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Impact of Environmental Contaminants on Milk Quality: A Study on Heavy Metals in Milk Available in Peshawar

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Original Article

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Keywords

Heavy metals, milk contamination, cadmium, chromium, lead, zinc, Peshawar, public health, environmental pollution.

Abstract

Milk and dairy products are essential dietary components, but they may also contain chemical contaminants and pollutants, including heavy metals such as lead, cadmium, chromium, and zinc. These heavy metals accumulate in milk and dairy products, posing a significant health risk, especially to infants and children who consume these products regularly. The present study focuses on the concentration of heavy metals in milk samples from different urban areas of Peshawar, with the aim of assessing potential health risks associated with milk consumption in the region. A total of 120 milk samples (60 buffalo milk and 60 cow milk) were collected from five urban locations in Peshawar and analyzed for cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn) content using Atomic Absorption Spectrophotometry (AAS). The findings were compared with the World Health Organization (WHO) permissible limits for heavy metal contamination in milk.

Introduction

Milk is an essential source of nutrition, particularly for children. However, its quality can be compromised by environmental pollutants, including heavy metals. Lead and cadmium are of particular concern, as they accumulate in the body over time and pose serious health risks, especially to vulnerable populations such as newborns and infants. (Mohamed H. Abd El-Salam et al., 2011). The widespread use of heavy metals in agricultural, industrial, domestic, and medical applications has led to their ubiquitous presence in the environment, raising concerns about their potential accumulation in food sources, including milk. The study intended to assess the concentration of heavy metals in milk samples from different areas of Peshawar and evaluate their potential impact on human health.

Milk Composition and Variability Between Cow and Buffalo Milk

Buffalo milk differs from cow milk in terms of its nutritional composition. It is richer in fat, lactose, proteins, calcium, and vitamins A and C, while containing lower levels of riboflavin, vitamin E, and cholesterol. Additionally, buffalo milk contains a unique bioactive pentasaccharide, biliverdin, and gangliosides, as well as a higher content of saturated fatty acids compared to cow milk. The larger casein micelles in buffalo milk are more mineral-rich and less stable than those in cow milk, which can influence its physical properties and nutritional profile. This study also explored the potential variations in heavy metal accumulation between buffalo and cow milk.

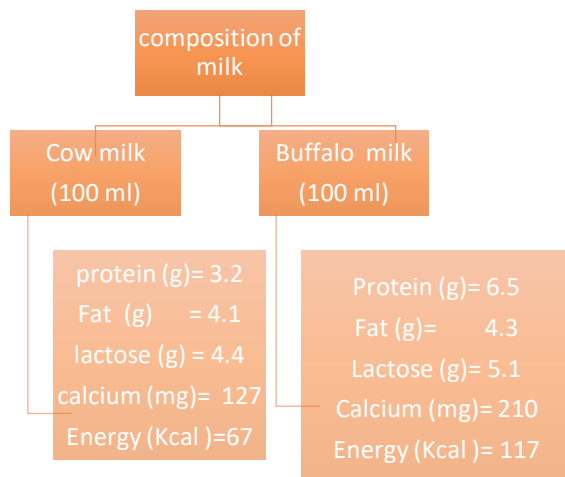
Methodology

Milk and dairy products can contain chemical hazards and pollutants. Lead and cadmium, which accumulate in drains, are particularly concerning in dairy products because they are commonly consumed by infants and young children (Ghosia Lutfullah et al., 2014). The widespread distribution of heavy metals in the environment, resulting from various agricultural, domestic, medical, industrial, and technological activities, has raised significant concerns about their potential impact on human health and the environment (Dr. Showkat Ahmad Bhat et al., 2019).

