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PJMLS OPEN ACCESS
Print ISSN: 2707-4471. Online ISSN: 2707-448X

Research Article	Pak-Euro Journal of Medical and Life Sciences
DOI: 10.31580/pjmls.v8isp3.3486	Copyright © All rights are reserved by Corresponding Author
Vol. 8 No. Special 3, 2025-26: pp.S269-S276	
www.readersinsight.net/pjmls	**Revised:** March 12, 2026 **Accepted:** March 24, 2026
Submission: January 19, 2026	**Published Online:** March 31, 2026

DETECTION OF HEAVY METAL LEVELS IN MILK OF DAIRY COWS AND ASSOCIATED FARM MANAGEMENT PRACTICES IN QUETTA DISTRICT

Abdul Waris[1], Kashif Kamran[1], Mahrukh Naseem[1]*

[1]**Department of Zoology,** University of Balochistan, Quetta, Pakistan

***Corresponding Author:** Mahrukh Naseem. E. mail: mahrukhnaseem@rocketmail.com

Abstract

Milk is a crucial source of proteins, vitamins, minerals and energy in human nutrition. The contamination of milk with heavy metals is a big threat to public health, as they are toxic, persistent, and bioaccumulative in nature. The present study was designed to investigate the levels of selected heavy metals in raw cow milk and to determine the practices of farms regarding contamination in District Quetta, Balochistan, Pakistan. In this study, a cross-sectional analytical design was used. A total of 150 milk samples were collected from nine major dairy-producing areas of District Quetta from dairy farms during August to November 2025. Data on feeding practices, water sources, sanitation and waste management were collected using structured questionnaires and direct observations on farms. The wet acid digestion method was followed for digestion of milk samples, and metal ions lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) was quantified by Atomic Absorption Spectrophotometry (AAS). Data were analyzed by SPSS version 26.

The mean concentrations of Pb, Cd, Cu, and Zn were 0.19 ± 0.13, 0.04 ± 0.03, 0.13 ± 0.07, and 2.20 ± 1.31 mg/L, respectively. The levels of lead and cadmium were found to be above WHO/FAO recommended limits, while copper and zinc were found to be within safe limits. For farms using wastewater or mixed water sources, the concentrations of lead and cadmium were comparatively high in comparison with those of the tube-well or municipal water sources used on the farms. The study concluded that raw cow milk in District Quetta contains lead and cadmium which are above the international standards of safety. There is a strong indication that contaminated water sources are a significant source of heavy metal build-up. Properly monitoring milk quality, providing safe water for the livestock and enhancing farm management are the keys to protecting public health and dairy product safety.

Keywords: *Dairy farms, Food safety, Heavy metals, Milk contamination, Quetta*

INTRODUCTION

Milk has been well known as one of the most nutritious natural foods for human consumption (1). It provides essential nutrients, such as proteins, fats, carbohydrates, vitamins and minerals for the growth, development and maintenance of physiological functions. Because of its nutritional balance, milk is an essential part of the diet for people of all ages, especially children and elderly people, and is consumed daily (2). Milk and dairy foods are major sources of food's nutrient content on a worldwide scale and are seen as essential to food security and nutritional wellbeing (3).

Pakistan is one of the world's significant milk producing countries and one of the highest contributors to the world production of milk (4). The livestock industry is one of the most important industries in the country's economy and plays a significant role in the agricultural gross domestic product. Dairy farming is a major source of livelihoods for millions of rural households and is an important source of nutrition and income. The Pakistan Economic Survey reports that there are more than 50 million tons of milk being produced annually with the main milk producing species being cattle and buffaloes. Dairy farming activities, particularly in the urban and peri-urban areas of the country are expanding rapidly, due to the growing demand for milk and dairy products (5).

Milk is an important food which can be contaminated by many biological, chemical and physical hazards during milk production, processing, transport and storage. Heavy metals are the subject of significant scientific interest among the chemical contaminants because of their toxicity, bioaccumulation, adverse human health effects and persistence in the environment (6). Heavy metals are naturally occurring elements, with relatively high atomic weight and density. Certain metals are micronutrients that are necessary for normal metabolic functions, including copper, zinc, iron and manganese. However, they can be toxic if present in too high a concentration. Metals like lead, cadmium, mercury and arsenic, however, have no known biological role and can be harmful at very low concentrations (7).

