



## Effects of dust phenomenon on heavy metals in raw milk in western Iran

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Received April 07, 2020; Accepted in revised form April 19, 2020; Published June 04, 2020

### Abstract:

**Introduction.** After the Iraq war, the dust phenomenon has increased in western Iran. Our study aimed to evaluate the effect of the dust phenomenon on the content of heavy metals in raw milk in Ilam province.

**Study objects and methods.** The dust samples were collected during one year. The concentrations of dust particles were determined with the Enviro Check Laser System, using the Dust Monitor Check. The concentration of heavy metals in dust was determined by using the high volume air samplers and glass fiber filters.

**Results and discussion.** Heavy metals (lead, arsenic, zinc, copper, and iron) were measured at four sampling sites in raw milk by the atomic absorption method. The mean and standard deviations of dust particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) were 105.6 ± 90.5 and 25.9 ± 15.4 µg/m<sup>3</sup>, respectively. The amounts of arsenic, zinc, lead, and copper were higher in the spring and summer. Lead levels in western and southern regions were higher than those in the east, center, and north.

**Conclusion.** We found similar trends for arsenic, zinc, copper, and iron in raw milk. Our results showed the potential effect of the dust phenomenon on the presence of heavy metals in raw milk.

**Keywords:** Heavy metal, dust phenomena, raw milk, atomic absorption

**Please cite this article in press as:** Karimi E, Yari M, Ghaneialvar H, Kazemi HR, Asadzadeh R, Aidy A, et al. Effects of dust phenomenon on heavy metals in raw milk in western Iran. *Foods and Raw Materials*. 2020;8(2):241–249. DOI: <http://doi.org/10.21603/2308-4057-2020-2-241-249>.

### INTRODUCTION

A dust storm is one of many air pollutants known to humans. About 800 trillion grams of dust particles are spread in Asia. Particulate matter (PM) is usually suspended in arid, semiarid, and desert areas [1]. Today, dust storms are one of environmental problems that threaten the world [2]. The phenomenon of dust in the atmosphere causes the spread of PM around the globe [3]. Dust phenomena can be triggered by such factors as environmental change, global drought, and land cover [4]. The dry currents of the Saudi air and lack of attention to the environment and desertification in Iraq have dried up many of the marshes there and created dusty areas. In the past, Iran, Iraq, and Saudi Arabia jointly funded the mulching of these lands during a particular season. The Iraq war obliterated this work, resulting in a spike in western Iran, and eventually almost throughout the whole country. According to

Harrington *et al.*, the United States soldiers involved in the Iraq war had respiratory problems due to the dust phenomenon in that country [5].

Biological particles, salt sprays and, in particular, dust phenomena have been reported to contain numerous heavy metals [6]. Furthermore, these metals lead to climate change in temperature and other seasonal changes, such as the wind speed and patterns [7]. Although trace heavy metals are fundamental to living organisms for a normal and healthy life, excessive levels of heavy metal contamination in the environment could cause harm [8, 9]. To reduce environmental pollution and mitigate the resulting degradation of soil and water resources, it is important to precisely determine heavy metal concentrations [10, 11].

Some heavy metals, for example, chrome (Cr), lead (Pb), cadmium (Cd), and mercury (Hg) in the form of suspended particles in the air produce significant toxicological effects on people and other

organisms by contaminating food and drinking water in the environment [12]. Particulate matter, which is contaminated with heavy metals, can pollute groundwater. It has been indicated that contamination is transmitted from the soil to the plant. As a result, contaminated plants ingested by humans or animals can cause a toxic effect. Consequently, the concentration of heavy metals in animal products, such as raw milk, also causes toxicity. The extent of toxicity depends on different factors, such as plant processes and the amount of raw materials used [13]. Moreover, heavy metals such as lead, cadmium, chrome, nickel, and cobalt can contaminate cows and their surroundings. Heavy metals are absorbed by plant roots from the soil. As a result, this pollution causes serious problems, changing the amount and structure of milk [14].

The International Agency for Research on Cancer (IARC, 2016) classifies arsenic (As) and chrome (Cr) as carcinogenic metals and lead as a possible carcinogen. Such metals can cause different types of cancer through dermal contact, inhalation, and ingestion [15].

