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Evaluation of biological (feed, water), seasonal, and geological factors affecting the heavy metal content of raw milk

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A R T I C L E I N F O

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A B S T R A C T

In volcanic regions worldwide, soil and water can be contaminated with heavy metals. Aksaray province is also an important region in this respect. Because this city is located around Hasandağı, an extinct volcanic mountain. In addition, the city is also an important dairy center. In this regard, evaluating the milk produced in Aksaray in terms of heavy metal contamination and studying the effect of feed and water on this contamination is essential. For this purpose, feed, water, and milk samples from 7 milk producers determined in Aksaray province were collected in 3 different seasons within six months. The presence and levels of arsenic (As), aluminum (Al), nickel (Ni), cadmium (Cd), and lead (Pb) were determined by ICP-MS analysis of the 126 samples obtained. The study found varying levels of heavy metals in feed, water, and milk. It was also observed that milk contained considerably lower quantities of metals and metalloids than feed and water. In addition, it has been determined that the distance to Hasandağı does not affect the trace element levels in water, milk, and feed, but there is a significant relationship between seasonal changes and trace elements in the samples. According to the analysis results, the highest level is the feed's aluminum level (298,290.1 μg/kg). However, the aluminum level in milk remained well below this level (96.15 μg/kg). It was determined that the cadmium level in milk reached the highest level in spring (average 0.06 μg/kg), whereas lead levels reached the highest level in summer (average 2.14 μg/kg). On the other hand, the arsenic level showed a relatively small change according to the distance to the volcanic region. The average arsenic level in milk from regions near the volcanic area was measured as 1.01 μg/kg. In remote areas, this amount was measured as 0.94 μg/kg, Furthermore, the highest heavy metal level in the milk was 182.08 μg/kg for nickel during the summer months in the study.

1. Introduction

Heavy metals cause many health problems, as repeatedly proven in research worldwide. It is also important that authorities emphasize the toxicity of heavy metals and the risk of foods in this respect. Trace elements are contaminants that are widespread in environmental matrices, pollute water and food, and have been shown in scientific studies to have acute and chronic harmful effects (IARC, 2012, 2023; Mitra et al., 2022; Sharma, 2018).

Increasing industrialization since the twentieth century has caused air, water, and agricultural pollution. Heavy metals, among these pollutants, emerge as an important topic due to the economic problems they cause and the health risks they create for living things. Heavy metals can be dispersed into the environment in different ways in nature's geological and biological cycles, and they can accumulate in animals and plants in the biological cycle by allowing them to exist in the food chain (Deshpande, 2002). The major threat caused by heavy metals to human health is exposure to lead, cadmium, mercury, and arsenic, as well as their mixing with biochemicals in normal body metabolic processes (Järup, 2003). It has been reported that cadmium can negatively affect calcium metabolism and lead to osteoporosis, bone diseases, and lung cancer. It can also affect the male reproductive system and sperm quality. Lead, on the other hand, has a broad negative impact on body systems. Symptoms are usually nonspecific and can cause a decrease in cognitive function in adults, miscarriage in women, infertility in men, and behavioral disorders in children (Alengebawy et al., 2021; Mitra et al., 2022) emphasized the extensive toxic effects of heavy metals in their comprehensive review. These toxic effects are classified as neurotoxic, nephrotoxic, hepatotoxic, and genotoxic. Additionally, the review highlighted the toxicity of heavy metals on the skin, immune and

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cardiovascular systems, and their carcinogenic effects (Mitra et al., 2022). Arsenic-related skin problems have also been emphasized in research. Skin lesions are one of the important symptoms of long-term arsenic exposure. Arsenic-induced skin cancers usually predict the development of other internal organ cancers. It is also claimed that this is due to the mechanism of immune dysregulation associated with arsenic (Huang et al., 2019).

Contamination of water and agricultural areas in trace elements-contaminated areas also impacts food samples from these areas, as vital components of food, soil, and air impact all stages of the food chain. Contaminated soil, water, and the contamination rates of these components directly impact food quality. The ratios of arsenic and lead in vegetables taken from contaminated soil were greater than those in samples taken from uncontaminated areas (Pendergrass and Butcher, 2006). As the concentration of cadmium, lead, and copper in the soil increases, so does the concentration of these trace elements in the plants in that region (Khan et al., 2008). The levels of toxic and heavy metals in soil and water, a significant problem due to the increasing generation of solid waste from urbanization and industrialization, have also been examined. It has been demonstrated that soil contamination with toxic and heavy metals is a significant problem, especially in urban and industrial areas where solid waste generation is increasing. (Ahmad et al., 2021). Studies also showed that soil and water constantly interact in heavy metal transfer. Depending on the increase in the number of heavy metals in the soil, it is reported that there is an increase in the number of heavy metals in the groundwater (Das et al., 2004), the concentration of heavy metals in vegetables (Huq et al., 2006) and fish tissues increase due to the increase in water (Abumourad et al., 2013).

