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LEAD LEVELS IN MILK AND ITS PRODUCTS FROM VARIOUS ENVIRONMENTS IN EGYPT

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ABSTRACT. Milk and its products are considered healthy due to their content of key nutritional elements. Despite their essential role in the human diet, they may be susceptible to contamination with many chemical pollutants from the surrounding environment, most notably heavy metals such as lead, which is considered toxic to consumers. This study evaluated lead concentrations in milk and dairy product samples collected from various Egyptian environments. The results showed significant differences ($p < 0.05$) in Pb concentrations in the samples collected from different environments in Egypt (industrial, traffic and rural). The average lead content in raw cow's milk, sterilised milk, Domiati cheese, Ras cheese, processed cheese and yoghurt samples from industrial areas were 2.23, 0.33, 3.19, 5.10, 0.11 and 0.09 mg/kg, respectively. In traffic areas, lead concentrations were 1.83, 0.30, 2.72, 4.72, 0.13 and 0.09, and in rural areas, they were 0.61, 0.27, 1.52, 3.13, 0.13 and 0.09. The data showed that Pb levels in dairy product samples collected from industrial areas are very high compared with those collected from traffic areas. By contrast, the lowest Pb concentrations were recorded in samples from rural areas. It is recommended that lead levels in different foods, especially milk and its products, be evaluated at regular intervals.

Keywords: dairy products; environments; lead; milk.

INTRODUCTION

Milk and its products are considered healthy foods because they contain important sources of essential nutrients for the body that cannot be easily obtained from plant foods. These elements include proteins, fats, carbohydrates, minerals and vitamins. The importance of these elements increases in vulnerable groups during the main stages of life, such as pregnancy and lactation, childhood, adolescence and older age (FAO, 2023). Milk protein is a complete protein vital for growth, cell restoration, immune system regulation and muscle mass augmentation throughout the body. Milk also contains various fatty acids, whether saturated or non-saturated, which benefit health. Milk carbohydrates include milk sugar (lactose) and other sugars such as galactose and fructose, along with many nitrogen-containing carbohydrates that fuel the body's activities and generate heat. Regarding minerals, among the most important are calcium, which is necessary to maintain healthy teeth and bones and reduce the risk of osteoporosis with age; potassium, which is essential for the functioning of organs and tissues, including the heart, brain, muscles and nerves; zinc, which helps the immune system to function and plays a role in metabolism and magnesium, which is essential for nerve and muscle functions. Among the vitamins in milk, the most important are those that are soluble in fat (A, D, E, K), as well as B12 and B1, which are necessary for the health of the nervous system, muscles and cells.

Despite the benefits of dairy products for humans, they may contain traces of some environmental pollutants present near milk production outlets, such as toxic heavy metals. According to the toxicity of some heavy metals and potential human exposure to them, ATSDR (2022) has listed lead as the second priority contaminant in food. In addition, IARC (2023) indicated that inorganic lead is considered a group 2A carcinogen. Accordingly, the presence of toxic metals in milk indicates the cleanliness of the production environment (Kwon *et al*., 2017). Therefore, evaluating the levels of toxic metals in dairy products is necessary to control the quality of the product and is an important public health measure.

Environmental pollution with lead is related to different sources such as lead alkyl additives in petrol (Filella and Bonet, 2017), as well as manufacturing processes, waste incineration and burning of coal; therefore, the presence of high levels of lead in places where factories and manufacturing processes abound is not surprising (Shammi *et al*., 2021). Also, contamination of milk and its products with lead may occur from other sources, including contamination of the original milk, the water used in production, or the equipment and utensils used in packaging and storage (Abdelkhalek *et al*., 2015).

The contamination of milk and its products with lead represents a major risk to consumer health due to its long-term toxic effects. Once lead enters the body, it is distributed to body organs such as the brain, liver, kidneys and bones and is stored in the teeth, where it accumulates over time (WHO, 2023). The magnitude of lead toxicity is highly related to the developmental stage, sex, means and timing of exposure, amount of intake, biodegradation, degree of absorption and disposal mechanisms (Sharaf *et al*., 2008). Therefore, continued exposure to lead, even in small doses, may cause serious human diseases, such as irregular blood functions, by reducing haemoglobin formation (Rahimi, 2013). In addition, lead can exert strong carcinogenic activity against vital tissues in the human body and influence various body systems, particularly the cardiovascular, nervous, renal and skeletal systems (Geraldes *et al*., 2016). Lead in milk is of particular concern to newborns and young children as they depend to a great extent on milk and dairy products for their diets (Aggarwal *et al*., 2022). A high level of lead may cause headaches, memory disturbances and immobility; loss of consciousness and death can occur due to neurological damage (Rehman *et al*., 2018).

The level of environmental pollution with lead depends on the type and intensity of activity. Industrial areas are those designated and planned for industrial development and may contain heavy industry companies such as iron steel, cement, forgings, chemicals etc. Despite the importance of industrial complexes to economies and for accelerating economic growth, the most important disadvantages are noise, traffic congestion, air pollution, sewage and health problems. Traffic areas are those crowded with traffic on the roads, whether pedestrians, vehicles, cars or other means of transportation. One of the most important negative effects of traffic congestion is the increased environmental pollution due to the increased use of cars and the resulting health problems. Rural areas are communities with very low population, traffic and industrial densities and are characterised by calm and clean air.

Recently, with the increasing interest in food safety, researchers have paid attention to research on pollution and contaminants and their danger to public health. In Egypt, due to the spread of industrial areas, which are famous for various industries, traffic areas characterised by traffic congestion and agricultural activities on a large scale, all with the daily use of dairy and its products, there has been an urgent need to evaluate the risks of lead in such products in these areas. From this standpoint, this study was conducted to determine lead levels in raw milk and some of its products from various Egyptian locations, including some industrial and traffic areas, and compare them to lead levels in rural areas during the summer and winter periods, as well as to detect unacceptably contaminated milk samples by comparing their lead levels to the maximum permissible limits.

MATERIALS AND METHODS

Description of the study areas

This study estimated the Pb concentrations in samples collected in three different environments in Greater Cairo, Egypt.

The first comprised the industrial areas of Helwan and Shoubra El-Kheima, which are among the most important industrial areas established in Egypt: the North Helwan Industrial area contains 16 factories, the Central Helwan Industrial area contains 10 heavy factories and the South Helwan Industrial area contains 6 factories in the field of iron and steel, as well as cement. The city of Shubra El Kheima includes many factories, most notably in textiles, ready-made clothing, light and consumer industries and factories of electrical cables, ceramics and concrete drainage pipes.