A total of 120 milk samples were collected from five urban locations in Peshawar: Board Bazar, University Campus, Sadar Bazar, Ring Road, and Qissa Khawani Bazar. The samples included both cow and buffalo milk. The heavy metals (cadmium, chromium, lead, and zinc) were measured using Atomic Absorption Spectrophotometry (AAS). Statistical analysis was performed using Materials and Methods:

1. **Sample Collection:** A total of 120 milk samples were collected from five urban areas of Peshawar: Board Bazar, University Campus, Ring Road, and Qissa Khawani Bazar. Each area provided 8 samples of both buffalo and cow milk, coded accordingly (e.g., Ma1, Ma2, for Board Bazar buffalo milk, Mb1, Mb2, for cow milk).
2. **Chemical Analysis:** The milk samples were analyzed for the presence and concentration of four heavy metals: cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn). Atomic Absorption Spectrophotometry (AAS) was employed for precise metal detection and quantification.
3. **Data Analysis:** The concentrations of the metals were compared with the World Health Organization (WHO) permissible limits for heavy metal contamination in food. The data were analyzed for statistical significance using standard statistical tools.

Composition of Milk



Buffalo milk differs from cow milk (CM) in several ways, including higher levels of fat, lactose, calcium, proteins, and vitamins A and C, while containing lower amounts of riboflavin, vitamin E, and cholesterol. It also contains bioactive components such as the biliverdin, gangliosides, and the blue-green pigment. The fat in buffalo milk differs from cow milk fat in terms of triglyceride distribution, physical properties, and slightly higher levels of saturated fatty acids. Buffalo milk casein micelles are larger, more mineral-rich, and more easily disrupted by alkali compared to cow milk. Although the proteins in both types of milk are highly homologous, buffalo milk casein shows less phosphorylation. Additionally, buffalo milk has lower thermal stability, faster coagulation, and higher viscosity than cow milk (Mohamed H. Abd El-Salam et al., 2011).

Results and Discussion

Heavy metal analysis was performed using an Atomic Absorption Spectrophotometer (AAS). The aim of the present study was to assess the levels of heavy metals—Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn)—in 60 buffalo milk samples and 60 cow milk samples, which were collected from five urban areas in the Peshawar district. The samples were coded based on their location: Ma1, Ma2, Ma3, Ma4, Ma5, Ma6, Ma7, and Ma8 for the first location, and Mb1, Mb2, Mb3, Mb4, Mb5, Mb6, Mb7, and Mb8 for the second location. The results were analyzed for statistical significance using Microsoft Excel. All values, including means and standard deviations, are presented in tables.

Table 1: Concentration (ppm) range of the selected heavy metals (mean ± standard deviation) in buffalo and cow milk samples collected from the Board Bazar area of District Peshawar.

	Sample code	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
		Mean ± S. D	Mean ± S. D	Mean ± S.D	Mean ±S.D
Cow milk	Ma1	0.061±0.0038	0.004±0.0016	0.003±0.032	4.265±0.2679
	Ma2	0.061±0.0038	0.003±0.0014	0.009±0.096	5.043±0.0453
	Ma3	0.057±0.0014	0.003±0.0014	0.004±0.106	6.977±0.1121
	Ma4	0.051±0.010	0.004±0.0016	0.003±0.032	1.772±0.0272
Buffalo Milk	Ma5	0.064±0.0060	0.004±0.0016	0.006±0.052	1.223±0.0141
	Ma6	0.061±0.0038	0.003±0.0014	0.005±0.033	1.554±0.0231
	Ma7	0.069±0.0090	0.006±0.0016	0.005±0.046	2.122±0.0372
	Ma8	0.034±0.0007	0.003±0.0009	0.004±0.050	2.112±0.0314
	Range	0.034-0.069	0.03-0.06	0.03-0.09	1.554-6.977
	WHO Limit	0.01-0.5ppm	0.05 ppm	0.02 ppm	0.03-1.0 ppm

** Determining the contamination levels of cadmium, chromium, zinc, and lead in cow and buffalo milk, along with their mean ± standard deviation, in comparison to the limits prescribed by the World Health Organization.*

The concentration of zinc was notably higher compared to cadmium, chromium, and lead. The zinc levels in cow milk samples were significantly higher than in buffalo milk samples, with a range of 1.223 to 6.977 ppm in cow milk and 1.554 to 2.112 ppm in buffalo milk. Cadmium and chromium were found in both milk types, with concentrations slightly exceeding WHO limits for some samples.