The western and southwestern climates of Iran are influenced by environmental conditions and markers such as geological, climatic, hydrological, and geomorphological characteristics [3]. Among the factors that cause dust storms are the development of deserts in Iraq, a decrease in volume and flow of rivers, and the Turkish dam on the rivers [16]. With a population of 172 000 people, the city of Ilam is located on the western border of Iran (33°38'N, 46°25'E). Due to a small population and a mountainous area, the city has low traffic and also no air pollution industry.

With the onset of spring, the phenomenon of dust comes to Iran from Iraq. This situation was aggravated by the Iraq war. In this study, we investigated the concentration of suspended particles in the environment and evaluated the effect of heavy metals on cow raw milk in the west of the country, Ilam province.

## STUDY OBJECTS AND METHODS

**PM concentration in dust.** The dust samples were collected from four districts of Ilam province: northern and central, southern, western, and eastern (28 samples in each). The sampling was performed on the roofs of buildings seven meters above the ground and two meters from the roof surface. During the sampling, we complied with all the standards of the US Environmental Protection Agency. In particular, we kept the required distance from natural and artificial obstacles, pathways, and sources of contamination. Suspended particles  $PM_{10}$  and  $PM_{2.5}$  were measured with the Enviro Check Laser System using the Dust Monitor Check (Grimm). This apparatus can directly and simultaneously measure the particle count,  $PM_{10}$  and  $PM_{2.5}$ . The system automatically saves the values in its memory and calculates the average on an hourly and a daily basis [17].

On normal days, the sampling was carried out every six days and on days with dust (a concentration

above  $150 \mu\text{g}/\text{cm}^3$ ), according to the Meteorological Organization and satellite sites, on a daily basis. The peak concentrations of  $PM_{10}$  and  $PM_{2.5}$  were recorded and measured on average every hour. The data obtained during a year were analyzed with the SPSS software [18].

**Heavy metals in dust.** Teflon and fiberglass filters were used to investigate heavy metals in the dust phenomenon. A 100-cm section of a filter was cut and transferred to a 100 mL beaker. Then, we added 50 mL of Aqua Regia ( $\text{HNO}_3 + 3 \text{HCl}$ ) and heated it to  $140^\circ\text{C}$  until the filter section was dry. Then, we removed it and washed the beaker with 10% nitric acid. This work was repeated three times. In the end, the prepared sample was kept at room temperature until it was cooled. Then, we transferred it into a 100-mL volumetric flask and diluted to volume with 10%  $\text{HNO}_3$ . The concentrations of heavy metals (lead, arsenic, zinc, copper, and iron) were determined by a Perkin-Elmer Analyst 800 atomic absorption spectrometer, including an AS-800 Autosampler equipped with Zeeman-effect background correction. Each result was an average of three readings. Blank filters were prepared by digesting clean glass fiber filters with the same digestion method used for the dust samples. Also, the dust samples were prepared in different seasons [19].