In terms of heavy metal pollution, milk, and dairy products, on the other hand, are food that should be considered, particularly in contaminated areas. For instance, the milk of animals fed with fodder grown on agricultural lands irrigated with wastewater has posed a risk in terms of Cd, Cr, Cu, Mn, Ni, and Pb (Iqbal et al., 2020). A study conducted in the Algerian region analyzed 88 raw milk samples obtained from local breeds. According to the study results, there is a potential risk of heavy metals, especially Pb, for infants through the consumption of raw milk (Boudebbouz et al., 2022). In another study conducted in Egypt, a total of seventy-five milk products were analyzed, including raw cow milk, raw buffalo milk, condensed milk, infant formula, and milk powder. The results showed that the levels of the toxic metals lead (Pb) and cadmium (Cd) were higher than the recommended daily intake (Saleh et al., 2019). In another study comparing the levels of heavy metals in cow and buffalo milk, the average concentrations of Pb, Cd, Cu, and Ni in cow milk samples were found to be 0.62 ± 0.25, 0.25 ± 0.22, 0.31 ± 0.20, and 21 ± 2 mg/kg, respectively, while in buffalo milk, they were 0.60 ± 0.3, 0.33 ± 0.15, 0.27 ± 0.11, and 18 ± 2.5 mg/kg, respectively. The researchers indicated that this situation was caused by excessive heavy metal pollution in the environment (Al-Rudha et al., 2021). Sant'Ana et al. (2021) reported that dairy products found in markets in São Luís were a source of heavy metal contamination (Hg, Pb, Se, Cu, Ni) (Sant'Ana et al., 2021).

Milk and its products, which play a vital role in our country's dietary habits, are included in the daily diets of people of all ages. In terms of composition, these natural foods may contain more than twenty trace elements (Enb et al., 2009). Location and environmental interaction are also crucial in contaminating foods with heavy metals. Wind-blown dust, volcanic particles, forest fires, flora, and sea salt are the most common natural sources of heavy metals (Edelstein and Ben-Hur, 2018). Adhesitic and basaltic rivers and pyroclastic and sedimentary rocks, the first products of Hasandağı volcanism in Aksaray province, are considered a significant source of arsenic in groundwater in the region (Altaş et al., 2011). Heavy metals are naturally occurring elements with high natural background levels in volcanic areas. Therefore, it is necessary to conduct a risk assessment and identify potential sources of heavy metals (Yang et al., 2022). Santos-Frances et al., (2017) reported the presence of high concentrations of toxic trace elements in soil samples obtained from the Andes Mountain region in Peru. In particular, the high concentration of lead, cadmium, zinc, and arsenic was emphasized in the study (Santos-Francés et al., 2017). A study that determined the possible pathways of As, Cd, and Pb transfer from the environment to raw milk demonstrates the importance of environmental contamination in milk with heavy metals. According to the study, arsenic follows the water-silage-milk pathway,y while cadmium generally transfers to milk from soil(water)-silage pathways. The same study highlighted that children are at higher risk than adults (Su et al., 2021).

To summarize, cadmium, lead, and arsenic are the major trace elements that contaminate food and cause serious health concerns. In studies that define the limits of trace elements in foods, FAO/WHO (Food and Agriculture Organization/World Health Organization) underlines the importance of these trace elements (Anon, 2002). Nickel, less common than these heavy metals but can be found in food, is also considered a heavy metal transported with food (D'Mello, 2003). In addition to these trace elements, aluminum has been regarded as a critical food contaminant. Aluminum safety was re-evaluated by JECFA (The Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives) in 2006, with a focus on the harmful effects of aluminum-containing components on experimental animals, particularly the neurological and reproductive systems (Wong et al., 2010) on the other hand, WHO, in the report prepared in 2007, stated that the main route of transmission of aluminum to humans is food and that people are regularly exposed to aluminum for this reason (Wong et al., 2010).