Table 2: The concentration (ppm) of the chosen heavy metals (mean \pm standard deviation) in Buffalo and Cow milk samples collected from the University Campus in District Peshawar.

	Sample code	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
		Mean \pm S.D	Mean \pm S.D	Mean \pm S.D	Mean \pm S.D
Cow Milk	Mb1	0.031 \pm 0.0016	0.002 \pm 0.0006	0.004 \pm 0.033	3.592 \pm 0.0334
	Mb2	0.053 \pm 0.0041	0.004 \pm 0.0016	0.005 \pm 0.041	2.479 \pm 0.0217
	Mb3	0.021 \pm 0.0012	0.007 \pm 0.0018	0.003 \pm 0.032	3.122 \pm 0.0291
	Mb4	0.023 \pm 0.0010	0.004 \pm 0.0015	0.004 \pm 0.106	5.621 \pm 0.0123
Buffalo Milk	Mb5	0.043 \pm 0.0013	0.002 \pm 0.0007	0.005 \pm 0.041	1.523 \pm 0.0271
	Mb6	0.017 \pm 0.0007	0.003 \pm 0.0009	0.006 \pm 0.052	2.340 \pm 0.0198
	Mb7	0.033 \pm 0.0019	0.006 \pm 0.0016	0.004 \pm 0.016	2.301 \pm 0.0174
	Mb8	0.021 \pm 0.0008	0.002 \pm 0.0006	0.009 \pm 0.051	1.415 \pm 0.0121
	Range	0.017-0.053	0.02-0.07	0.03-0.09	2.301-5.621
	WHO Limit	0.01-0.5ppm	0.05 ppm	0.02 ppm	0.03-1.0ppm

* *Determining the contamination levels of cadmium, chromium, zinc, and lead in cow and buffalo milk, along with their mean \pm standard deviation, and comparing these values with the limits set by the World Health Organization.*

The results presented in Table 2 show the presence of all four heavy metals (Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn)) in both buffalo and cow milk samples. Zinc (Zn) exhibited the highest concentration (5.261 ppm), followed by cadmium (Cd) (0.053 ppm), lead (Pb) (0.009 ppm), and chromium (Cr) (0.007 ppm). Zinc had the highest concentration, while chromium showed the lowest (0.002 ppm) results were in line with P. Zhuang et al,2009.

In cow milk, the average concentration of zinc (5.261 ppm) in samples Mb1, Mb2, Mb3, and Mb4 was higher compared to buffalo milk samples Mb5, Mb6, Mb7, and Mb8, which had an average concentration of 1.415 ppm. All milk samples tested positive for the presence of the examined heavy metals.

The highest concentration of Cd was found in cow milk sample Mb2 (0.053), with the lowest in Mb3 and Mb8 (0.021). Chromium levels were highest in Mb3 (0.007) and lowest in Mb5 and Mb8 (0.002). Lead concentrations ranged from 0.003 to 0.009 ppm, with the highest in cow milk sample Mb8 and the lowest in Mb1, Mb4, and Mb7. The highest concentration of Zn was in cow milk sample Mb4 (5.621), while the lowest was in buffalo milk sample Mb8 (1.523).

Table 3.: The concentration (ppm) of the selected heavy metals in Buffalo and Cow milk samples collected from Sadar Bazar in District Peshawar.