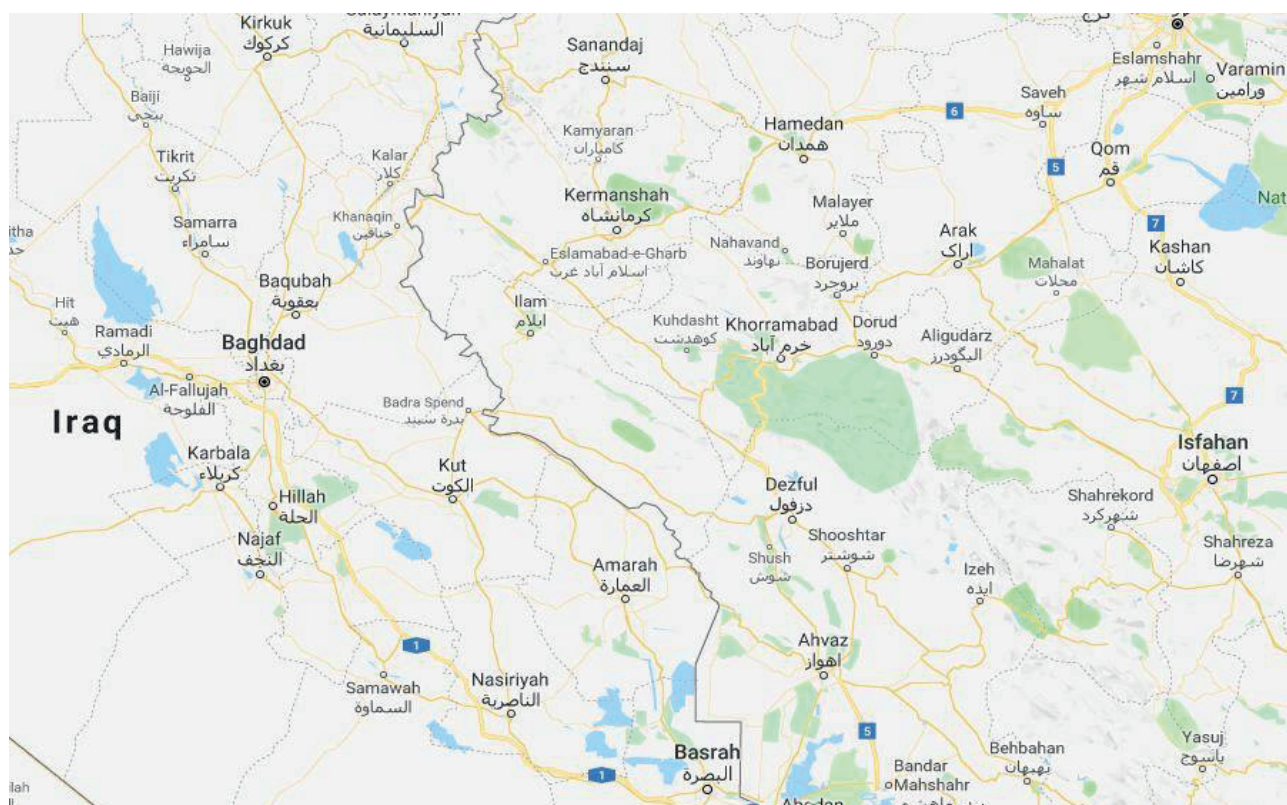
**Heavy metals in raw milk.** A total of 112 samples of cow raw milk were collected from four districts of Ilam province: northern and central, southern, western, and eastern (28 in each), at the same places as dust samples. All the samples were collected in nitric acid-washed polyethylene containers. They were immediately transported to the laboratory in a cooler with ice packs and stored at  $-20^\circ\text{C}$  until analysis. The raw milk samples were analyzed based on AOAC official methods. The amounts of heavy metals (lead, arsenic, zinc, copper, and iron) were measured by a Perkin-Elmer Analyst 800 atomic absorption spectrometer, including an AS-800 Autosampler equipped with Zeeman-effect background correction. Each sample was studied three times [20]. The limit of detection and the limit of quantitation of the atomic absorption device were 0.08 ppm and 0.15 ppm, respectively.

**Statistical analysis.** The SPSS 21 software was used to extract the data ( $P < 0.05$ ). The results of three repetitions were analyzed by ANOVA, using an SPSS statistics package.

## RESULTS AND DISCUSSION

Ilam is bordered by Iraq and close to the countries of Saudi Arabia and Kuwait, which are the main sources of dust events in the Middle East (Fig. 1).

According to Table 1, the sampling took 87 days. The average  $PM_{10}$  and  $PM_{2.5}$  were about  $105.6 \pm 82.9$  and  $25.9 \pm 15.4 \mu\text{g}/\text{m}^3$ , respectively. The maximum particle size of  $PM_{10}$  and  $PM_{2.5}$  was about 806.3 and  $213.2 \mu\text{g}/\text{m}^3$ , respectively.



