports, especially walking and running, are some of the most important activities for maintaining a healthy life. However, a clean and healthy sports field should be chosen for doing sports. For this purpose, stadiums in cities can be used by the public. It has been reported by the Ministry of Environment and Urbanization that air pollution is the main environmental problem in Karabük because of industrial activities [15]. For these reasons, atmospheric dust deposition was collected from the stadium in Karabük University in this study and heavy metal and its morphological structure were studied. In order to evaluate the effects of heavy metal pollution on health, a health risk assessment was carried out in two different scenarios for an adult who does sports as well as daily activities.

2 Materials and methods

2.1 Study area

The sample site is located in Karabük, in the western part of the Black Sea area, at an altitude of 340 m, at 41° 12′ 18′′ north latitude and 32° 39′ 24′′ east longitude. It is cold and snowy in winter, hot in summer and average precipitation is 780 mm [16]. Topographic structure of Karabük does not allow air pollution to disperse. Since high hills surround Karabük from four directions, it is under the effect of an artificial greenhouse. In addition, turbulences, air -flows and whirlpools occur in the city as high hills cause the wind speed to slow down. As a result, pollutants released into the atmosphere from the industry affect the city; however, they cannot be transported out of the city by air due to topographical factors. It may be possible to see the most air pollution around iron-steel plants. In addition, rolling mills, randomly scattered across the city, and heating fuels can be ordered as sources of air pollution in other regions of the city. Furthermore, since the prevailing wind direction is from south to north, the pollutants emitted from iron-steel plants reach urban areas, and the air pollution in the city is sometimes seen at the highest level [17],[18].

The stadium, where samples were collected, is located 2.5 km southwest of the largest industrial plant, 1 km northwest of other rolling mills of various sizes, 2 km west and 1.5 km north of residential areas. The east and south sides of the stadium are hilly and green areas, and it is also surrounded by a highway that runs from southwest to northeast (Figure 1).

2.2 Sampling strategy and sample preparation

Surface dust samples were collected from plastic seats in the stadium in June 2020. Dust deposits, from a total of 250 seats in each direction of the stadium were collected to prepare a composite sample. A total about 0.30 kg dust sample was taken by gently sweeping with plastic dustpans and brushes and transferred to the laboratory in a polyethylene bag. The sample was passed through a stainless steel 100-mesh laboratory test sieve and then dried overnight at 105 °C before extraction.

2.3 Analytical procedures

After being dried, 0.25 g of sample was weighed and poured into the Teflon tubes of the device for digestion. The digestion procedure was performed by mixing of perchloric acid, hydrogen peroxide, nitric acid, and hydrofluoric acid (1:2:4:2) in 1200 W microwave oven (Milestones Microwave Digestion) for sample. After digestion at 200°C for 20 minutes, a sample was taken from the system, cooled, and 50 ml of solution was obtained by adding ultrapure water. Thus, the sample became ready for analysis in digested solution form. Inductively coupled plasma mass spectrometry (ICP-MS) was used to assess the concentration of Cr, Pb, Co, V, Ni, Sn, Sc, Bi, Sb, Ag, As, Mo, Hg and Cd, while Inductively Coupled Plasma - Optical Emission Spectroscopy (ICP-OES) was used to determine the concentrations of Si, Fe, Al, Ti, Mn, Zn, Sr and Ba elements. In this method, validation was performed using serial dilution of the multi-element standard stock solution. The recovery values of metals were found a range of 95% and 110%. Further details of the analytical procedure were described in the previous study [3].