Environmental contamination has become a huge source of heavy metal exposure in both human beings and animals. Industrial emission, mining activities, car exhaust, chemicals from agriculture, municipal waste, sewage irrigation and atmospheric deposition play a major role in environmental pollution. These chemicals bio-accumulate in soil, water and plants and then end up in the food chain through livestock feed and drinking water (8). Heavy metals can be accumulated by dairy animals that are exposed to contaminated environments in several tissues, including the mammary glands, leading to the production of contaminated milk (9).

Milk contamination with heavy metals is a real public health problem since the milk is consumed daily by vulnerable population groups such as infants, children, pregnant women and elderly people (10). Toxic metals can have significant health concerns at low exposures if exposure is chronic. Many studies have been carried out around the world and found the presence of heavy metals in milk and milk products, where concentrations have been found to be higher than the maximum safe levels set internationally (11). Hence, the detection of heavy metals in milk has become an important part of food safety surveillance program.

The quality and contamination of milk are also greatly influenced by farm management. The unhygienic environment on the farms may result in environmental contamination that can increase due to poor hygiene conditions, inadequate waste disposal system, improper feed storage, and lack of sanitation measures (12).

Milk samples collected from industrial and agricultural areas in Yang *et al.* (2025) were found to contain recurring amounts of lead, cadmium, mercury and arsenic (13). Likewise, Sharma et al. (2025) found that the level of toxic metal in milk samples collected from the dairy farms situated in the industrial area was significantly higher than the samples collected from the rural area. These investigations highlight the need of source identification and prevention of contamination at both environmental and farm levels (14).

A 2022 study by PMC on heavy metal in milk and serum detected anthropogenic waste (industrial effluent, municipal dumping, and agrochemical residues) as the primary source of heavy metals in the environment close to dairy farms and recommended for adopting an integrated approach comprising of environmental regulation, milk surveillance, and adoption of best practices by farmers to prevent contamination of the human food chain (15). The current study aimed to investigate the levels of selected heavy metal in raw cow milk and to determine the practice of farms regarding contamination in District Quetta.

MATERIALS AND METHODS

STUDY AREA AND STUDY DESIGN

This study was carried out in District Quetta of Balochistan Province of Pakistan. Quetta is one of the major urban centers of the Province and is a city with rapidly expanding dairy farming activities. The district includes both urban and peri-urban dairy production systems where pollution from the environment, traffic emissions, agricultural activities and waste products from the farms can impact milk quality and safety.

A cross sectional analytical research was carried out to estimate the levels of heavy metals in the milk of dairy cows and to examine the farm management practices that are likely to cause the contamination of milk during the period August to November-2025.

SAMPLE SIZE AND SAMPLING STRATEGY

The dairy farms in District Quetta were proportionately sampled, from the major dairy farming areas of Kuchlak, Sariab Road, Pashtoonabad, Brewery Road, Spinny Road, Nosar, Airport Road, Jan Muhammad Road and Eastern Bypass. To achieve geographical diversity, the selected farms were across management systems and environmental conditions. A total of 150 raw milk samples were taken from above mentioned locations from a lactating dairy cow for analysis (Table I).

COLLECTION OF FARM MANAGEMENT DATA

A structured questionnaire and field trip was used to gather information on the farm management practices. The questionnaire aimed to provide detailed data on various aspects of the dairy farm management system, such as feed management, water sources, waste disposal, and overall sanitation. Observational assessments were also done to assess overall hygiene status of each dairy farm. The indicators used for the assessment of farm hygiene were related to the cleanliness of animal sheds, milking equipment, feed storage area, waste management system and farm environment.

COLLECTION OF MILK SAMPLES

Raw milk was aseptically collected from each of the selected dairy cows in sterile polyethylene containers and the volume was approximately 50 mL. Samples were collected and packaged properly and refrigerated for transportation to the laboratory. Samples were all kept at 4°C prior to analysis.

SAMPLE PREPARATION AND DIGESTION

Heavy metal analysis of milk samples was performed after wet acid digestion. In brief, controlled laboratory digestion of milk samples using concentrated nitric and perchloric acids were performed until the samples yielded a clear solution. They were filtered after digestion and diluted in deionized (DI) water to desired volumes.