**Figure 1** Geographical location of Ilam province and Iraq (Google map)

**Table 1** Concentrations of  $PM_{10}$  and  $PM_{2.5}$  in different months of sampling in Ilam province,  $\mu g/m^3$

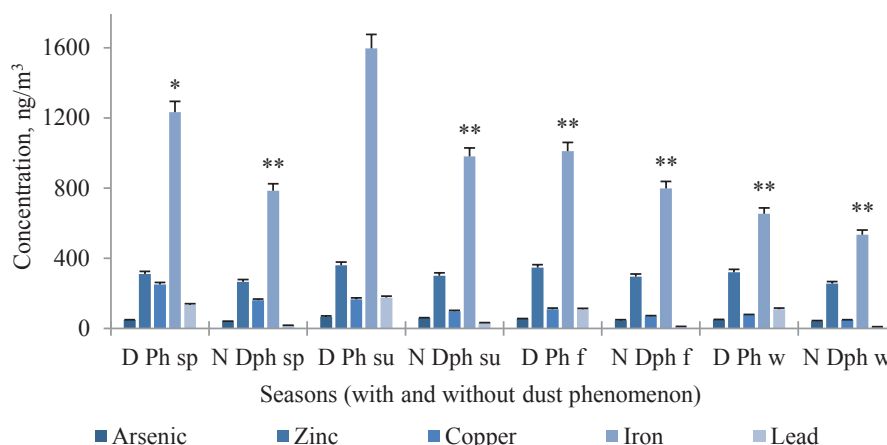
Months	Number of sampling days	Average		Maximum		Minimum		Median		Standard deviation	
		$PM_{10}$	$PM_{2.5}$	$PM_{10}$	$PM_{2.5}$	$PM_{10}$	$PM_{2.5}$	$PM_{10}$	$PM_{2.5}$	$PM_{10}$	$PM_{2.5}$
March-April	12	178.3	42.7	725.1	171.1	31.7	8.3	179.1	31.2	185.2	41.7
April-May	9	142.4	31.3	562.3	210.4	62.7	12.5	142.3	37.1	127.5	32.4
May-June	16	210.3	56.6	806.3	213.2	91.8	17.7	181.3	35.8	197.3	30.1
June-July	7	112.7	27.2	351.7	98.2	51.2	10.3	125.2	29.6	110.2	12.5
July-August	9	139.9	37.5	393.4	99.1	57.4	12.1	139.1	28.8	123.1	13.1
August-September	6	79.8	25.1	185.2	55.3	26.6	8.7	76.6	12.5	31.5	9.2
September-October	4	56.7	12.7	100.1	21.1	18.7	6.2	43.9	8.7	26.7	6.7
October-November	5	58.7	13.3	110.7	20.7	19.2	6.0	45.2	8.4	27.1	7.3
November-December	4	62.7	14.1	211.2	18.7	30.1	11.8	52.2	9.7	30.7	10.9
December-January	4	48.4	12.2	89.6	12.9	15.2	4.4	38.3	3.5	20.3	5.2
January-February	4	39.6	11.5	75.3	12.1	13.3	4.1	35.2	4.1	18.7	4.9
February-March	7	137.5	26.9	300.8	121.6	41.3	9.6	127.5	11.2	97.3	10.4
Study period	87	105.6	25.9	325.9	87.8	38.3	9.3	98.8	18.4	82.9	15.4

Five heavy metals (lead, arsenic, zinc, copper, and iron) were measured in all the samples. Fig. 2 shows the range and mean concentrations ( $ng/m^3$ ) of the selected heavy metals analyzed at the sampling stations. In the spring and summer, the amounts of heavy metals were higher than in the other seasons, especially iron. Lead and copper levels were lower in all the seasons compared to other metals.

Average values of lead content in the raw milk samples are shown in Table 2. The highest average lead

level was determined in the western region ( $57.1 \mu g/kg$ ). The statistical analysis revealed a significant difference in lead concentrations between the western and southern regions compared to the east and north of Ilam province ( $P$ -value  $< 0.05$ ).