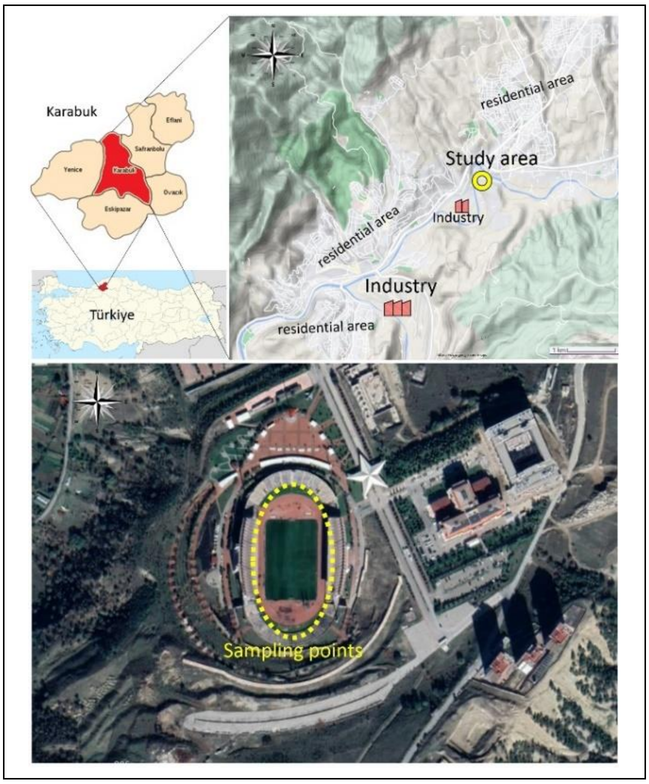

Figure 1. Study area.

2.4 Microscopic structure of surface dust by SEM

A focused beam of high-energy electrons was used to image a high-resolution surface in the scanning electron microscope (SEM) [19]. The morphological structure of the sample was analyzed by SEM (JEOL JSM 6510) as it could characterize the texture properties of the particles and enable the identification of dust sources. This process was carried out at Bingöl University Central Laboratory Application and Research Center.

2.5 Health risk assessment method

The health risks assessment of exposure to metals in dust deposition were carried out using the method developed by the

US Environmental Protection Agency [20] to predict potential carcinogenic and non-carcinogenic adverse health effects now or in the future. Humans are exposed to dust by direct ingestion, inhalation, and skin contact. Equation 1-3 are used to calculate daily intake by inhalation (D_{inh}), ingestion (D_{ing}) and dermal (D_{der}) pathways. Equation 4-6 are used to estimate the non-carcinogenic risks (hazard index (HI) and hazard quotient (HQ)) and potential carcinogenic risk(CR) [21].

$$D_{ing} = C \text{ x } (ingR \text{ x } EF \text{ x } ED) \ / \ (BW \text{ x } AT) \text{ x } 10^{-6} \quad (1)$$

$$D_{inh} = C \text{ x } (inhR \text{ x } EF \text{ x } ED) \ / \ (PEF \text{ x } BW \text{ x } AT) \quad (2)$$

$$D_{der} = C \text{ x } (SL \text{ x } SA \text{ x } ABS \text{ x } EF \text{ x } ED) \ / \ (BW \text{ x } AT) \text{ x } 10^{-6} \quad (3)$$

$$HQ = D \ / \ RfD \quad (4)$$

$$HI = \sum HQ_{ing,inh,der} \quad (5)$$

$$CR = D \ x \ SF \quad (6)$$

For carcinogenic metals, daily intake is multiplied by cancer slope factor (SF) (kg-day/ mg) to calculate (CR) while for non-carcinogenic metals, daily intake is divided by reference dose (RfD) (mg/kg/day) to calculate hazard quotient (HQ). HI is determined by the sum of the calculated HQ values for all exposure pathways [21]. When HI is greater than 1, it exhibits that there may be a possible non-carcinogenic effect, while it is less than 1, it exhibits that there may not be a risk. If the CR value is in the range of 1.0E-6 to 1.0E-4, the estimated cancer risk is generally considered tolerable [22].

In this study, the values of HQ, HI and CR were calculated for an adult human in two scenarios: 1) maintaining normal daily life and 2) normal daily life with running 2 hours every day in the stadium. EF and inhR are important parameters for calculating daily intake because they are directly related to activity duration, frequency, and inhaled air volume. Considering all year, exposure frequency was found to be 30 days (365 days x 2 hours/24 hours) for running activity and exposure duration was assumed to be 24 years [23]. In the study [24], it was reported that the volume of air ventilated in the lungs increased 10-12 times during exercise [25]. Therefore, the inhalation rate was multiplied by 10 to calculate the inhR value during sports activity. The other parameters are shown in Table 1 [21],[26],[27].