Regarding nutritional habits, milk is a common food item in our country. Milk and its products are regularly included in the diets of people of all ages. The relevance of evaluating the toxicity of milk and its products in terms of heavy metals and arsenic is critical, especially given the large volume consumed. The importance of dairy in Aksaray and the trace elements risks caused by Hasandağı's volcanic activity make the issue even more important. The presence of Hasandağı is also known to have poisoned the waters with trace elements. However, the fact that this contamination has not been evaluated in terms of its presence in raw milk in Aksaray province, which has a significant position in dairy, constitutes an important study area.

In light of all this information, evaluating raw milk in terms of heavy metals and arsenic in Aksaray province is important. With this study, while the effects of contaminated water on raw milk will be assessed based on Aksaray province, it will also be possible to evaluate domestic waters in terms of trace elements.

2. Material and method

2.1. Material

Drinking water and feed used for raising animals and raw milk samples from dairy animals were collected from different regions of Aksaray province for this study. Collecting raw milk, feed, and water samples was completed by taking samples from the same point three times over six months.

Samples were obtained from the milk of animals fed only with feed to provide control. Milk samples were taken into cooling (4 °C) tanks immediately after automatic milking. Here the cooled and mixed milk was taken as a sample. To prevent contamination from the transport containers, the samples were carried in polyethylene containers that had previously been cleaned with nitric acid. To represent all of the characteristics of the sample, a 250 mL sample of water and milk was taken from each sample, and a 300 g sample of feed was taken from each sample. The samples were rapidly taken into the sample preparation procedure after being brought to the laboratory while maintaining the cold chain via an in-car refrigerator.

In addition to these, the water profile of Aksaray province was examined in terms of trace elements. In this context, two different tap waters from different regions were taken (Tap Water 1 – Tap Water 2). In addition, a water sample was taken from the filtration system connected to the Tap water line (Treated water). Two different city waters (City Water 1 – City Water 2) were also supplied from different parts of Aksaray province. Packaged water was also taken as a sample for comparison purposes. All water samples, except packaged water, were made with the water sampling procedure from the farms.

2.2. Sample preparation and microwave incineration

Firstly, the water samples were diluted 1:1 with a 2% solution prepared with 65% (supra pure) nitric acid (E. Merck, Darmstadt, Germany). The diluted samples were passed through 0.45 μm syringe type filters (ISOLAB, Eschau, Germany) and taken into sample tubes. Following this process, it was stored at + 4 °C until ICP-MS (Inductively Coupled Plasma - Mass Spectrometer) analysis.

After 2 mL of milk samples were taken, 8 mL of 65% (extra pure) nitric acid (E. Merck, Darmstadt, Germany) and 1 mL of 30% hydrogen peroxide (E. Merck, Darmstadt, Germany) were added, and the mixture was held mouthed under a fume hood for 15–20 min. The samples were then burned using a microwave combustion device (Cem Corporation, Mars 5, U.S.A. Maximum pressure 1600 psi, maximum temperature 310 °C). After microwave digestion, samples were filtered through 0.45 μm syringe filters and kept at + 4 °C until ICP-MS analysis.

The feeds used to feed animals are Total Mixed Ration (TMR). All raw materials, such as roughage, silage, and concentrated feed, were mixed in certain proportions in the feed content. In the collected feed samples, 0.2 g of sample was weighed (Precisa Gravimetrics AG, Switzerland), and 9 mL of 65% (extra pure) nitric acid (E. Merck, Darmstadt, Germany) was added to it and left mouthed for 15–20 min under the fume hood. After this process, the feed samples were subjected to the incineration process in the microwave combustion system. The samples were taken after this process was passed through 0.45 μm syringe filters and kept at + 4 °C until ICP-MS was performed. After the sample preparation process, the blank samples were also collected to be kept throughout the analysis. Microwave combustion and ICP-MS analysis conditions are shown in Table 1.

2.3. ICP-MS analysis

The ICP-MS device (ThermoFisher Scientific, X series II, Germany) was used to determine the trace elements content of the samples, which were collected and microwave digested for analysis. Standards (Sigma Chem, St. Louis, ABD) with concentrations of 1, 5, 6, 10, 30, 50, 100, 150, and 200 μg/kg were made from 10 mg/kg pure standards with equal concentrations of trace elements for this purpose, and a calibration curve was drawn using them (Ahamad et al., 2017).

Table 1
Analysis Conditions.