	Sample code	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
		Mean ± S.D	Mean ± S.D	Mean ± S.D	Mean ± S.D
Cow milk	Mc1	0.011±0.0006	0.006±0.0016	0.012±0.052	3.610±0.0374
	Mc2	0.010±0.0007	0.004±0.0017	0.006±0.051	5.043±0.1011
	Mc3	0.027±0.0011	0.002±0.0007	0.005±0.041	3.141±0.0107
	Mc4	0.023±0.0012	0.002±0.0009	0.004±0.026	1.776±0.0268
Buffalo milk	Mc5	0.018±0.0019	0.008±0.0024	0.003±0.020	1.623±0.0142
	Mc6	0.052±0.0041	0.003±0.0012	0.007±0.053	2.194±0.0211
	Mc7	0.025±0.0011	0.004±0.0016	0.011±0.054	1.320±0.0152
	Mc8	0.041±0.0033	0.001±0.0005	0.006±0.019	2.501±0.0243
	Range	0.010-0.052	0.01-0.08	0.03-0.012	1.320-5.043
	WHO Limit	0.01-0.5ppm	0.05 ppm	0.02 ppm	0.03-1.0ppm

* Assessing the contamination levels of cadmium, chromium, zinc, and lead in cow and buffalo milk, including the calculation of mean ± standard deviation, and comparing these findings with the limits established by the World Health Organization.

The results presented in Table 3 indicate the presence of all four heavy metals (Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn)) in both buffalo and cow milk samples. Zinc (Zn) showed the highest concentration (5.043 ppm), followed by cadmium (Cd) (0.052 ppm), chromium (Cr) (0.008 ppm), and lead (Pb) (0.0012 ppm). Zinc had the highest concentration, while chromium exhibited the lowest (0.001 ppm).

In cow milk, the average concentration of zinc in samples Mc1, Mc2, Mc3, and Mc4 (5.043 ppm) was higher than that in buffalo milk samples Mc5, Mc6, Mc7, and Mc8 (1.320 ppm). All milk samples contained detectable levels of the examined heavy metals. The highest cadmium concentration was found in buffalo milk sample Mc6 (0.0052 ppm), while the lowest was observed in cow milk sample Mc2 (0.010 ppm).

Table 4: The concentration (ppm) of the selected heavy metals in Buffalo and Cow milk samples collected from Ring Road in District Peshawar.

	Sample code	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
		Mean ± S.D	Mean ± S.D	Mean ±S.D	Mean ± S.D
Cow milk	Md1	0.020±0.0007	0.003±0.0009	0.06±0.041	2.326±0.0241
	Md2	0.031±0.0018	0.003±0.0008	0.05±0.032	6.711±0.1121
	Md3	0.028±0.0016	0.003±0.0009	0.01±0.007	4.533±0.0334
	Md4	0.010±0.0011	0.002±0.0006	0.05±0.031	4.567±0.2679
Buffalo milk	Md5	0.052±0.0042	0.007±0.0011	0.04±0.024	1.881±0.0262
	Md6	0.041±0.0033	0.004±0.0007	0.05±0.032	2.221±0.0217
	Md7	0.030±0.0019	0.005±0.0031	0.04±0.022	2.221±0.0218
	Md8	0.030±0.0019	0.004±0.0014	0.03±0.052	2.230±0.0223
	Range	0.010-0.052	0.02-0.07	0.03-0.06	1.881-6.711
	WHO Limits	0.01-0.5ppm	0.05 ppm	0.02ppm	0.03-1.0ppm

* Determining the contamination levels, including the range and mean ± standard deviation, of cadmium, chromium, zinc, and lead in cow and buffalo milk, and comparing these results with the limits prescribed by the World Health Organization.

he results presented in Table 4 indicate the presence of all four heavy metals (Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn)) in both buffalo and cow milk samples. Zinc (Zn) exhibited the highest concentration (6.711 ppm), followed by cadmium (Cd) (0.052 ppm), chromium (Cr) (0.007 ppm), and lead (Pb) (0.006 ppm). Zinc had the highest concentration, while chromium showed the lowest (0.002 ppm). Similar findings were reported by Ahsan Kabir, et al.2017, In cow milk, the average zinc concentration in samples Md1, Md2, Md3, and Md4 (6.711 ppm) was higher than that in buffalo milk samples Md5, Md6, Md7, and Md8 (2.230 ppm). All milk samples contained detectable levels of the examined heavy metals.