Table 1. Definition and reference value of parameters for risk assessment

Factor	Definition	Unit	Value
C	Heavy metal concentration in dust	mg/kg	
inhR	Inhalation rate for normal activity	m^3/day	20
inhR	Inhalation rate for sportive activity (20 x 10)	m^3/day	200
EF	Exposure frequency for normal activity	day/year	350
EF	Exposure frequency for sportive activity (365 x 2/24)	day/year	30
ED	Exposure duration	year	24
PEF	Particle Emission factor	m^3/kg	1.36E+09
BW	Body weight of the exposed individua	kg	70
AT	Average time for non-carc. (EDx365)	day	8,760
AT	Average time for carc.	day	25,550
ingR	Ingestion rate	mg/day	100
SL	Skin adherence factor	mg/cm^2/day	0.07
SA	Exposed skin surface area	cm^2	5700
ABS	Dermal absorption factor	-	0.001

3 Results and discussion

3.1 Concentration of heavy metals

The concentrations of Si, Fe, Al, Ti, Mn, Zn, Sr, Ba, Cr, Pb, Co, V, Ni, Sn, Sc, Bi, Sb, Ag, As, Mo, Hg, and Cd in surface dust deposition showed a decrease in the following order: 96256.12, 15621.37, 8765.12, 1320.12, 566.21, 425.12, 248.12, 126.15, 50.21, 10.24, 10.21, 8.24, 0.87, 0.80, 0.26, 0.24, 0.21, 0.08, 0.04, 0.03, 0.02, and 0.01 mg/kg (Table 2).

As, Cr and Ni are classified as class A and Cd as class B carcinogens [26, 28]. In addition, Co was also evaluated as carcinogenic [5]. Although Cr (III) was not classified as a carcinogen by IRIS, the entire Cr value was considered as a carcinogen in the present study since it could not be measured separately. In this study, Cr was at the highest concentration while Cd was at the lowest concentration among metals evaluated carcinogenic by IRIS. The concentrations of these elements ranged from 0.01 to 50.21 mg/kg.

All of the metals that were shown to be carcinogenic had lower concentrations than their average crustal values [29]. The ratio of measured and crustal concentrations of Co, Cr, Cd, Ni, and As decreased in the order of 0.590, 0.546, 0.133, 0.018, 0.008, respectively. Si concentration was found to be at the maximum level compared to other elements due to the properties of dust in general in Turkish cities [30]. In addition, Fe and Al, as well as Ti and Mn, are abundant elements in the earth's crust, and thus it is normal to observe them in high levels in this study. Zn, Sr, and Ba were found to be dominating in dusts. Also Pb and V element concentrations were close to each other. Zn, Pb, Sb and Co were affected by vehicle emissions, while Pb and V were affected by coal and oil combustion. [5],[31]. In general, other anthropogenic-based elements including Sn, Sc, Bi, Sb, Ag, Mo, and Hg had concentration values ranging from 0.01-0.80 mg/kg. The crustal concentrations of Zn and Bi were 6.345 and 1.475 times higher than their measured concentrations, respectively. The others were in the range of 0.001- 0.775.

Table 2 also shows the concentrations of heavy metals found in street dust in different studies and compares the concentrations of heavy metal detected in surface dust in the present study to other studies into cities around the world. Firstly, the heavy metal concentrations obtained in this study were compared with those obtained in the study conducted in Luanda, the capital city of Angola [32]. In this comparison, the Ti concentration in this study was found to be 12 times higher. Fe, Al, Mn, Zn, Sr, Cr, Co, and Bi concentrations were also found to be 1.3-3.5 times higher. However, it was determined that Ba, Pb, V, Ni, Sc, Sb, Ag, As, Mo, Hg, and Cd concentrations were lower than those obtained in Luanda. The comparison was carried out with another study conducted in a polluted area located within Erbil steel factory. Although the concentrations of all heavy metal species determined in Erbil were higher than the concentration determined in this study, the Fe concentration was 9.2 times higher in this study [33].