DETERMINATION OF HEAVY METALS

Standard analytical procedures recommended by Association of Official Analytical Chemists (AOAC, 2000) were employed to determine the concentration of lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) by Atomic Absorption Spectrophotometry (AAS) with air-acetylene flame. The analyses of each metal were performed at their respective wavelengths and concentrations were reported in mg/L using calibration standards. Calibration curves were prepared by making standard solutions of certified metal solutions. Blank samples, duplicate analyses and instrument calibration tests were used to conduct quality control.

STATISTICAL ANALYSIS

The data were inserted into MS. EXCEL and analyzed by statistical package for social sciences (SPSS) version 26. Frequency, percentage, mean and standard deviation were used for descriptive statistics. Data are contained in tables and figures. The mean concentrations of the heavy metals were compared with the permissible limits set by WHO/FAO to establish the safety of milk.

RESULTS

DISTRIBUTION OF DAIRY FARMS

A total of 70 dairy farms were surveyed in total from 9 major dairy farming areas of District Quetta and total of 150 raw milk samples were collected. Sariab Road and Spinny Road areas had the maximum number of farms (12.9% in each) and the other areas had 10.0% each in the sample while Pashtoonabad, Nosar, Airport Road and Eastern Bypass had the lowest (10.0%). The overall results indicate a fairly even set of farms sampled based on the areas chosen for sampling (Table I).

FEEDING PRACTICES OF DAIRY COWS

Feeding practices of the dairy cows were recorded to understand the feeding management system which was being followed by the dairy farmers in the study area. The data points out the percentage of farms with various feeding methods (Fig. 1a).

Table I. Distribution of dairy farms according to location

Location	No. of farms	Percentage (%)	No. of milk samples collected	Percentage (%)
Kuchlak	8	11.4	18	12
Sariab Road	9	12.9	20	13.33
Pashtoonabad	7	10.0	15	10
Brewery Road	8	11.4	22	14.67
Spinny Road	9	12.9	21	14
Nosar	7	10.0	9	6
Airport Road	7	10.0	10	6.67
Jan Muhammad Rd	8	11.4	15	10
Eastern Bypass	7	10.0	20	13.33
Total	70	100	150	100

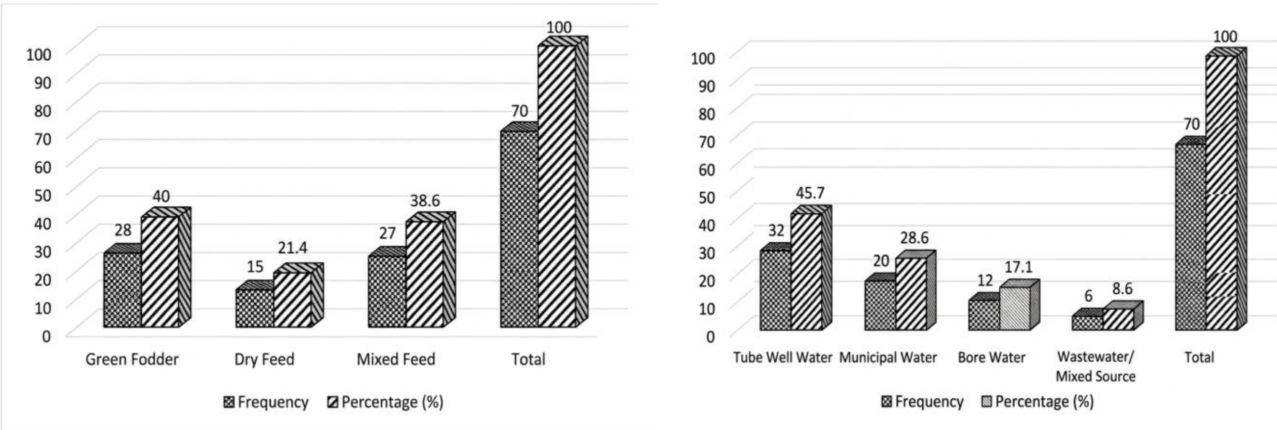

Fig. 1 (a). Feeding practices of dairy cows; **(b).** Source of drinking water for dairy cows

These results show that green fodder was most commonly used feed (40.0%) followed by mixed feed (38.6%) and least used was dry feed (21.4%). This shows that the dairy farmers preferred natural feeding & combined feeding system.

DRINKING WATER SOURCES

Sources of drinking water supplied to dairy cows were documented to help determine water quality exposure risks for dairy cows. A variety of water sources were utilized in the farms surveyed.