The second area is one of heavy traffic, represented by the Faysal area, one of those most crowded with cars and one of the largest and most densely populated residential neighbourhoods. It is a commercial area, and due to traffic congestion and population increase, this may lead to increased contamination of food exposed to the atmosphere.

The third area is rural, represented by some parts of El-Qaliubiya; these are rural areas far from factories and traffic, and samples were collected from farms and animal breeding facilities. *Figure 1* shows a map of the sampling sites in Greater Cairo, Egypt, including three areas (industrial, traffic and rural).

Materials

Standard solution and acids

Standard lead element solution with a concentration of 1000 mg litre, as well as high-quality concentrated nitric acid, were purchased from Merck (Merck, Darmstadt, Germany). Re-distilled water was used to dilute the samples and wash the tools used to prepare and estimate Pb in the various samples.

Milk and dairy products

A total of 480 samples of raw cow's milk and its products (160 of each area) belonging to six different products (raw cow's milk, sterilised milk, Domiati cheese, Ras cheese, processed cheese and yoghurt) were collected from industrial (Shoubra El-Kheima and Helwan), heavy traffic (Faysal) and rural areas (El-Qaliubiya) throughout the summer and winter seasons in Greater Cairo (Egypt) as shown in (*Table 1*), and the collected samples were stored at −20°C until analysis.

Methods and procedures

Milk and dairy product samples were extracted according to the AOAC (2000), and Pb contents were estimated with an atomic absorption spectrophotometer (PG- 990 Instruments Ltd) with a flame atomiser (air-acetylene), equipped with a 10-cm burner and a deuterium lamp for background correction.

Maximum absorbance was obtained by adjusting the cathode lamp to the proper wavelength (217.0 nm).

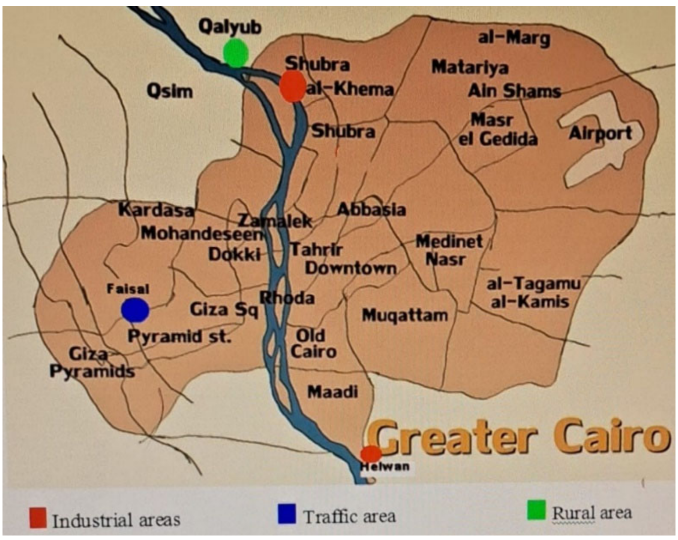

Figure 1 – A map of sampling sites in Greater Cairo, Egypt showing three districts (industrial, traffic and rural)

Table 1 – Milk and some dairy product samples collected from each area (industrial, traffic and rural) in Greater Cairo, Egypt

Items	Number	Sample description
1. Raw cow's milk	60	liquid
2. Sterilized milk	10	liquid
3. Domiati cheese	60	Semi-solid
4. Ras cheese	10	Solid
5. Processed cheese	10	Semi-solid
6. Yoghurt	10	Semi-solid
Total samples from each area	160	

The results obtained were statistically analysed according to the method of Snedecor and Cochran (1980). The least significant difference (L.S.D) test was used to determine significant differences between means and to separate means at ($p \leq 0.05$) using the SPSS package version 15.0.

Method validity

Quality assurance rules and precautions were implemented to ensure the reliability of the results, including thorough calibration of instruments, validation of methods and maintenance of cleanliness through washing and protocols to avoid contamination. To evaluate the efficiency of the method used to extract the samples, known lead concentrations (0.1, 0.2 and 0.4 mg/kg) were added to milk and Domiati cheese samples. The data showed that lead recovery in fortified samples was between 96.0% and 97.0% in milk and between 94.0% and 95.0% in Domiati cheese. The detection limit for lead was calculated and reported as 0.012 mg/L for both sample types.

RESULTS

The concentrations of Pb in raw and sterilised milk, Domiati cheese, Ras cheese, processed cheese and yoghurt collected from the three different environments were determined, and the data are presented in *Table 2* and *Figure 2*. The data revealed that Pb levels in the collected samples were differentiated according to the sample collection areas, and there were significant differences ($p \leq 0.05$) in lead concentrations. The results obtained indicate that the highest mean Pb concentrations were found in raw milk, sterilised milk, Domiati cheese and Ras cheese from industrial areas, which were 2.23, 0.33, 3.18 and 5.10 mg/kg, respectively.

However, the highest level of Pb in processed cheese and yoghurt was found in traffic areas, which recorded 0.13 and 0.09 mg/kg, consecutively. In addition, it was noted that there were no significant differences ($p \geq 0.05$) in lead concentrations between processed cheese samples collected from traffic areas and those collected from rural areas. Regarding the samples collected from rural areas, the mean concentrations of Pb were 0.61, 0.27, 1.52, 3.13 and 0.09 mg/kg in raw milk, sterilized milk, Domiati cheese, Ras cheese and yoghurt, respectively. These levels were lower than those detected in the other two areas.

Lead levels in raw milk and its products in the present study were determined during two periods, summer and winter. The data in *Table 3* show that the highest Pb concentrations were found in samples collected from industrial and traffic areas during the winter season, which were recorded as 2.87 and 2.07 mg/kg, respectively, but no significant differences ($p \geq 0.05$) were found between Pb concentrations in samples collected from rural areas in the summer and winter.

Statistical analysis confirmed that Pb concentrations in industrial and traffic areas differed significantly between the winter and summer ($p \leq 0.05$).