Table 2. Metal concentrations (mg/kg) in street dust in different cities.

Elements	This Study	Rundick and Gao [29]	Luanda, Angola [32]	Erbil, Iraq [33]	Mexico City- [34]	Worldwide [36]	Southeastern of Moscow [37]
Si	96256.12	311395.97	-	-	-	-	-
Fe	15621.37	39200.00	11572	1686.8	5722.2	25522.2	-
Al	8765.12	55415.03	4839	-	10853.3	-	-
Ti	1320.12	3835.74	107	-	412.3	-	-
Mn	566.21	774.45	258	2125.46	235.2	601.8	418.5
Zn	425.12	67.00	317	13844.28	280.7	634.6	348.6
Sr	248.12	320.00	172	-	-	-	121.3
Ba	126.15	624.00	131	-	128.2	156.7	155.6
Cr	50.21	92.00	26	472.02	51.4	104.3	81.35
Pb	10.24	17.00	351	792.42	128.2	502.9	55.67
Co	10.21	17.30	2.9	139	7.4	13.5	8.25
V	8.24	97.00	20	-	26.8	54.1	52.57
Ni	0.87	47.00	10	301.68	36.3	50.4	34.99
Sn	0.80	2.10	-	-	-	-	-
Sc	0.26	14.00	1.3	-	-	-	-
Bi	0.24	0.16	0.17	-	-	-	-
Sb	0.21	0.40	3.4	-	-	-	4.22
Ag	0.08	53.00	0.58	-	-	-	0.36
As	0.04	4.80	5	233.81	-	27.1	11.84
Mo	0.03	1.10	2	-	-	-	2.22
Hg	0.02	0.05	0.13	-	-	56.5	0.2
Cd	0.01	0.09	1.1	-	-	3.7	0.6

Another comparison was made with Mexico City, where the population is estimated to have reached 23.5 million inhabitants. The city has 4,000,000 vehicles running in daily traffic as well as 40,000 small and medium-sized industries [34],[35]. As in the two previous comparisons, the Fe concentration in this study was higher than that in Mexico City. In addition, Ti, Mn, Zn, and Co concentrations were found to be greater in the present study than those in Mexico City as in Luanda. However, the concentrations of Al, Ba, Cr, Pb, V, and Ni were lower in the current study than those in Mexico City.

The current study was also compared to another study, which focused on other studies from throughout the world. The concentration of all the elements in the present study was lower than those in this study [36]. The current study was compared to another study done in Moscow's Southeastern administrative region [37]. Mn, Zn, Sr, and Co concentrations in that study were higher than in the present study, while other element concentrations were lower. Since street dust or surface dust composition is affected by traffic density, local pollution sources, and socio-economic, topographic, and meteorological characteristics of the region [5], different results can be obtained in each study.

3.2 Microscopic structure of surface dust by SEM

SEM is used by many researchers to get high-resolution images of the material's surface features with qualitative information [38]-[40] Since the particles in SEM images have different microscopic structures, it is useful in determining whether the source of the particulate in dust is natural or anthropogenic [19],[41] and characteristics [42]. Different colors, shapes, and fundamental signals of anthropogenic particles can be used to recognize them from other particles [43]. Morphologically it is possible to see particles exhibiting sharp angularity in the uncontaminated soil sample; however, the edges of the dust particles have a floccule-like morphological appearance with a specific surface area significantly more extensive than that of the uncultivated soil [44]. If a porous structure is observed on the surface of particles smaller than 1 µm in the SEM analysis, this indicates that it may be due to photochemical reactions between dolomite, calcite and SOx and NOx [42].