Microwave Combustion Unit Conditions (Lehutso et al., 2021)	Temperature (°C): 210 Ramp (mm: ss): 15:00 Pressure (psi): 800 Power (W): 900–1800 Stirring: Off
ICP-MS Analysis Conditions	İgnition power 1100 W Forward power: 1400 W Plasma coolant gas flow rate 13.0 L min− 1 Auxiliary gas flow rate 0.7 L min− 1 Nebulizer gas fow 0.80 L min− 1 Nebulizer type PFA ST Microflow nebuliser Sample uptake rate 1.0 mL min− 1 Pump rate 40 rpm during the analysis

2.4. Statistical analysis

The data conformity with Way ANOVA to the normal distribution was analyzed by drawing Q-Q plots. SPSS (Statistical Package for the Social Science) 15.0 licensed program was used for statistical analysis of the data of all samples. In addition, regression analysis was performed to understand the effect of water and feed on milk. The contents of five different trace elements (Al, As, Cd, Ni, Pb) and their relations were evaluated in 126 (n = 126) samples in a study with two replications (water, feed, milk).

3. Results and discussion

The obtained data were evaluated according to the distance and proximity to Hasandağı and the season difference (summer, autumn, winter) taken according to the type of samples (water, milk, feed). The average values of the samples are given in Table 2, and the statistical analysis data are presented in Table 3.

According to the results of the study, the average levels of As, Al, Ni, Cd and Pb trace elements in water in all samples were 21.88 μg/kg, 2.97 μg/kg, 16.61 μg/kg, 0.33 μg/kg and 0.10 μg/kg, respectively. The important contaminant of the region, arsenic, draws attention to its level in the water. It has also been observed that the trace elements in the water are not significantly affected by the proximity to the volcanic region and the season (Table 3). On the contrary, in the studies of Obasi and Akudinobi (2020), Pb2 + (11.42 mg/L), Ni2 + (1.260), Cd2 + (15.67 mg/L), As(4.13 mg/L) and Zn2 + (10, 53 mg/L) were found in the water sources in the mining area. Researchers have drawn attention to the contamination of water resources. They also reported that the levels of trace elements in water were higher in areas close to active mines. The study also shows a decrease in the concentration of chemical components in the rainy season compared to the dry season (Obasi and Akudinobi, 2020).

When looking at Table 2, the aluminum content in feed (298,290 μg/kg) stands out in terms of average results. WHO indicated in a 2007 report that food is the main route of aluminum transmission to humans

Table 2
Average trace elements contents of the samples (μg/kg).

	Arsenic	Aluminum	Nickel	Cadmium	Lead
Nearby regions (around 25 km to Hasandagi)					
Water	33.28	2.98	23.03	0.05	0.15
Feed	58.93	231,401.7	1633.45	11.98	231.48
Milk	1.01	71.89	98.53	< LOQ	0.85
Remote regions (around 60–80 km to Hasandagi)					
Water	7.85	32.74	41.35	0.02	0.04
Feed	42.29	171,034.2	1747.41	17.53	175.07
Milk	0.94	128.50	98.47	0.06	0.92
All Samples					
Water	21.88	2.97	16.61	0.33	0.10
Feed	60.16	298,290.1	2124.75	19.30	284.10
Milk	0.98	96.15	98.50	0.02	0.88
Summer samples					
Water	10.95	1.81	19.80	0.03	< LOQ
Feed	128.34	242,548.5	1753.25	30.15	239.25
Milk	2.82	148.03	182.03	< LOQ	2.14
Autumn samples					
Water	4.54	49.50	63.10	0.04	0.76
Feed	23.48	118,718.26	1083.87	14.10	113.95
Milk	0.02	116.90	105.15	0.06	< LOQ
Winter samples					
Water	46.20	2.28	13.70	0.04	0.08
Feed	< LOQ	242,387.08	2234.17	< LOQ	256.63
Milk	0.09	35.64	8.32	< LOQ	0.51

LOQ Values; As: 1.43 μg/kg, Al:4.41 μg/kg, Ni: 1.60 μg/kg, Cd: 4.52 μg/kg, Pb: 5.49 μg/kg

Table 3
Statistical analysis of data.

	Arsenic	Aluminum	Nickel	Cadmium	Lead
Distance					
Water	,088	,989	,148	,011	,253
Feed	,294	,019	,187	,671	,015
Milk	,917	,233	,999	,130	,875
Season					
Water	,021	,077	,794	,443	,239
Feed	,000	,515	,671	,000	,758
Milk	,000	,180	,000	,177	,000
Sample Type	,000	,000	,000	,000	,000
Effect of Water and Feed on Milk	,000	,771	,545	,421	,239

*Means in the same row with different superscripts are significantly different ($P < ,005$)

and that people are constantly exposed to aluminum (Wong et al., 2010). In this context, the high aluminum content of the feed (96.15 μg/kg) is critical for animal nutrition and milk transfer. Regarding its average amount in milk, aluminum is also a significant contaminant. Turkey was found to have the highest aluminum level in milk in a study conducted in nine countries from different parts of the world (Zwierzchowski and Ametaj, 2018). Our study determined that Al reached the highest level, especially in summer, forming 148.0 formations in milk. However, no significant relationship was found between Al in water and feed and Al in milk.