Average concentrations of arsenic in the milk samples are shown in Table 3. Although arsenic was higher in the south and west compared to the northern and central region or the east of the province, we found no significant difference. The highest average



**Figure 2** Seasonal average concentrations of heavy metals (lead, arsenic, zinc, copper, iron) in dust phenomena. Dust phenomenon in spring (D Ph sp), non-dust phenomenon in spring (N Dph sp), dust phenomenon in summer (D Ph su), non-dust phenomenon in summer (N Dph su), dust phenomenon in fall (D Ph f), non-dust phenomenon in fall (N Dph f), dust phenomenon in winter (D Ph w), non-dust phenomenon in winter (N Dph w), \*  $P$ -value < 0.05, \*\*  $P$ -value < 0.001 vs. the other group

**Table 2** Lead contents in raw milk samples

Northern and Central region		Eastern region		Southern region		Western region	
Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$
1	29	1	31	1	49	1	48
2	29	2	33	2	48	2	55
3	23	3	35	3	53	3	49
4	28	4	29	4	59	4	63
5	27	5	37	5	57	5	61
6	31	6	39	6	61	6	65
7	25	7	38	7	55	7	59
Average	27.4	Average	34.6	Average	54.6	Average	57.1
Max	31	Max	39	Max	61	Max	65
Min	23	Min	29	Min	48	Min	48

**Table 3** Arsenic contents in raw milk samples

Northern and Central region		Eastern region		Southern region		Western region	
Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$	Sample	Content, $\mu\text{g/kg}$
1	11	1	10	1	13	1	12
2	11	2	10	2	12	2	13
3	12	3	12	3	12	3	12
4	10	4	12	4	14	4	14
5	10	5	13	5	10	5	12
6	12	6	10	6	13	6	11
7	11	7	9	7	12	7	13
Average	11	Average	10.9	Average	12.3	Average	12.4
Max	12	Max	13	Max	14	Max	14
Min	10	Min	9	Min	10	Min	11

arsenic level was observed in the west, amounting to 12.4 mg/kg.

Table 4 shows average zinc values in the raw milk samples. The highest average amount of zinc was determined in the western region (4582.8  $\mu\text{g/kg}$ ). According to the statistical analysis, there was a

significant difference in zinc concentrations between the western and southern regions compared to the east and north of Ilam province ( $P$ -value < 0.05).

The concentrations of copper in different regions are shown in Table 5. As we can see, the average level of copper in the western and southern regions was



**Table 4** Zinc contents in raw milk samples

Northern and Central region		Eastern region		Southern region		Western region	
Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg
1	3120	1	3210	1	4650	1	4740
2	3190	2	3460	2	4770	2	4400
3	2870	3	3110	3	4390	3	4810
4	3150	4	3060	4	3880	4	5030
5	3210	5	2930	5	4810	5	4560
6	3010	6	3420	6	4230	6	4330
7	2460	7	3250	7	4560	7	4210
Average	3001.4	Average	3205.7	Average	4470	Average	4582.8
Max	3210	Max	3460	Max	4810	Max	5030
Min	2460	Min	2930	Min	3880	Min	4210

**Table 5** Copper contents in raw milk samples

Northern and Central region		Eastern region		Southern region		Western region	
Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg
1	210	1	200	1	230	1	170
2	300	2	320	2	690	2	480
3	190	3	170	3	410	3	550
4	180	4	350	4	520	4	400
5	250	5	420	5	450	5	670
6	310	6	300	6	360	6	510
7	200	7	380	7	590	7	430
Average	234.3	Average	305.7	Average	464.3	Average	458
Max	310	Max	420	Max	690	Max	670
Min	180	Min	170	Min	230	Min	170

**Table 6** Iron contents in raw milk samples

Northern and Central region		Eastern region		Southern region		Western region	
Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg	Sample	Content, µg/kg
1	2554	1	2654	1	3865	1	3845
2	2129	2	2863	2	3978	2	3693
3	2763	3	2341	3	4762	3	4236
4	3327	4	3496	4	3687	4	4122
5	2645	5	2029	5	4831	5	3541
6	2431	6	2585	6	3573	6	3655
7	3504	7	3051	7	2985	7	4032
Average	2764	Average	2717	Average	3954	Average	3874
Max	3504	Max	3496	Max	4831	Max	4236
Min	2129	Min	2029	Min	2985	Min	3541

higher than in the eastern and northern regions. The lowest average copper concentration (234.3 µg/kg) was observed in the northern and central region.