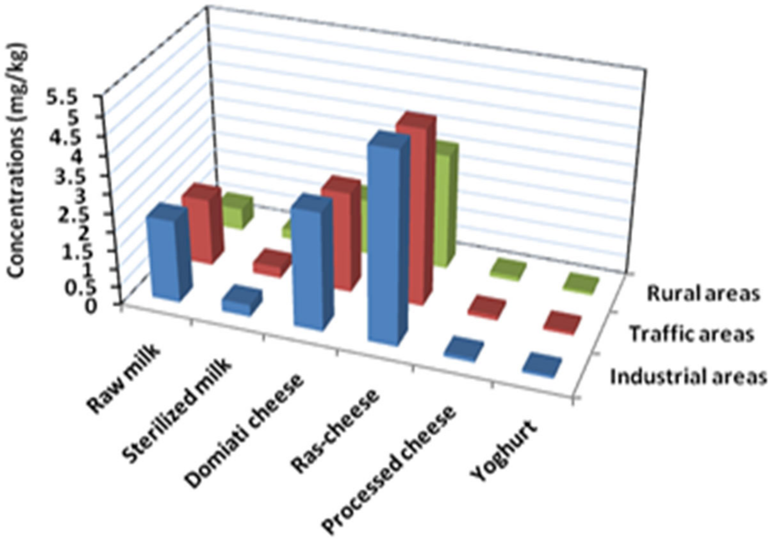

Figure 2 – Lead levels (mg/kg) in milk and some dairy products collected from industrial, traffic and rural areas in Greater Cairo, Egypt

Table 2 – Lead levels (mg/kg) in milk and some dairy products collected from industrial, traffic and rural areas in Greater Cairo, Egypt

Milk and its products	Concentrations (mg/kg)						LSD at 5%
	Industrial areas		Traffic areas		Rural areas		
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	
Raw cow's milk	2.23a±0.23	0.02–9.14	1.83b±0.07	0.54–7.37	0.61c±0.04	0.06–2.09	0.37
Sterilized milk	0.33a±0.03	0.07–0.70	0.30ab±0.03	0.05–0.52	0.27b±0.02	0.04–0.80	0.12
Domiati cheese	3.18a±0.19	1.06–9.05	2.72b±0.14	1.02–6.06	1.52c±0.06	0.52–3.60	0.44
Ras cheese	5.10a±0.10	2.37–8.19	4.72a±0.16	3.08–7.13	3.13b±0.18	2.01–4.43	1.50
Processed cheese	0.11b±0.02	0.05–0.17	0.13a±0.02	0.07–0.23	0.13a±0.02	0.05–0.23	0.11
Yoghurt	0.09b±0.02	0.02–0.29	0.09a±0.02	0.03–0.22	0.09b±0.02	0.03–0.33	0.10

All values are means of sample number determinations in each area ± standard deviation (SD). Means within columns with different letters are significantly different ($p \leq 0.05$). (%) samples outside the maximum permissible level of Pb (0.02 mg/kg wet weight) set by the commission regulation (EUR-Lex, 2015) were 100%

Table 3 – Lead levels (mg/kg) in milk and some dairy products collected from industrial, traffic and rural areas in the summer and winter seasons

Areas	Mean concentrations (mg/kg) ±SD		LSD at 5%
	Summer	Winter	
Industrial	2.18b±0.02	2.87a±0.13	0.51
Traffic	1.99b±0.07	2.07a±0.11	0.42
Rural	1.04a±0.07	0.97a±0.09	0.24

(%) samples outside the maximum permissible level of Pb (0.02 mg/kg wet weight) set by the commission regulation (EUR-Lex, 2015) were 100%

DISCUSSION

Milk and dairy products are a key component of the human diet and are considered by diverse cultures as one of the main food groups, as they contain many essential minerals, vitamins, proteins, fats and carbohydrates (FAO, 2023). Despite these benefits, milk and dairy products may contain traces of some environmental pollutants generated near milk production outlets, such as toxic metal elements. The levels of toxic metals in the environment are increasing with increasing industrial or agricultural emissions (Ngo *et al*., 2021). Lead is considered one of the most important toxic metals transferred to dairy products and other foods and causes major health problems for the consumer. Many sources cause the transfer of lead to dairy products, including direct pollution through pastures and crops used as animal feed and soil pollution (Gakidou *et al*., 2017), water used in production, equipment and tools used in packaging and storage (Abdelkhalek *et al*., 2015) and environmental emissions resulting from industrial practices close to milk production outlets (Ngo *et al*., 2021).

The lead levels in milk and its products vary according to the degree of contamination of production environments and animal feed (Bousbia *et al*., 2019). In the current study, the lead content of milk (raw and sterilised) and dairy products (Domiati cheese, Ras cheese, processed cheese and yoghurt) was high in all three environments. The results revealed that the highest concentrations of Pb were recorded in samples collected from industrial areas, followed by traffic, and then rural areas. The data showed that Domiati and Ras cheese contained high levels of lead compared to other dairy products, and this may be due to the transfer of lead from milk to cheese during manufacturing processes. Also, heat evaporation during the manufacture of milk products concentrates the milk, thus concentrating pollutants in the final products.

In addition, some studies have proven that lead is linked to milk caseins, which are transferred to the curd during the coagulation step in cheese processing (Yabrir, *et al*., 2016). On the other hand, lead in raw milk may be due to the contamination of drinking water and animal feed with lead due to industrial waste, which is secreted in milk.

When the concentrations of Pb in samples collected from the three environments were compared with the permissible limits, the data indicated that the mean Pb levels were higher than the maximum permissible level of 0.02 mg/kg wet weight set by the commission regulation (EUR-Lex, 2015).

From the results obtained, there are differences in lead levels according to the locations where the samples were collected, as follows.

Industrial areas

Considering the levels of Pb in milk and dairy product samples collected in this study from industrial areas (Helwan and Shubra El Kheima), the average concentrations were 2.23, 0.33, 3.18, 5.10, 0.11 and 0.09 mg/kg in raw milk, sterilised milk, Domiati cheese, Ras cheese, processed cheese and yoghurt samples, respectively (*Table 2* and *Figure 2*). Comparing these levels of Pb with those of other levels in previous Egyptian research, Khalil (2018) reported a large discrepancy between the metal contents in the sites of Aswan, especially Edfu, Kom-Ombo and Toshka, where the concentrations of heavy metals were higher in the city of Edfu compared to other sites.