The results showed that tube well water was the most common source of water used (45.7% of the respondents), followed by municipal water (28.6%) and bore water (17.1%) with the least being used was wastewater or mixed water sources (8.6%) (Fig. Ib). This indicates that groundwater resources were mainly used in the study area.

HEAVY METAL CONCENTRATION IN MILK SAMPLES

Milk samples were analyzed in the laboratory to quantify some heavy metals. International permissible limits were used to assess contamination level from the results obtained. The results showed that the concentrations of lead (Pb) and cadmium (Cd) were found to be above the permissible limits of WHO/FAO but that of copper (Cu) and zinc (Zn) were within permissible limits (Table II). This shows a possible contamination problem with certain heavy metals.

Table II. Mean concentration of heavy metals in milk samples

Heavy metal	Mean ± SD (mg/L)	WHO/FAO limit (mg/L)	Status
Lead (Pb)	0.19 ± 0.13	0.05	Above Limit
Cadmium (Cd)	0.04 ± 0.03	0.01	Above Limit
Copper (Cu)	0.13 ± 0.07	0.50	Within Limit
Zinc (Zn)	2.20 ± 1.31	5.00	Within Limit

COMPARISON WITH WHO/FAO STANDARDS

Concentrations of heavy metals observed in milk samples were also compared to the recommended safe limits of WHO/FAO to determine the possible risks to human health due to consumption of milk. For comparative purposes, observed levels of heavy metal in the samples have been compared with the recommended limits by WHO/FAO shown in table III. The findings indicate that the levels of lead (Pb) and cadmium (Cd) exceeded the permissible limit and hence are not safe for consumption. On the other hand, the Cu and Zn concentrations were within the safe limits that are recommended in international safety norms, showing that these are safe for human utilization.

ASSOCIATION BETWEEN WATER SOURCE AND HEAVY METALS

The association between water source and heavy metals were also determined. A correlation was performed to look at the relationship between various water sources on farms and the levels of the different heavy metals that were found in the milk samples.

Water sources used on dairy farms and the associated levels of heavy metals in milk samples is shown in the Fig. II. The results indicate that farms which used wastewater or mixed water sources had the maximum concentration of Cd and Pb. Farms using tube well water, on the other hand, had comparatively low concentrations indicating strong association between water quality and heavy metal contamination of milk.