According to Table 6, there was a significant difference between the amounts of iron in the west and south compared to the east and north of the province. The highest average concentration of iron (3954 µg/kg) was found in the southern region.

Typically, dust particles with a diameter of 616–660 µm remain in their places of origin. Particles sized 31–62 µm are dispersed over approximately 320 km from their origin, while those sized 16–30 µm, up to

1600 kilometers. Particles below 16 µm travel longer, and particles ranging from 2–50 µm have been reported to mostly originate in deserts like Iraq, Saudi Arabia, and Africa [21]. The main source of dust phenomenon in the southwest of Iran is the deserts of Iraq [22].

In our study, the mean and standard deviations of PM<sub>10</sub> and PM<sub>2.5</sub> were  $105.69 \pm 0.5$  and  $25.9 \pm 15.4$  µg/m<sup>3</sup> at the time of sampling, and the maximum PM<sub>10</sub> and PM<sub>2.5</sub> concentrations were 806.3 and 213.2 µg/m<sup>3</sup> in June, respectively. According to Draxler *et al.*, the main sources of dust phenomenon in the southwest and west of Iran are Kuwait, Iraq,

and Saudi Arabia. The authors showed that  $PM_{10}$  concentrations exceeded  $3000 \mu\text{g}/\text{m}^3$  [23]. In the study by Shahsavani *et al.*, which agrees with our results, the mean and standard deviations of  $PM_{10}$  and  $PM_{2.5}$  in Ahwaz, southwest of Iran, were  $407.07 \pm 319.1$  and  $83.2 \pm 69.5 \mu\text{g}/\text{m}^3$ , while the maximum  $PM_{10}$  and  $PM_{2.5}$  concentrations were  $5337.6$  and  $910.9 \mu\text{g}/\text{m}^3$  in June, respectively [24]. In another study, in the southwest of Iran, the mean and standard  $PM_{10}$  and  $PM_{2.5}$  deviations in the entire study period were  $775.3 \pm 598.9$  and  $129.5 \pm 114.9 \mu\text{g}/\text{m}^3$ , whereas their maximum concentrations reached  $4730.1$  and  $774.4 \mu\text{g}/\text{m}^3$  in February, respectively [17]. The difference between the maximum concentrations found by the authors and our results may be due to differences in geographical and atmospheric conditions and the distance from the dust source in the period of particle measurement. Also, in another study of 2007, the mean total concentration of suspended particles was  $282 \mu\text{g}/\text{m}^3$  and the  $PM_{10}$  and  $PM_{2.5}$  concentrations were  $165$  and  $67 \mu\text{g}/\text{m}^3$ , respectively [25]. Finally, a 2010 study conducted in China reported the mean concentrations of  $PM_{10}$  and  $PM_{2.5}$  to reach  $322 \pm 237.4 \mu\text{g}/\text{m}^3$  and  $141.5 \pm 108.8 \mu\text{g}/\text{m}^3$ , respectively [26].

According to Jacobs *et al.*, of 16.4 million homes in the United States with more than one child below six, 25% still had significant amounts of lead-contaminated deteriorated paint, dust, or adjacent bare soil [27]. Lu *et al.* detected the presence of heavy metals in soil by spectroscopic methods [28]. In another study, the voltammetric method found cadmium ( $0.06 \mu\text{g}/\text{L}$ ) and lead ( $0.65 \mu\text{g}/\text{L}$ ) in soil [29]. However, the atomic absorption technique is also very important for analyzing heavy metals in air samples. Factors such as high sensitivity, high performance, low cost, and accuracy make this method a good choice. The amount of heavy metals in the atmosphere depends on the origin and the distance from the source of pollution. Seasonal changes also affect concentrations of heavy metals in the atmosphere [30]. Our results showed that the amounts of arsenic, zinc, lead, and copper were higher during the spring and summer. Zinc and iron had a higher level compared to the others. Due to high temperatures during the spring and summer, dust is denser than in the fall or winter, and it is easier for animals and humans to inhale them. In a study by Al-Dabbas *et al.*, the X-ray powder diffraction method was used to detect the presence of heavy metals (Fe, Co, Ni, Cu, Zn, and Pb) and dust particles in the streets of southern Iraq [31]. Also, in Ahwaz, southwest Iran, heavy metals (Cd, Cr, Co, Ni, Pb, Zn, and Al) were identified in particles with  $PM_{10}$  [32].