The variations were due to the intensity of industrial activity, which is higher in the city of Edfu than in the city of Toshka, which is considered a non-industrial area. In the Egyptian Beni Suef Governorate, Abdou *et al.* (2017) reported that mean Pb levels in raw milk samples collected from traditional and industrial sites from four various locations in Beni Suef were 0.40, 0.18, 0.28 and 0.38 (mg/kg) in Somosta (famous for agriculture and fishing), Ehnasia (famous for urban and agricultural projects), Beni Suef (famous for cement factories and other agriculture-based industries such as cotton ginning and textile manufacturing) and Naser (famous for manufacturing and exporting handmade carpets), respectively (*Table 4*). In addition, El Sayed *et al.* (2011) reported that cow's milk samples collected from Helwan and Shubra recorded Pb levels 0.28 and 0.58 mg/kg, consecutively (*Table 4*).

A comparison of Pb levels in this study with those in studies conducted in Romania (Miclean *et al.*, 2019), India (Kumar, 2019), Iran (Sobhanardakani, 2018) and Kazakhstan (Sarsembayeva *et al.*, 2020) revealed lower Pb concentrations of 24.0, 0.21, 32.83 and 11.60 µg/kg, respectively (*Table 4*). In China, Su *et al.* (2021) reported that the highest Pb concentration (2.68 µg/kg) in raw milk (*Table 4*) was detected in Tianjin, which was in an industrial area compared to Pb levels (2.29 µg/kg) in raw milk samples from Hohhot (non-industrial area). They reported that the levels of metals in raw milk vary in some areas due to the differences in contamination levels (Boudebbouz *et al.*, 2021). In Poland, Sujka *et al.* (2019) reported that the Pb content in samples of dairy and milk products was related to the level of industrialisation in the sample collection area. Higher levels of Pb were found in products from Silesia (the most industrialised region of Poland) than in those from the other (non-industrialised) regions, which recorded a mean value of 0.23 mg/kg.

In 2022, Zyambo *et al.* (2022) studied the extent of Pb contamination of cow's milk from cattle raised near a Pb and zinc mine in Kabwe, Zambia. They reported that Pb levels in cow's milk had different concentration patterns depending on the season, distance and location of the farmer from the Pb and zinc mine, with average Pb levels generally ranging between 0.60 and 2.22 µg/kg and 0.50 and 4.24 µg/kg in the wet and dry seasons, consecutively. In

Rajasthan, a state in northern India, Ram Bilas Meena, Meena and Dakshene (2022) reported that mean Pb levels were 0.15 mg/kg (*Table 4*).

Generally, Pb contamination levels in milk and dairy products in industrial areas depend on several factors related to geographical locations and the extent of industrial activity as well as the resulting exhausts and the Pb they carry in these sites, which contaminates animal feed, water and soil (Meshref *et al*., 2014).

Moreover, the food chain is subject to Pb contamination as a result of absorption by plants from the polluted environment (Nachiyunde *et al*., 2013); consequently, Pb accumulates in the body and tissues of farm animals and is excreted in milk (Younus *et al*., 2016). In addition, climatic conditions, the lactation period of farm animals and animal feed ingredients may have a significant impact on Pb levels in milk (Bousbia *et al*., 2019).

Traffic areas

This study reported the extent of contamination of milk and its products by Pb in traffic areas in Cairo that suffer from traffic and population congestion, such as the Faysal area specifically, the sample collection area. The results indicated that the Pb content in the samples of milk and its products under investigation was high. The mean levels of Pb in raw milk, sterilised milk, Domiati cheese, Ras cheese, processed cheese and yoghurt were 1.83, 0.30, 2.72, 4.72, 0.13 and 0.09 mg/kg, respectively (*Table 2* and *Figure 2*).

In general, Pb levels in the samples of dairy products during this research were higher than those in some other Egyptian studies. This may be due to many causes, the most important of which is the heavy traffic in the sample collection area and the accompanying Pb exhaust that pollutes the environment. Therefore, the main source of Pb in this area is heavy traffic emissions, although many Egyptian national projects are using unleaded gasoline and natural gas cylinders. The level of Pb in the atmosphere varies from one country to another, depending on the density of motor vehicles.

Previous Egyptian studies (*Table 4*) confirmed high lead concentrations in raw milk and its products from local markets, some of which were higher than the permissible international levels. A comparison of lead levels in raw milk in the present study with those in studies conducted in Cairo (Abou-Arab *et al*., 2008), Alexandria (Amer *et al*., 2021), Beni-Suef (Meshref *et al*., 2014), Mansoura (Elafify *et al*., 2023), Damanhour (Saleh *et al*., 2019) and Assiut (Wafy, 2019) reported lower Pb concentrations of 0.03, 0.05, 0.21, 0.10, 0.11 and 0.08 mg/kg, respectively. By contrast, Malhat *et al*. (2012) detected higher levels of Pb in El-Qaliubiya in 2012. On the other hand, Khalil (2018) found that Pb concentrations in the types of buffalo milk, cow's milk, goat's milk and sheep milk samples collected from the markets of Aswan City varied, as these concentrations ranged between (0.16 and 0.73), (0.21 and 0.43), (0.14 and 0.25) and (0.15 and 0.74 mg/kg), respectively. In general, these concentrations are lower than those detected in the current study. Regarding Pb levels in sterilised milk, the data proved that these levels were higher than those detected in Cairo (Abou-Arab *et al*.,

2008) and Alexandria (Gomaa *et al*., 2008), which recorded 0.02 and 0.21 mg/kg, consecutively.

Concerning Domiati cheese, the data indicated that Pb concentrations were higher than those detected in Alexandria (Abo El-Makarem *et al*., 2019) and Aswan (Khalil, 2018), which had mean values of 0.26 mg/kg and (0.11–0.17 mg/kg), respectively (*Table 4*). Concerning Ras cheese, Pb concentrations were higher than those detected in the samples collected from El-Qaliubiya markets, which averaged 1.33 mg/kg (Elbarbary and Hamouda, 2015).