The study detected cadmium at an average level of 0.02 μg/kg in milk. Cadmium is present in all foods but in low concentrations (0.1 mg/kg) (WHO, 2010). In this regard, our milk samples include significantly lower amounts of cadmium. A study found cadmium levels in drinking milk were between 0.055 and 0.184 mg/kg. The cadmium content in milk samples taken from animals raised in industrial zones and rural areas far from highways was lower than in areas where industrialization progressed in this study conducted to determine the effect of environmental pollution (Temurci and Güner, 2006). In the milk samples taken from the industrial regions of India, the researchers detected Cd at the level of 0.18 mg/L (Yasotha et al., 2021). Compared to these studies, the Cd level of our study's milk samples was quite low.

Nickel's connection to food begins with polluted soils. Nickel residues are found in different amounts in vegetables and fruits grown in these soils. Nickel is also a significant contaminant in all of the samples. Vegetables (0.80–9.2 mg/kg dry weight) and legumes (3.47–7.0 mg/kg dry weight) were found to have the highest nickel concentration in contaminated areas in the studies (Onianwa et al., 2000), followed by oatmeal (0.80–4.7 g/g) and peas (0.13–0.8 g/kg) (Flyvholm et al., 1984). Additionally, agricultural areas in urban areas contain higher nickel than agricultural areas in rural areas, and industrial activity is shown as the main reason for this situation (Demirezen and Aksoy, 2006). Relatively, less nickel is detected in milk than in agricultural products. In their study, Alexander and Rohman (2019) detected Ni at 0.1396 ± 0.0045 mg/L in milk samples (Alexander and Rohman, 2019). According to the study results, there is an average of 16.61 μg/kg in water samples, an average of 2124.75 μg/kg in feed, and 98.50 μg/kg in milk. In this context, our study suggests that milk transport containers may contaminate the low amount of nickel in water compared to milk. Ni is also known as the main pollutant of heavy metals in volcanic regions, especially soils, which are specially minted with Ni (Yang et al., 2022). It is thought that feeding the cows whose milk is examined with feed prevents contamination from the soil.

Table 3 shows that the variation of the sample type creates a significant difference in all trace element's contents. But the study shows that water and feed do not affect the presence of heavy metals in milk. However, the presence of arsenic in milk is affected by feed and water. In studies, heavy metals in milk have been related to contaminated water and feed (Enb et al., 2009). Yasotta et al. found significant ($P < 0.05$) positive relationships between Cu, Cr, Pb, and Cd concentrations in milk and environmental samples (water or feed) in their current study (Yasotha et al., 2021). At the same time, the determination of residual metal content in milk is regarded as an indirect indicator of the sanitary quality of the milk as well as the degree of contamination in the environment in which it is produced (González-Montaña et al., 2012). According to studies, several heavy metals can be identified in milk for many reasons. The importance of heavy metal contamination in milk from different countries and areas has been highlighted in numerous research (Pavlovic et al., 2004). While Abou-Arab found 0.05 mg/kg lead and 0.348 mg/kg cadmium in raw milk in the study (Abou-Arab, 1991), Bilandžić et al. (2011) detected lead in milk that was above the maximum residue limit in their research in Croatia (Bilandžić et al., 2011). In another study, Researchers studying camel milk found cadmium, lead, arsenic, nickel, and aluminum levels of 0.4–1 - 0.2–3 and 51 ng/g, respectively (Ahamad et al., 2017). This reveals that heavy metals in the environment are transmitted to dairy animals via feed and drinking water, digested in their bodies, and passed into the milk. Even studies show that milk transport containers can contaminate heavy metal t containers (Tajkarimi et al., 2008).