It has been well demonstrated that heavy metals such as cadmium, chrome, nickel, and cobalt, which contaminate the environment around animals, e.g. cows, penetrate into cow milk and cause tissue problems. Heavy metals can penetrate into plants through their roots. Through contaminated drinking water and

water used in agriculture and food production, they enter animal and human bodies [33]. As reported by Razafsha *et al.*, plants contaminated with particles containing heavy metals increase the risk of raw milk contamination [34].

Dairy products are a vital part of a healthy diet, and milk is widely used in feeding infants and children. Therefore, studying the presence of metals in milk is especially important to ensure the safety of milk production that is greatly reduced in a contaminated and toxic environment [35, 36].

According to the FAO/WHO guidelines and the Codex standard, the levels of lead, arsenic, zinc, and iron in milk and dairy products are 2.0, 0.050, 0.9, and  $0.6 \mu\text{g}/\text{kg}$ , respectively [37].

We examined the amounts of heavy metals in cow milk in Ilam, west of Iran, and found that lead levels in the western and southern regions were higher than in the east, center, and north. This situation was also consistent with arsenic, zinc, copper, and iron. The average concentrations of arsenic and copper were generally lower than those of zinc, lead, and iron. Farm animals, which are used for milk and meat, tend to get polluted with heavy metals through the environment. According to recent observations, the concentrations of remaining heavy metals in milk are significantly higher than those approved by international authorities [38].

Consistent with our study, Konuspayeva *et al.* reported that seasonal changes influenced the level of lead in camel milk: it was lower in the spring compared to other seasons [39]. They also found that the presence of arsenic in camel milk and its contamination level depended on the distance from the source of pollution, wind and farm topography (soil type, vegetation type), etc. [40]. Another study reported that the amount of iron and copper in the milk collected in industrial areas was higher than that of lead in traffic-intensive and industrial regions [20]. This shows the effect of the environment on the content of heavy metals in milk. Awasthi *et al.* and Malhat *et al.* reported that the levels of cadmium, iron, and zinc in cow milk were higher in industrial areas compared to others [41,42]. A study in Egypt found that the amount of cadmium in cow milk produced in contaminated air was significantly higher [43].

It has been shown that all the milk samples collected from different governorates contained lead and iron in higher concentrations than those recommended for milk by the IDF standard (1979). Lead is an environmental pollutant that is toxic to humans and animals [44].

Similar to our study, Kabir *et al.* presented the average concentrations of metals in 50 samples of cow milk from contaminated environments in the following order:  $\text{Fe} > \text{Cr} > \text{Mn} > \text{Zn} > \text{Ni} > \text{PB} > \text{Hg} > \text{Sc} > \text{Cd} > \text{As}$  [45].

## CONCLUSION

We analyzed the particle matter and the amounts

of heavy metals in the dust phenomenon in western Iran (Ilam province) over one year and also studied the presence of heavy metals in the raw milk samples collected in its four regions. As a result, we can conclude that the dust phenomenon that comes from Iraq to Iran is probably one of the sources of milk contamination in western Iran.

#### CONTRIBUTION

Naser Abbasi designed the work and took the lead in writing the manuscript together with Elahe Karimi; Ali Aidy performed the experiments; Monireh Yari and Hori Ghaneialvar derived the models and analyzed the data; Hamid Reza Kazemi and Reza Asadzadeh contributed to the interpretation of the results.

#### CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

#### ACKNOWLEDGEMENTS

This work was supported by the Ilam University of Medical Sciences.

#### ETHICAL STATEMENT

The authors confirm that they have adhered to the journal's ethical policies specified on its author guidelines page, and received the approval of the appropriate ethical review committee. The authors also confirm that they have followed the EU standards for the protection of animals used for scientific purposes and feed legislation.

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