Table 4 – Lead levels in raw milk and its products reported in the different countries studied (mg/kg)

Reference	Country	Characteristics of the collection	Mean Pb levels in milk	Mean Pb levels in dairy products
Khalil (2018)	Egypt	Aswan: Markets	Buffalo milk (0.16–0.73) Cow's milk (0.21–0.43) Goat milk (0.14–0.25) Sheep milk (0.15–0.74)	Domiati cheese (0.11 to 0.17)
Abdou *et al.* (2017)	Egypt, Beni Suef Governorate	Somosta: It is famous for agriculture. Ehnasia: It is famous for urban projects. Beni Suef: It is famous for cement factories. Naser: It is famous for manufacturing and exporting handmade carpets.	0.40 0.18 0.28 0.38	
El Sayed *et al.* (2011)	Egypt	Helwan: Industrial area Shubra: Industrial area Awseem: Farms Menofia: Farms Mansoura: Farms Gharbia: Farms	0.28 0.58 0.14 0.61 0.14 0.14	
Miclean *et al.* (2019)	Romania	Free-range cattle farms situated near Baia Mare	0.024	
Kumar (2019)	India	Haryana state: Rural areas	0.002	
Sobhanardakani (2018)	Iran	Hamadan City: Markets	0.032	
Sarsembayeva *et al.* (2020)	Kazakhstan	Almaty region: Farms	0.011	
Su *et al.* (2021)	China	Tianjin: Industrial area Hohhot: Non-industrial area	0.003 0.002	
Sujka *et al.* (2019)	Poland	Silesia: The most industrialized regions of Poland	0.23	
Zyambo *et al.* (2022)	Zambia	Kabwe: Pb -zinc mine	0.0.001–0.002	

Meena and Dakshene (2022)	India	Rajasthan: Rural and urban areas	0.15	
Abou-Arab *et al.* (2008)	Egypt	Cairo: Markets	0.03	
Amer *et al.* (2021)	Egypt	Alexandria: Samples were collected from artisanal producers	0.05	
Meshref *et al.* (2014)	Egypt	Beni-Suef: Farmers and dairy shops	0.21	
Elafify *et al.* (2023)	Egypt	Mansoura: Farmers, supermarkets, and vendors	0.10	
Saleh *et al.* (2019)	Egypt	Damanhour: Farms and pharmacies	0.11	
Wafy (2019)	Egypt	Assiut: Farmers, dairy shops, and street vendors	0.08	
Malhat *et al.* (2012)	Egypt	El-Qaliubiya: Benha, Kaha, Shebin El-Kanater, Tokh and KafrShokr farms	1.850, 3.500, 2.900, 4.404 and 3.053	
Gomaa *et al.* (2008)	Egypt	Alexandria: Local market	0.21	
Abo El-Makarem *et al.* (2019)	Egypt	Alexandria: Supermarkets and groceries		Domiati cheese (0.26)
Elbarbary and Hamouda (2015)	Egypt	El-Qaliubiya: Markets		Ras cheese (1.33) Processed cheese (0.57)
Hussien and Nosir (2017)	Egypt	Menofia: Markets		Processed cheese (0.43)
Abd EL Rahim *et al.* (2012)	Egypt	Assiut: Markets		Processed cheese (0.02)
Enb *et al.* (2009)	Egypt	Mansoura: Farms	Raw buffalo's milk (0.08) Raw cow's milk (0.07)	
Ateteallah *et al.* (2015)	Egypt	Sohag and Qena governorates: Villages	Raw buffalo's milk (0.09)	
Mansour *et al.* (2019)	Egypt	Sharkia: Farms and dairy shops	Raw cow’s milk (2.68) Raw buffaloes' milk (2.04) Raw sheep’s milk (2.78) Raw goat’s milk (1.85) UHT milk (1.94)	Kariesh cheese (2.26)

Bilandžić *et al.* (2016)	Croatia	Rural areas	Raw milk (0.011)
Sharifi, *et al.* (2022)	Iran	Tehran: Farms	Raw milk (0.003–0.19)

Regarding Pb levels in processed cheese, they were lower than those detected in El-Qaliubiya (Elbarbary and Hamouda, 2015) and Menofia (Hussien and Nosir, 2017) samples, which were 0.57 and 0.43 mg/kg, respectively, and higher than those detected in Assiut samples (Abd El Rahim *et al*., 2012), which averaged 0.02 mg/kg. The results obtained show the variation in Pb levels in the collected samples. The levels of Pb in Domiati cheese and Ras cheese were much higher than the Pb percentage in milk and other products. This may be due to the type of milk used in manufacturing cheese, in which the level of Pb in cheese is concentrated, as well as the type of salt used (NaCl) in the cheese-making process (Abou-Arab and Abou Donia, 2002).

Similar results were obtained in France (Maas *et al*., 2011) and Romania (Năstăsescu *et al*., 2020); conversely, higher mean concentrations of Pb were detected in the Iğdır region in Turkey (Koyuncu and Alwazeer, 2019).

Rural areas

Regarding rural area samples in the present study, the data showed significantly lower Pb levels in raw milk, sterilised milk, Domiati cheese and Ras cheese than those detected in industrial and traffic areas, where the mean concentrations recorded were 0.61, 0.27, 1.52 and 3.13 mg/kg, respectively (*Table 2* and *Figure 2*). As for Pb concentrations in the three areas from which samples of processed cheese and yoghurt were collected, their lead concentrations were very similar.

However, average Pb concentrations in rural area samples were higher than international permissible limits. Several studies in Egypt regarding the contamination of milk and its products collected from rural areas confirmed that Pb concentrations were higher than permissible international limits. In the present study, Pb levels were higher than those detected in Mansoura (Enb *et al*., 2009) as well as Sohag and Qena governorates (Ateteallah *et al*., 2015), which were 0.08 in raw buffalo's milk and 0.07 mg/kg in raw cow's milk and 0.09 mg/kg in raw buffalo's milk, respectively (*Table 4*). El Sayed *et al*. (2011) reported that the mean concentrations (mg/kg) of lead in raw milk samples collected from farms in Awseem, Menofia, Mansoura and Gharbia were 0.14, 0.61, 0.14 and 0.14, respectively, while Abdou *et al*. (2017) detected Pb levels in raw cow's milk samples from four dairy farms in different cities representing Beni Suef governorate, Egypt.

It was shown that the average Pb concentrations were 0.40 (Somosta City), 0.18 (Ehnasia City), 0.28 (Beni Suef City) and 0.38 mg/kg (Naser City). In addition, Mansour *et al*. (2019) reported that mean Pb levels in the samples of milk and dairy products collected from Sharkia governorate, Egypt were 2.68, 2.04, 2.78, 1.85, 1.94 and 2.26 (mg/kg) in raw cow's milk, raw buffaloes' milk, raw sheep's milk, raw goat's milk, UHT milk and Kariesh cheese, respectively. The mean values of Pb in the examined samples reported herein were relatively higher than those obtained for raw milk (*Table 4*) by Bilandžić, (2016) in Croatia (11.40 µg/l), Ram Meena (Meena and Dakshene, 2022) in Rajasthan, India (0.04 mg/kg) and Sharifi (Sharifi *et al*., 2022) in Tehran province from Iran (0.003–0.19 mg/kg). Although Pb levels in rural areas were lower than those in industrial and traffic areas, Pb concentrations were higher than permissible international limits and higher than Pb concentrations in many local and international studies.