Fig. 1 shows a graph of trace element levels for all samples based on their average values. Arsenic levels were determined to be greater than other heavy metal concentrations, especially in water, as seen in the figure. The waterways in and around Aksaray province are known to be contaminated with arsenic due to geographical factors (Altaş et al., 2011). It can be said that lead and aluminum levels are especially high in feed. Feed, on the other hand, is regarded as a vital source of all heavy metal content. This is thought to be due to increased dry matter content from drying the feed. When evaluating milk, the levels of Al (96.15 μg/kg) and Ni (98.50 μg/kg) is remarkable. Afterward, the amounts of As (0.98 μg/kg), Pb (0.88 μg/kg), and Cd (0.02 μg/kg) were determined in our milk samples, respectively. In a study conducted in Pakistan, researchers emphasized that lead, cadmium, and copper were found in high amounts in milk in some regions (Ismail et al., 2015). It has been reported that toxic heavy metals (Hg, Cr, Cd, Pb, and As) were detected in milk and dairy products in 16 studies conducted in 20 provinces of China (Yan et al., 2022). On the contrary, in a different study in which 64 milk samples were examined, it was reported that there was no heavy metal in milk samples (except copper) at a level that could pose a risk (Hasan et al., 2022). These different results are thought to be due to the regional and different variables of heavy metal pollution.

As another parameter, sampling at different seasons also affected trace element levels in the water, milk, and feed. It was detected that the arsenic level of the milk taken at different seasons was affected by this process. While a significant relationship was detected between As and Cd in the feed and the seasons, the seasonal changes did not affect the presence of trace elements in the water. As important data of the study, it was also noted that sampling at different times significantly changed the levels of arsenic, nickel, and lead in milk. A similar study emphasized that the level of lead in milk changes depending on the seasons (Limani and Karapetkovska-Hristova, 2022). On the other hand, they reported that seasonal variation did not affect the Pb level (Pastorelli et al., 2023). The level of arsenic in the samples was also higher than in other purchases, especially in the summer. All levels are generally similar, implying that they are unaffected by seasonal changes. Seasonal changes, according to studies, affect the number of heavy metals in milk (Shahbazi et al., 2016).

Moreover, there was no significant relationship between the distance to Hasandağı and the discovery of trace elements in milk, water, and feed. However, it is also observed that the amount of arsenic in the samples decreases partially as one moves away from Hasandağı. The increase in arsenic levels around Hasandağı due to volcanic activity was interpreted as the cause of this situation. LookingLooking at the situation regarding milk, it can be concluded that the level of trace elements in the milk does not alter greatly with distance. In another study conducted in Egypt, lead and cadmium levels of milk taken from different regions were found to be above acceptable levels (El Sayed et al., 2011).