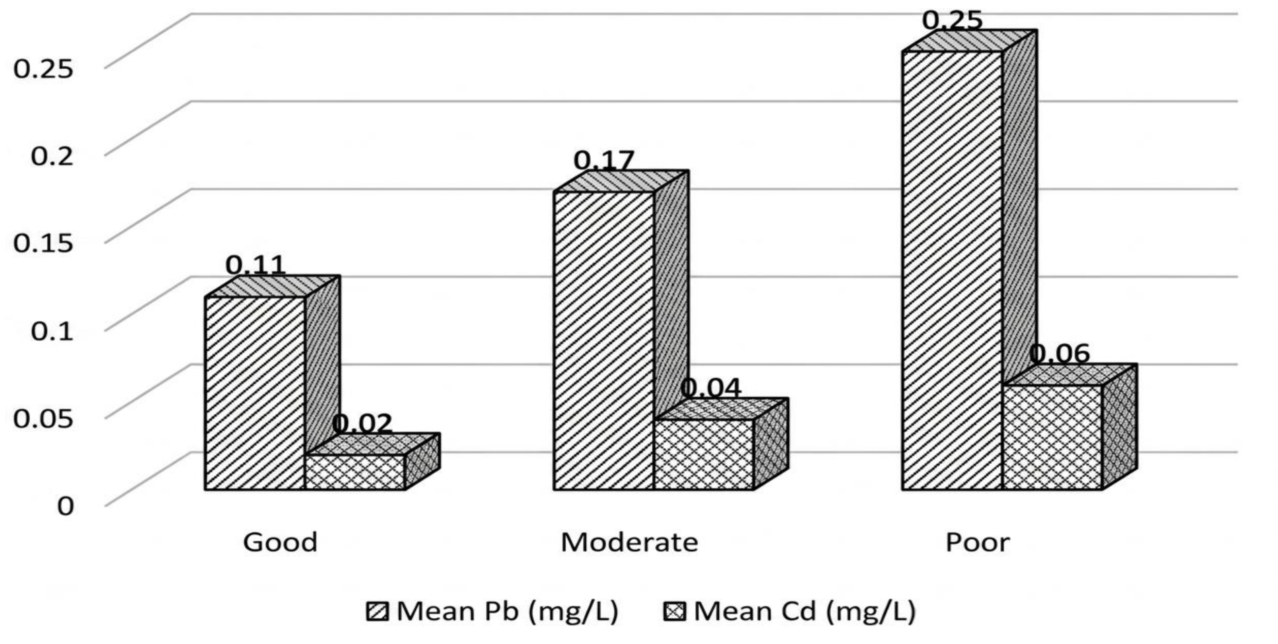

Fig. 2. Association of water source with heavy metal concentration

DISCUSSION

The results of the present study showed that the levels of lead (Pb) and cadmium (Cd) were found to be above the recommended limits set by the WHO/FAO and the level of copper (Cu) and zinc (Zn) were within recommended limits. The findings suggest a serious public health problem as milk is an essential food product which is consumed on a daily basis by the vulnerable sections of the society such as children, pregnant women and elders.

The study also showed that the type of drinking water had a significant effect on the levels of the heavy metals in milk. The level of contamination was found to be higher in farms using wastewater or mixed water source than in tube-well and municipal water. This means that polluted water is a significant channel in which toxic metals enter into the dairy production system. The same result has been found in other studies that the use of contaminated groundwater and wastewater irrigation led to high concentration of heavy metals in animal food products.

In a study of milk in China, Yang *et al.* (2025) found the presence of lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As) in a significant number of samples from industrial and agricultural areas.

According to their study, industrial emissions, contaminated irrigation systems and environmental pollution are major contributors to high levels of heavy metals in dairy products (16).

Prasad *et al.* (2026) pointed out that the anthropogenic activities like industrial waste disposal, agricultural runoff and municipal pollution are the important factors causing heavy metal contamination in dairy production system. The higher levels of Pb and Cd found in the current study could thus be attributed to the growing rapid urbanization, traffic emissions, waste disposal habits and environmental degradation in and around Quetta (17).

Milk from dairy farm in Calabria (Italy) was investigated by Licata *et al.* (2004) and the presence of toxic metals such as Pb and Cd in milk samples was reported, highlighting the importance of environmental contamination on milk quality. In a study by the authors, industrial activities and pollution were found to be significant factors in polluting dairy products with metals (18).

Castro-Bedriñana *et al.* (2023) analyzed raw cow milk from the Peruvian Andes and reported mean concentrations of 0.062 mg/kg of Pb, 0.014 mg/kg of Cd and 0.030 mg/kg of As were found to be above the maximum limits set by international standards. The authors also reported that the calculated hazard index was above the safe limits for children, which could pose a potential public health concern because of the potential for chronic exposure via milk consumption (19).

The higher concentration of Cd found in the present study is also in line with previous reports that showed environmental contamination and dairy products are associated. Cadmium is a non-essential toxic metal and can enter into milk as a result of contamination from feed, water and soil which are eaten by the animals. Chronic health effects including kidney dysfunction, skeletal damage and more have been linked to long-term exposure. Multiple studies in industrial and agricultural areas have shown clear correlations between the presence of Cd in milk and environmental pollutants and farming activities.

CONCLUSION

It is concluded that raw Cow Milk collected from District Quetta is found to be contaminated with toxic heavy metals like Lead (Pb) and Cadmium (Cd) above the recommended permissible limits by WHO/FAO. On the other hand, copper (Cu) and zinc (Zn) levels were found to be under the recommended safe concentration. The results also show that contaminated water sources, particularly wastewater and mixed water sources are significant factors in the bio-accumulation of heavy metals in milk. The high concentrations of Pb and Cd are a possible public health threat because of the common use of milk. To reduce the risk of heavy metal contamination and provide safe forage for livestock consumption, it is important to regularly monitor the quality of milk, provide safe drinking water for livestock, improve management practices on farms, and adhere to food safety regulations.

Conflict of interest:

The authors declare that they have no competing interest.

Author's Contributions:

AW Conceptualization, methodology, sample collection, laboratory analysis, data curation, writing original draft; KK Methodology, validation, formal analysis; MN Conceptualization, supervision, project administration, resources, writing review and editing.