This may be due to many causes, such as raising pasture animals near industrial or traffic areas, which can be considered one of the possible causes of contamination of livestock feed and water, and as a result, high Pb contamination in raw milk.

Furthermore, the livestock farming environment and surrounding atmosphere may be contaminated with high concentrations of Pb, which in turn causes contamination of the milk at all stages of production.

Lead levels in the samples through the summer and winter seasons

The data revealed that Pb concentrations were variable among samples collected through two seasons (*Table 3*). There were significant differences ($p \leq 0.05$) in Pb concentrations between samples collected from industrial and traffic areas through the summer and winter seasons. This variation depends on the production season and regional differences (Saleh *et al*., 2019). It is worth mentioning that the differences in Pb levels between samples confirm its variation and instability in the environment and thus the varying levels of pollution due to seasonal variation. Some studies have been conducted on the seasonal variation in Pb levels in the environment and atmosphere. In one of the studies on the city of Cairo during the period from the winter of 1998 to the winter of 1999, Meshref *et al*. (2014) reported that Pb levels were high in the winter compared to the summer, and these levels decreased during the period 2001 and 2002 in the atmosphere of the Faysal region, but Pb levels were also higher in winter than in summer (Rehman *et al*., 2018).

CONCLUSIONS AND RECOMMENDATIONS

Therefore, the main source of Pb in the area is likely to be heavy vehicle traffic, although it is also possible that historical pollution entering the food chain via contaminated soils plays a role. Further studies/references are needed to confirm these findings.

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REFERENCES

Abdelkhalek, A.; Elsherbini, M.; Gunbaej, E.E. Assessment of heavy metals residues in milk powder and infant milk formula sold in Mansoura city, Egypt. *Alexandria Journal of Veterinary Sciences.* **2015**, 47, 71-77. http://dx.doi.org/10.5455/ajvs

Abd EL Rahim, A.M.; Mohamed, T.H.; Tammam, A.A. Assessment of toxic heavy metal residues in some types of cheese by using ICP-OES. *Journal of Food and Dairy Sciences*. **2012**, 3, 725-733. https://dx.doi.org/10.21608/jfds.2012.81743

Abdou, Kh.A.; Meshref, A.M.S.; Srour, S.M.; Mahmoud, H.A.; Mahmoud, N.H. Concentrations of Lead, Cadmium, Copper and Iron in Raw Cow's Milk in Beni Suef Province, Egypt. *European Journal of Academic Essays*. **2017**, 4, 239-250.

Abo El-Makarem, H.S.; Amer, A.A.; Abdel Naby, H.A. Prevalence of some dangerous heavy metal residues and aflatoxins in milk and some dairy products. *Alexandria Journal of Veterinary Sciences*. **2019**, 62, 158-165. http://dx.doi.org/10.5455/ajvs.

Abou-Arab, A.A.K.; Abou Donia, M.A.; Enb, A. Chemical composition, metals content and pesticide residues in raw, pasteurized and UHT milk and their dietary intake. *Egyptian Society of Clinical Toxicology Journal.* **2008**, 39, 111-121.

Abou-Arab, A.A.K.; Abou Donia, M.A. Lead content in Egyptian foods and the role of washing and peeling on its levels. *Egyptian Society of Clinical Toxicology Journal.* **2002**, 26, 13-21.

Aggarwal, A.; Verma, T.; Ghosh, S. Heavy Metal Residues in Milk and Milk Products and Their Detection Method. Trends and Innovations in Food Science. June 28th, 2022. https://www.intechopen.com/chapters/82436

Amer, A.A.; Abo El-Makarem, H.S.; El-Maghraby, M.A.; Abou-Alella, S.A. Lead, cadmium, and aluminum in raw bovine milk: Residue level, estimated intake, and fate during artisanal dairy manufacture. *Journal of Advanced Veterinary and Animal Research.* **2021**, 8, 454 - 464. https://doi.org/10.5455%2Fjavar.2021.h534

AOAC. Association of Official Analytical Chemists. Official Methods of Analysis, Metals and other elements at trace levels in foods. Published by AOAC International Suite 400 2200 Wilson Boulevard Arlington, Virginia, 22201-3301 USA. 2000.

Ateteallah, H.A.; Mohran, M.A; Abd EL Rahim, A.M.; Abd El Kher, A.A. Assessment of Cadmium and Lead in Buffalo's Raw Milk and its Rural Products in some villages of Sohag and Qena Governorates, Egypt. *Egyptian Journal Agricultural Research*. **2015**, 93, 1-11.

ATSDR. Agency for Toxic Substances and Disease Registry. Substance Priority List. Agency for Toxic Substances and Disease Registry; Atlanta, GA, USA: 2022. https://www.atsdr.cdc.gov/spl/#2022spl

Bilandžić, N.; Sedak, M.; Čalopek, B.; Lubirić, Đ.B.; Kolanović, B.S.; Varenina, I.; Đokić, M.; Kmetič, I.; Murati, T. Lead concentrations in raw cow and goat milk collected in rural areas of Croatia from 2010 to 2014. *Bulletin of Environmental Contamination and Toxicology.* **2016**, 96, 645-649. https://doi.org/10.1007/s00128-016-1749-z

Boudebbouz, A.; Boudalia, S.; Bousbia, A.; Habila, S.; Boussadia, M.I.; Gueroui, Y. Heavy metals levels in raw cow milk and health risk assessment across the globe: A systematic review. *Science of The Total Environment.* **2021**, 10.

https://doi.org/10.1016/j.scitotenv.2020.141830

Bousbia, A.; Boudalia, S.; Gueroui, Y.; Ghebache, R.; Amrouchi, M.; Belase, B.; Meguelati, S.; Belkheir, B.; Benidir, M.; Chelaghmia, M.L. Heavy metals concentrations in raw cow milk produced in the different livestock farming types in Guelma Province (Algeria): Contamination and risk assessment of consumption. *Journal of Animal and Plant Sciences.* **2019**, 29, 386-395.