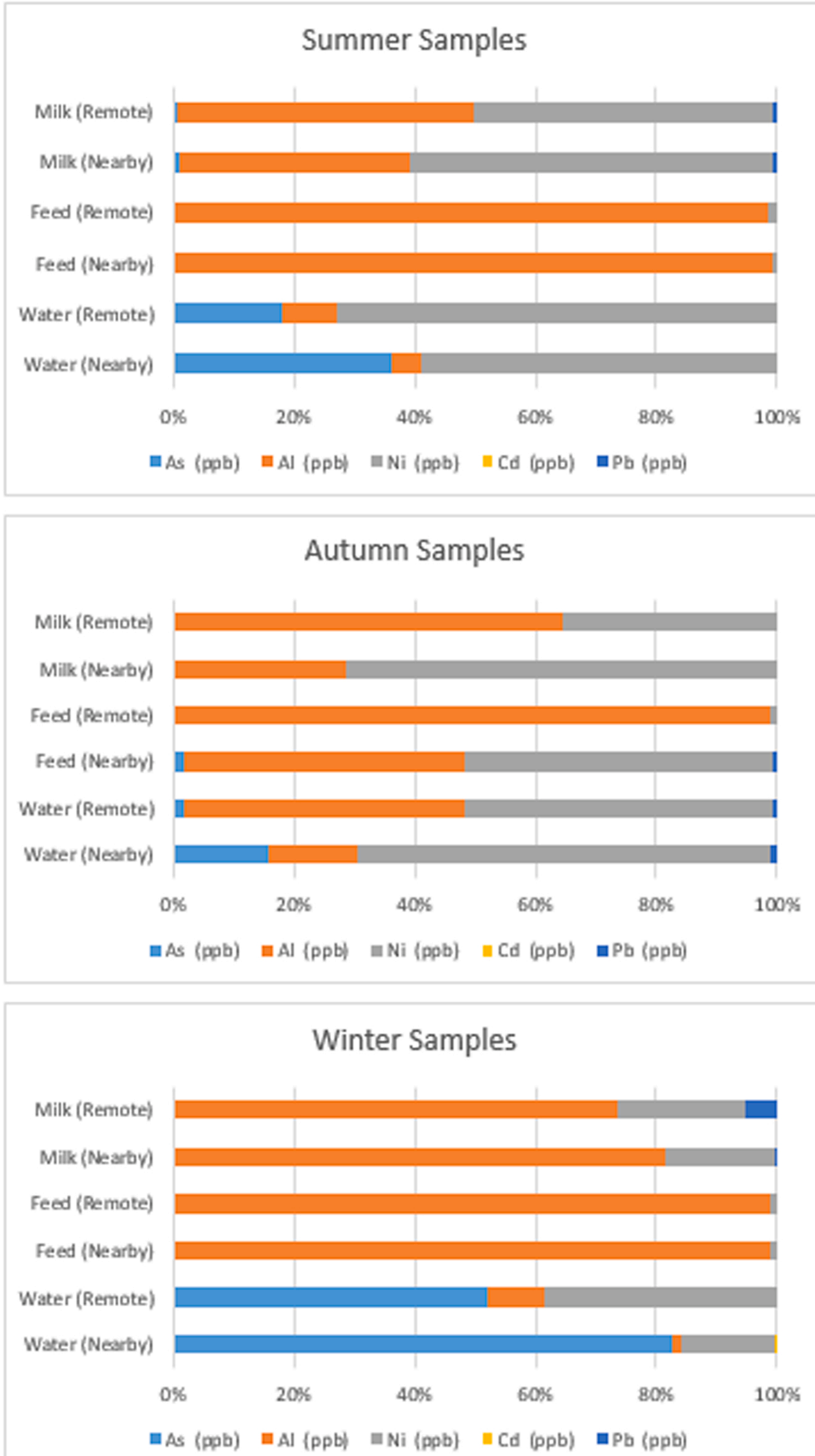

Fig. 1. The frequency trace elements levels of the samples.

In another study, Cd, Ni, and As are important ecological contaminants and risk factors in volcanic regions (Yang et al., 2022). Vargas-Solana et al. (2019) emphasize that Pb levels in volcanic regions are above acceptable limits (Vargas-Solano et al., 2019). Unlike these studies, regional differences did not create significant changes in our study. It is thought that this situation may yield better results with studies to be conducted in wider geographical areas.

It was expected that by accomplishing this preliminary study, the risk parameters, risky trace elements, and corrective activities might be determined (Table 4 – Fig. 2). In this context, it has been found that a simple home-type filtration system designed specifically for milk producers will provide an advantage in terms of major regional contaminant arsenic. It was also observed that the iron, cobalt, nickel, copper, and zinc level decreased with the filtration. However, it was also

Table 4
Aksaray province waters and packaged water analysis results in μg/kg.

Samples	Al	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
Packaged water	1.471	0.392	16.97	0.079	4.37	1	1.088	0.899	<LOQ	1.935
Tap water 1	1.253	0.595	43.87	0.566	13.61	98.51	718.500	6.191	0.049	0.747
Tap water 2	9.313	0.903	54.84	10.96	2.484	557.700	6.634	2.562	10.77	0.793
City water 1	2.225	0.597	17.85	0.129	4.731	7.598	76.19	5.755	0.004	0.449
City water 2	24.46	0.99	39.18	0.412	10.68	11.69	61.02	6.314	0.021	0.503
Treated water	17.250	6.544	40.28	3.433	0.738	36.45	<LOQ	0.049	11.51	1.454

City Water 1 and City Water 2 are samples from two different taps in the same building.
City Water 1 and 2 and Tap Water 1 and 2 are samples taken from different locations in Aksaray.
A treated water sample is taken from a tap with a domestic treatment system. This water was taken from the same line as tap water 2.