References:

1. Cimmino F, Catapano A, Petrella L, Villano I, Tudisco R, Cavaliere G. Role of milk micronutrients in human health. Frontiers in Bioscience-Landmark. 2023;28(2):41.
2. Kober AH. Milk and dairy foods: nutrition, processing and healthy aging. CRC press: 2024.
3. Tripathi P, Patani K. The Crucial Role of Dairy in the Transformation of Where Health and Nutrition Are Most Common Worldwide. Revolutionizing Agri-food Systems: Sustainability, Health, and Innovation. 2025:569-81.
4. Aranguiz AA, Spoelstra M. Trends and Outlook of Dairy Production in Pakistan. Wageningen Livestock Research: Wageningen, The Netherlands. 2025.

5. Nadeem M, Ahmad MH. Sustaining the dairy sector in Pakistan: challenges and strategies for growth. Dairy Sciences-Current Technological Trends and Future Perspectives. SciknowPub, USA. 2024:221-34.
6. Boudebbouz A, Boudalia S, Bousbia A, Gueroui Y, Boussadia MI, Chelaghmia ML, Zebsa R, Affoune AM, Symeon GK. Determination of heavy metal levels and health risk assessment of raw cow milk in Guelma Region, Algeria. Biological Trace Element Research. 2023;201(4):1704-16.
7. Parida L, Patel TN. Systemic impact of heavy metals and their role in cancer development: a review. Environmental Monitoring and Assessment. 2023;195(6):766.
8. Angon PB, Islam MS, Das A, Anjum N, Poudel A, Suchi SA. Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain. Heliyon. 2024;10(7).
9. Souto MR, Pimenta AM, Catarino RI, Leal MF, Simões ET. Heavy metals in milk and dairy products: Safety and analysis. Pollutants. 2025;5(3):29.
10. Alinezhad Z, Hashemi M, Sany SBT. Concentration of heavy metals in pasteurized and sterilized milk and health risk assessment across the globe: A systematic review. PLoS One. 2024;19(2):e0296649.
11. Kerdoun MA, Djafer R. Heavy metal levels in camel milk and health risk assessment: A global systematic review. J Trace Elem Miner. 2024;8:100131.
12. Ovuru KF, Izah SC, Ogidi OI, Imarhiagbe O, Ogwu MC. Slaughterhouse facilities in developing nations: Sanitation and hygiene practices, microbial contaminants and sustainable management system. Food Sci Biotechnol. 2024;33(3):519-37.
13. Yang Y, Pan M, Lin Y, Xu H, Wei S, Zhang C, Lu S, Niu B. Assessing heavy metal risks in liquid milk: Dietary exposure and carcinogenicity in China. *Journal of Dairy Science*. 2025;108(7):6838-51.
14. Sharma A, Gupta S, Shrivas K, Chakradhari S, Pervez S, Deb MK. Heavy metal contamination in cow and buffalo milk from industrial and residential areas of raipur, India: A health risk assessment. Food and Chemical Toxicology. 2025; 196:115178.
15. Hernández-Montoya DA, Castañeda-Miranda AG, Martinez-Fierro ML, Talavera-Lopez A, Sandoval-Arechiga R, Gómez-Rodríguez JR, Rodríguez-Abdalá VI, Castañeda-Miranda R, Flores-Chaires LA, Vázquez-Reyes S, Ibarra-Delgado S. Heavy Metal Contamination in Foods: Advances in Detection Technologies, Regulatory Challenges, and Health Risks. 2026; 18(9):4280.
16. Ziarati P, Shirkhan F, Mostafidi M, Zahedi MT. An overview of the heavy metal contamination in milk and dairy products. Acta scientific pharmaceutical sciences. 2018;2(7):1-4.
17. Prasad M, Mahawer SK, Das MM, Coumar MV, Saha JK, Kumar S, Palsaniya DR. Heavy-metals contamination and associated risks in the water–soil–fodder–livestock continuum after long-term sewage-water irrigation in peri-urban areas: Evidence from Central India. Environmental Monitoring and Assessment. 2026;198(2):156.
18. Licata PA, Trombetta DO, Cristani M, Giofre F, Martino D, Calò MA, Naccari FR. Levels of “toxic” and “essential” metals in samples of bovine milk from various dairy farms in Calabria, Italy. Environment international. 2004;30(1):1-6.
19. Castro-Bedriñana J, Chirinos-Peinado D, Ríos-Ríos E, Castro-Chirinos G, Chagua-Rodríguez P, De La Cruz-Calderón G. Lead, cadmium, and arsenic in raw cow’s milk in a central Andean area and risks for the Peruvian populations. Toxics. 2023;11(10):809.