Elafify, M.; EL-Toukhy, M.; Sallam, K.I.; Sadoma, N.M.; Abd-Elghany, S.M.; Abdelkhalek, A.; El-Baz, A.H. Heavy metal residues in milk and some dairy products with insight into their health risk assessment and the role of *Lactobacillus rhamnosus* in reducing the lead and cadmium load in cheese. *Food Chemistry Advances.* **2023**, 2, 100261. https://doi.org/10.1016/j.focha.2023.100261

Elbarbary, H.A.; Hamouda, A.F. Assessment of Some Trace Elements in Some Dairy Products and Table Eggs Retailed in Egyptian Markets. *Alexandria Journal of Veterinary Sciences*. **2015**, 47, 175-182. http://dx.doi.org/10.5455/ajvs.

El Sayed, E.M.; Hamed, A.M.; Badran, S.M.; Mostafa, A.A. A survey of selected essential and heavy metals in milk from different regions of Egypt using ICP-AES. *Food Additives and Contaminants*. **2011**, 4, 294-298. https://doi.org/10.1080/19393210.2011.639093

Enb, A.; Abou Donia, M.A.; Abd-Rabou, N.S.; Abou-Arab, A.A.K.; El-Senaity, M.H. Chemical Composition of Raw Milk and Heavy Metals Behavior During Processing of Milk Products. *Global Veterinaria*. **2009**, 3, 268-275.

EUR-Lex. European Union law. Commission Regulation (EU) No 2015/1005 of 25 June 2015 amending Regulation (EC) No 1881/2006 as regards maximum levels of lead in certain foodstuffs (Text with EEA relevance). Official Journal of the European Union, An official website of the European Union. 2015. http://data.europa.eu/eli/reg/2015/1005/oj

FAO. Meat, eggs, and milk, essential source of nutrients especially for most vulnerable groups, new FAO report says. FAO Organizational Chart 25/04/2023.

Filella, M.; Bonet, J. Environmental Impact of Alkyl Lead (IV) Derivatives: Perspective after Their Phase-out. From the book Lead: Its Effects on Environment and Health. Published by Walter de Gruyter GmbH, Berlin/Munich/Boston, 2017.

Gakidou, E.; Afshin, A.; Abajobir, A.A.; Abate, K.H.; Abbafati, C.; Abbas, K.M.; Abd-Allah, F.; Abdulle, A.M.; Abera, S.F.; Aboyans, V.; Abu-Raddad, L.J.; Abu-Rmeileh, N.M.E. Global, regional, and national comparative risk assessment of 84 behavioral environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*. **2017**, 390, 1345-1422. https://doi.org/10.1016/S0140-6736(17)32366-8

Geraldes, V.; Carvalho, M.; Goncalves-Rosa, N.; Tavares, C.; Laranjo, S.; Rocha, I. Lead toxicity promotes autonomic dysfunction with increased chemoreceptor sensitivity. *Neurotoxicology*. **2016**, 54, 170-177. https://doi.org/10.1016/j.neuro.2016.04.016

Gomaa, N.F.; Hashish, M.; Kassem, M.M. Quality Assessment of Milk in Alexandria. *Bulletin of High Institute of Public Health*. **2008**, 38, 290-305. https://dx.doi.org/10.21608/jhiph.2008.20888

Hussien, H.; Nosir, S. Assessment of Heavy Metals Residues in Some Food Stuffs and Its Biocontrol by Probiotic Strain Enterococcus facium (E980) In an Experimental Model. *Alexandria Journal* *of Veterinary Sciences*. **2017**, 52, 87-96. https://www.bibliomed.org/gotodoi.php?mno=253280&gdoi=10.5455/ajvs.

IARC. International Agency for Research on Cancer. Monographs on the Identification of Carcinogenic Hazards to Humans. World Health Organization, 25 avenue Tony Garnier, CS 90627, 69366 LYON CEDEX 07, France. https://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans

Khalil, O.S.F. Risk Assessment of Certain Heavy Metals and Trace Elements in Milk and Milk Products Consumed in Aswan Province. *Journal of Food and Dairy Sciences*. **2018**, 9, 289-296. https://dx.doi.org/10.21608/jfds.2018.36018

Koyuncu, M.; Alwazeer, D. Determination of trace elements, heavy metals, and antimony in polyethylene terephthalate–bottled local raw cow milk of Iğdir region in Turkey. *Environmental Monitoring and Assessment*. **2019**, 191, 666. https://doi.org/10.1007/s10661-019-7851-z

Kumar, V. Assessment of lead and cadmium status in feedstuffs, milk and water samples in Haryana State of India. *International Journal of Livestock Research*. **2019**, 9, 129-137. http://dx.doi.org/10.5455/ijlr.20180807114242

Kwon, J.C.; Nejad, Z.D.; Jung, M.C. Arsenic and heavy metals in paddy soil and polished rice contaminated by mining activities in Korea. *Catena*. **2017**, 148, 92-100. https://doi.org/10.1016/j.catena.2016.01.005

Maas, S.; Lucot, E.; Gimbert, F.; Crini, N.; Badot, P.M. Trace metals in raw cows' milk and assessment of transfer to Comté cheese. *Food Chemistry*. **2011**, 129,7-12. https://doi.org/10.1016/j.foodchem.2010.09.034

Malhat, F.; Haggag, M.; Saber, A.; Fayez, A. Contamination of cow's milk by heavy metal in Egypt. *Bulletin of Environmental Contamination and Toxicology*. **2012**, 88, 611-613. https://doi.org/10.1007/s00128-012-0550-x

Mansour, M.A.H.; Abdelfatah, E.N.; Ahmed, N.I.; El-Ganzory, H.H. Heavy metal and trace element residues and health risk assessment in raw milk and dairy products with a trail for removal of copper residues. *Benha Veterinary Medical Journal*. **2019**, 36, 403-417. http://dx.doi.org/10.21608/bvmj.2019.123431

Meena, R.B.; Dakshene, M. Assessment of Lead in Raw Milk of Rural and Urban Areas of Kota, Rajasthan. *International Journal of Engineering Research & Technology*. **2022**, 11, 238-241. http://dx.doi.org/10.17577/IJERTV11IS120137

Meshref, A.M.S.; Moselhy, W.A.; Hassan, N.E.Y. Heavy metals and trace elements levels in milk and milk products. *Journal of Food Measurement and Characterization*. **2014**, 8, 381-388. http://dx.doi.org/10.1007/s11694-014-9203-6