In the study, SEM analysis focused on identifying particles containing Cu, Sb, and Sn in urban areas and particles containing Cr, Mo, Ni, and W around steel mills. Particles with diameters ranging from a few µm to 60 µm have been frequently observed in samples of street dust collected in urban areas. Ferrous oxides are often found in spherical of particles that are similar to that around steel mills in urban street dust. Soot particles composed of Al, Ca, Fe, Mg, and Si are other spherical particles with traces of K, Na, and Ti. Particles in dust containing Fe-Mn-O particle and trace amount of Al, Cu, S, Si, Sn, and Zn were bright on the electron image. It was emphasized that irregular, tile-like shaped particles below 20 µm can occur with mechanical wear of brake pads, while organic thread-like particles can be formed by tire wear. Spherical and irregular particle types were identified as carriers of Cr, Mo Ni, and W in the street dust collected around the steel mills by SEM images [45]. In another study, it was reported that particles in dust were smooth, shiny, laminated and ridged, and they were stretched and narrow in size. Particles in this shape show that mineral and rock fragments can be an effective source [46]. In the study, the surfaces of particles in the samples were generally rough, irregular in shape and dense in texture. It was also reported that the particles were irregular in shape possibly caused by natural soil, asphalt, concrete, paint particles, roads or building construction. Moreover, porous particles may have been affected by the salt in the sea. On the other hand, differences in particle size may have derived from industrial sources [19].

According to the data given above, we can make the following explanations for this study. There were no tile-like and thread-like shaped particles reflecting tire wear or mechanical wear of brake pads. In addition, there were no porous-shaped particles with salt in the sea, as expected. Moreover, particles in surface dust have not been found to be stretched and narrow in size; thus, it can be concluded that mineral and rock fragments are not an effective source for this study. However, with the naked eye, particles of rough and irregular shape and different sizes were detected. Figure 2 shows the size distribution of the particles in the surface dust. After sieved, particles with diameters ranging from 5 to 9.9 µm were identified in 46% of surface dust samples, whereas particles with diameters ranging from 0 to 4.9 µm were found in 21%. The ratios of 15%, 10%, 6%, and 2% reflect the size distribution of the particles in the range of 10.0-14.9, 15.0-19.9, 20.0-24.9, and 25.0-35.0 µm, respectively (Figure 2).

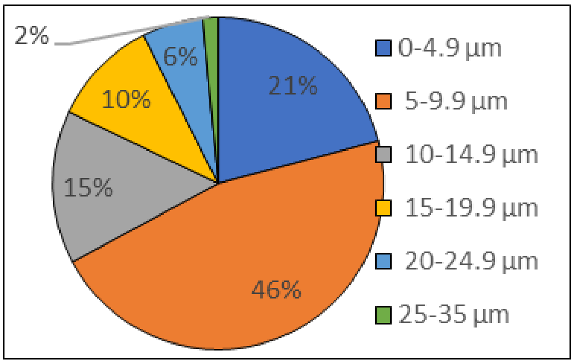

Figure 2. Size distribution of particles in surface dust.

The differences in sizes indicate that the sources can also be different, while natural soil, asphalt, concrete, paint particles, roads or building construction can possibly be sources of rough and irregularly shaped particles. In this study, particles of different sizes were identified in a spherical shape, so it could be argued that the industry is an effective source for this region, especially since spherical particle types are seen in dust collected around steel mills (Figure 3). It is worth noting that heavy metal pollution increasing with industrialization is one of the important environmental problems [47]. In addition, rapid urbanization, increasing highway transportation and increasing number of vehicles are known as the most important sources of heavy metal pollution in the soil [48].

3.3 Health risk assessment and management

Possible non-cancer and cancer risks were evaluated for the adult individual for two scenarios 1) normal daily activity and 2) normal daily activity with sports activity (2 hours per day). Result of assessment including HI, HQ, and CR for all three pathways for two scenarios were shown in Table 3. For scenario 1, the pathways of heavy metal exposure to dust are defined as ingestion > inhalation > dermal contact, while for scenario 2 the order is inhalation > ingestion > dermal contact. As respiration increased during running, HQ value for inhalation increased, but dermal contact and ingestion remained the same.