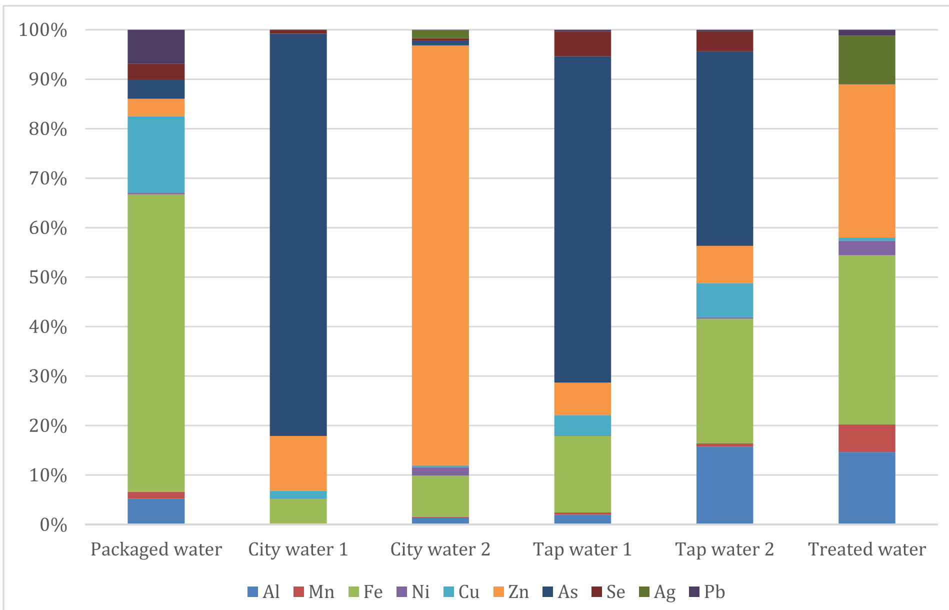

Fig. 2. Aksaray province waters and packaged water analysis results. City Water 1 and City Water 2 are samples from two different taps in the same building. City Water 1 and 2 and Tap Water 1 and 2 are samples taken from different locations in Aksaray. A treated water sample is taken from a tap with a domestic treatment system. This water was taken from the same line as tap water 2.

determined that the filter system did not affect the amount of aluminum, manganese, cadmium, and lead. Compared to the waters of Aksaray province, it is observed that the waters taken from the farms are high in terms of As and Ni. Other heavy metals are at similar levels.

Heavy metals in milk and dairy products can be caused by pollution, feed, and packaging materials surrounding the farm. Metal elements can be transferred via soil-silage-milk, water-silage-milk, water-milk, and air-milk routes. However, clear data are needed on which pathway is responsible for which metals and how much (Yan et al., 2022). In addition to environmental conditions influencing heavy metal levels in food, the foods consumed, dietary habits, and individual factors all play a role in heavy metal consumption. The type and amount of heavy metals consumed vary substantially depending on dietary habits (Roychowdhury et al., 2002), and studies suggest that characteristics such as age, gender, lifestyle, and pregnancy affect heavy metal toxicity. Individual variability in the number of heavy metals consumed in food and excreted in urine can be explained by the kinetics of heavy metals in the body (Amzal et al., 2009).

4. Conclusion

In conclusion, once the data analysis was completed, a general evaluation of the trace elements-milk relation in Aksaray province, a major dairy producer, was conducted. In addition, samples from different parts of Aksaray province and packaged water were evaluated as part of the preliminary research that provides a basis for the study's beginning. The analysis results of water and packaged-treated water samples received from different regions of Aksaray.

The most important result of the study was that around Hasandağı were contaminated areas, especially in terms of feed and water, but the milk was not contaminated at the same level. While heavy metals are digested in the body of animals, the majority of them accumulate. In this regard, examining the internal organs of the animal, especially the liver, will provide significant findings for future research.

Another important result of the research is that seasons affect trace element levels in milk, feed, and water samples. Accordingly, As, Ni, and Pb levels in milk are affected by seasonal changes. However, there is no significant relationship between the heavy metal level in the water and the seasons. In the study, milk's highest heavy metal level was 182.08 μg/kg at the nickel level in summer.

Due to the toxic effects of trace elements, it is critical for public health to determine the types and amounts of trace elements regionally and to take the required precautions. This study is also expected to be a first step in moving such research forward. Since heavy metal and metalloid residues are environmental contaminants, it is important to conduct regional studies.

An important outcome of the study is that filtration's advantages, use, and investigation should be evaluated. Arsenik, an important trace element in the region, has been significantly eliminated by the filtration system. As a result of the study, it is recommended to expand the use of filtration systems in farms near Hasandağı.

One of the research hypotheses was that the distance to the volcanic region would change the level of trace elements in the samples. However, no correlation was found between the distance to Hasandağı and the trace elements in the samples. It is thought that conducting the study in a wider geographical area will make sense of the data on distance.

CRediT authorship contribution statement

Sena Özbay: Conceptualization, Formal analysis, Writing – original draft. **Emrah Dikici**: Validation, Investigation, Writing – review & editing. **Caner Soylukan**: Validation, Investigation, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflict of interest in this work.

Data Availability

No data was used for the research described in the article.

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