Miclean, M.; Cadar, O.; Levei, E.A.; Roman, R.; Ozunu, A.; Levei, L. Metal (Pb, Cu, Cd, and Zn) Transfer along Food Chain and Health Risk Assessment through Raw Milk Consumption from Free-Range Cows. *International Journal of Environmental Research and Public Health*. **2019**, 16, 4064. https://doi.org/10.3390%2Fijerph16214064

Nachiyunde, K.; Ikeda, H.; Okuda, T.; Nishijima, W. Assessment of dissolved heavy metal pollution in five Provinces of Zambia. *Journal of Environmental Protection*. **2013**, 4, 80-85. http://dx.doi.org/10.4236/jep.2013.41B015

Năstăsescu, V.; Mititelu, M.; Goumenou, M.; Docea, A.O.; Renieri, E.; Udeanu,

D.I.; Oprea, E.; Arsene, A. L; Dinu-Pîrvu, C.E.; Ghica, M. Heavy metal and pesticide levels in dairy products: Evaluation of human health risk. *Food and Chemical Toxicology*. **2020**, 146,111844. https://doi.org/10.1016/j.fct.2020.111844

Ngo, H.T.T.; Watchalayann, P.; Nguyen, D.B.; Doan, H.N.; Liang, L. Environmental health risk assessment of heavy metal exposure among children living in an informal e-waste processing village in Vietnam. *The Science of The Total Environment*. **2021**, 763. https://doi.org/10.1016/j.scitotenv.2020.142982

Rahimi, E. Lead and cadmium concentrations in goat, cow, sheep, and buffalo milks from different regions of Iran. *Food Chemistry*. **2013**, 136, 389-391. https://doi.org/10.1016/j.foodchem.2012.09.016

Rehman, K.; Fatima, F.; Waheed, I.; Akash, M.S.H. Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of Cellular Biochemistry*. **2018**, 119, 157-184. https://doi.org/10.1002/jcb.26234

Saleh, E.A.; Elleboudy, A.; Elsakhawy, A.Z.; Eman, H.A. Heavy metals in raw milk and some dairy products at local markets. *Damanhour Journal of Veterinary Sciences*. **2019**, 1, 27-30. https://doi.org/10.21608/DJVS.27082

Sarsembayeva, N.B.; Abdigaliyeva, T.B.; Utepova, Z.A.; Biltebay, A.N.; Zhumagulova, S.Z. Heavy metal levels in milk and fermented milk products produced in the Almaty region, Kazakhstan. *Veterinary World*. **2020**, 13, 609-613. https://doi.org/10.14202/vetworld.2020.609-613

Shammi, S.A.; Salam, A.; Khan, Md.A.H. Assessment of heavy metal pollution in the agricultural soils, plants, and in the atmospheric particulate matter of a suburban industrial region in Dhaka, Bangladesh. *Environmental Monitoring and Assessment*. **2021**, 193, 1-12. https://link.springer.com/article/10.1007/s10661-021-08848-y

Sharaf, N.V.; Shakour, A.A.; Amer, N.M.; Abou-Donia, M.A.; Khatab, N. Evaluation of children's blood lead level in Cairo, Egypt. *American-Eurasian Journal of Agricultural & Environmental Sciences*. **2008**, 3, 414 - 419.

Sharifi, S.; Sohrabvandi, S.; Mofid, V., Javanmardi; F., Khanniri, E.; Mortazavian, A.M. The assessment of lead concentration in raw milk collected from some major dairy farms in Iran and evaluation of associated health risk. *Journal of Environmental Health Science and Engineering*. **2022**, 20, 181-186. https://doi.org/10.1007/s40201-021-00765-z

Snedecor, G.W.; Cochran, W.G. Statistical Methods, 7th Ed. Oxford and IBIT public. Co. New York. 1980.

Sobhanardakani, S. Human health risk assessment of Cd, Cu, Pb and Zn through consumption of raw and pasteurized cow's milk. *Iranian Journal of Public Health*. **2018**, 47, 1172-1180.

Su, C.; Gao, Y.; Qu, X.; Zhou, X.; Yang, X.; Huang, S.; Han, L.; Zheng, N.; Wang, J. The Occurrence, Pathways, and Risk Assessment of Heavy Metals in Raw Milk from Industrial Areas in China. *Toxics*. **2021**, 9, 320. https://doi.org/10.3390/toxics9120320

Sujka, M.; Pankiewicz, U.; Kowalski, R.; Mazurek, A.; Ślepecka, K.; Góral, M. Determination of the content of Pb, Cd, Cu, Zn in dairy products from various regions of Poland. *Open Chemistry*. **2019**, 17, 694-702. http://dx.doi.org/10.1515/chem-2019-0072

Wafy, Y. Estimation of some heavy metals concentration in water supply of dairy farm and raw cow's milk sold in Assiut City, Egypt. *Assiut Veterinary Medical*

Journal. **2019**, 65, 33-38. https://doi.org/10.21608/avmj.2019.168938

WHO, World Health Organization. Lead poisoning. WHO on 11 August 2023. https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health

Yabrir, B.; Chenouf, A.; Chenouf, N.S.; Bouzidi, A.; Gaucheron, F.; Mati, A. Heavy metals in small ruminant's milk from Algerian area steppe. *International Food Research Journal*. **2016**, 23, 1012-1016.

Younus, M.; Abbas, T.; Zafar, M.; Raza, S.; Khan, A.; Saleem, A.H.; Idrees, M.A.; Nisa, Q.U.; Akhtar, R.; Saleem, G. Assessment of heavy metal contamination in raw milk for human consumption. *South African Journal of Animal Science.* **2016**, 46, 166-169. https://doi.org/10.4314/sajas.v46i2.7

Zyambo, G.; Yabe, J.; Muzandu, K.; M'kandawire, E.; Choongo, K.; Kataba, A.; Chawinga, K.; Liazambi, A.; Nakayama, S.M.M.; Nakata, H.; Ishizuka, M. Human Health Risk Assessment from Lead Exposure through Consumption of Raw Cow Milk from Free-Range Cattle Reared in the Vicinity of a Lead-Zinc Mine in Kabwe. *International Journal of Environmental Research and Public Health*. **2022**, 19, 4757. https://doi.org/10.3390/ijerph19084757

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