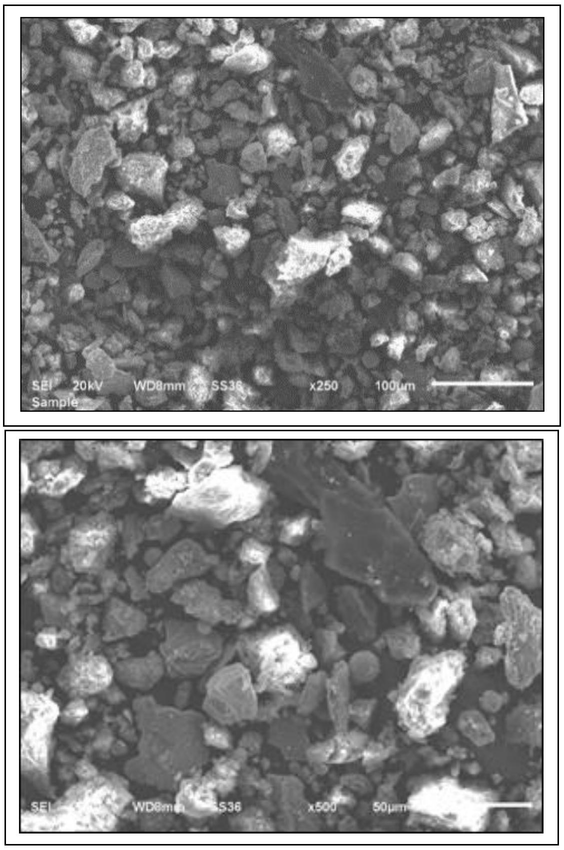

Figure 3. SEM images of particles in surface dust.

Since the HI (∑HQ) value was less than 1 for both scenarios, it did not pose a health risk. However, the HI value of scenario 2 was higher than that of scenario 1, albeit by a small margin. The assessment of cancer risk (CR) was performed by inhalation of As, Cd, Co, Cr, and Ni metals in the surface dust. CR values for both scenarios were found in decreasing order as Cr > Co > Ni > As > Cd. The total CR values were calculated as 1.53E-07 and 2.70E-07 for scenario 1 and scenario 2, respectively. This indicates that exposure to surface dust, if inhaled during normal daily activities or sports activities, does not pose a critical health risk.

The result obtained in the carcinogen risk assessment is consistent with the result of the non-cancer health risk assessment. As a result, those most affected by surface dust pollution on sports arenas are those who play sports as their exposure is relatively higher due to more breathing. For this reason, considering air quality in the selection of areas for sports events is of great importance in terms of health management as well as environment and public health.

The crucial environmental investments of large iron-steel industry plants, considered the most essential pollutant sources in the study area, have the largest share in reducing the problems experienced. However, environmental investments, especially for air quality and human health, should be maintained effectively and the results should be evaluated. For example, in the study conducted by Oğuz (2007), heavy metal accumulation around the largest iron-steel plant in the study area was investigated with biomonitors. All metals subject to the research were determined mainly in the region close to this plant, and when compared to similar studies in Europe, Fe, As and Pb values were determined to be much higher in this region [49].

Table 3. Hazard quotients, hazard indices, and cancer risk values of metals in surface dust

Elements	N	(N+S)	N and (N+S)	N and (N+S)	N	(N+S)	N	(N+S)
	Inh.HQ	Inh.HQ	Ing.HQ	Derm.HQ	HI=∑HQ	HI=∑HQ	CR	CR
Cr(VI)	4.40E-03	7.79E-03	2.29E-02	4.57E-03	3.19E-02	3.53E-02	1.46E-07	2.58E-07
Co	3.61E-04	6.39E-04	6.99E-04	3.49E-06	1.06E-03	1.34E-03	6.91E-09	1.22E-08
Ni	8.30E-09	1.47E-08	5.92E-05	8.76E-07	6.01E-05	6.01E-05	5.02E-11	8.89E-11
As	-	-	1.64E-04	1.64E-06	1.66E-04	1.66E-04	3.73E-11	6.61E-11
Cd	-	-	3.29E-05	3.22E-06	3.61E-05	3.61E-05	5.22E-12	9.25E-12
Fe	1.43E-02	2.53E-02	2.55E-03	1.22E-03	1.81E-02	2.91E-02	-	-
Al	1.26E-03	2.23E-03	1.20E-02	4.79E-04	1.37E-02	1.47E-02	-	-
Mn	8.15E-03	1.44E-02	5.54E-03	5.53E-04	1.42E-02	2.05E-02	-	-
Zn	2.85E-07	5.06E-07	1.94E-03	3.87E-05	1.98E-03	1.98E-03	-	-
Sr	-	-	5.66E-04	1.13E-05	5.78E-04	5.78E-04	-	-
Ba	1.82E-03	3.22E-03	8.64E-04	4.93E-05	2.73E-03	4.13E-03	-	-
Pb	5.89E-07	1.04E-06	4.01E-03	1.06E-04	4.11E-03	4.11E-03	-	-
V	-	-	1.61E-03	6.43E-04	2.25E-03	2.25E-03	-	-
Sb	-	-	7.29E-05	1.46E-04	2.18E-04	2.18E-04	-	-
Ag	-	-	2.14E-05	-	2.14E-05	2.14E-05	-	-
Mo	-	-	6.85E-06	7.19E-08	6.92E-06	6.92E-06	-	-
Hg	5.03E-08	8.91E-08	9.77E-05	5.57E-06	1.03E-04	1.03E-04	-	-
∑	3.03E-02	5.37E-02	5.32E-02	7.83E-03	9.13E-02	1.15E-01	1.53E-07	2.70E-07

N: Normal daily activity, (N+S): Normal daily activity coupled with sporting activity.

This study provides information about the sources of the pollutant. In another study conducted in breast milk, it was revealed that the maximum Pb and Cd concentrations obtained were above the limit values of WHO. In addition, it was emphasized in the study that heavy metal sources should be questioned [50]. Additionally, potential toxic elements found in street dust in urban areas were evaluated in terms of human health [51]. This study clearly demonstrates the impact of pollutants on human health. These studies provide information about sources of pollutant that are important for environmental and health management.

4 Conclusion

The surface dust sample from stadium seats were collected to determine heavy metal concentrations, to examine pollution level, microscopic structure, and health risk assessment. The concentrations of heavy metals were in the following decreasing series: Si>Fe>Al>Ti>Mn>Zn>Sr>Ba>Cr>Pb>Co>V>Ni>Sn>Sc>Bi>Sb> Ag>As>Mo>Hg>Cd. The concentration of the earth crustal elements in this study was found to be at the maximum level compared to other elements due to the properties of dust in general in Turkish cities.

The crustal concentrations of all heavy metals except Zn and Bi were lower than their crustal concentration. For this reason, it can be concluded that the heavy metal level is not extremely polluted. However, concentrations of some heavy metals were close to the crust concentration level. Shape and size of the particles indicate that the environment has the potential to be affected by the natural soil source and anthropogenic sources such as industry, traffic, and residential heating. Since the prevailing wind direction is from south to north, the pollutants emitted from the industries can reach urban areas, and the air pollution in the city is sometimes seen at the highest level. Thus, the impact of iron-steel industry can be seen on the stadium, which is the subject of the study. The results of the health risk and cancer risk assessments via metal exposure showed that risk values were within permissible values both for normal daily activity and normal daily activity along with sportive activity. However, the risk for normal daily activity along with sportive activity was higher than daily activity because of the higher inhalation rate. While the dermal contact and ingestion pathways of heavy metals exposure to dust were the same, exposure to dust by inhalation pathway also increased as the respiratory rate increased. Therefore, when choosing an area for sporting events, it is important to consider the suitability of the area for environmental and public health. Identifying the sources and composition of dust particles on surfaces is an important area for developing appropriate pollution reduction plans for both environmental and public health management.

5 Author contribution statements

In the scope of this study, the Kadir ULUTAŞ in the formation of the idea, the design and the literature review; in the assessment of obtained results, collecting the samples used and examining the results; the spelling and checking the article in terms of content were contributed.

6 Ethics committee approval and conflict of interest statement

There is no need to obtain permission from the ethics committee for the article prepared.

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