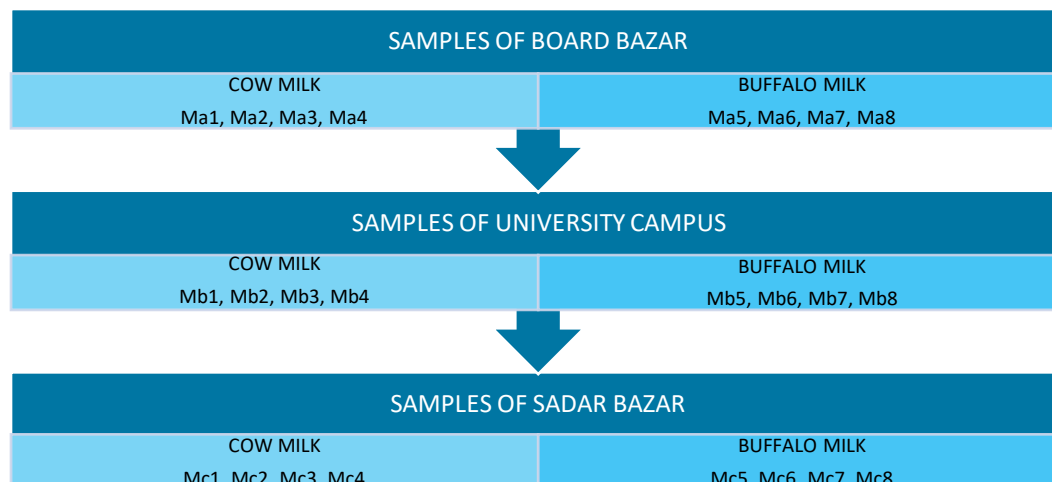
The highest cadmium concentration was found in buffalo milk sample Md5 (0.0052 ppm), while the lowest was in cow milk sample Md1 (0.020 ppm). Chromium concentrations were highest in buffalo milk sample Md5 (0.007 ppm) and lowest in cow milk sample Md4 (0.002 ppm). Lead concentrations ranged from 0.001 to 0.006 ppm, with the highest in cow milk sample Md1 and the lowest in sample Md3. The highest zinc concentration was in cow milk sample Md2 (6.771 ppm), while the lowest was in buffalo milk sample Md5 (1.881 ppm).

Table 5: The concentration (ppm) of the selected heavy metals in Buffalo and Cow milk samples collected from Qissa Khawani Bazar in District Peshawar.

	Sample code	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
		Mean ± S.D	Mean ± S.D	Mean ± S.D	Mean ± S.D
Cow milk	Me1	0.016±0.006	0.004±0.0012	0.004±0.026	3.442±0.0284
	Me2	0.033±0.0019	0.006±0.0016	0.016±0.041	1.823±0.0216
	Me3	0.021±0.0012	0.005±0.0014	0.005±0.032	2.645±0.0272
	Me4	0.010±0.0005	0.004±0.0013	0.006±0.034	1.223±0.0164
Buffalo milk	Me5	0.034±0.0018	0.006±0.0017	0.004±0.025	1.415±0.0050
	Me6	0.045±0.0021	0.003±0.0012	0.012±0.056	1.523±0.0191
	Me7	0.045±0.0021	0.006±0.0017	0.009±0.051	2.122±0.0183
	Me8	0.031±0.0017	0.004±0.0012	0.008±0.038	2.645±0.0273
	Range	0.010-0.045	0.03-0.06	0.04-0.016	1.223-3.442
	WHO Limit	0.01-0.5ppm	0.05ppm	0.02ppm	0.03-1.0ppm

* Analyzing the contamination levels, including the range and mean ± standard deviation, of cadmium, chromium, zinc, and lead in cow and buffalo milk, and comparing these values with the World Health Organization's prescribed limits.

Zinc concentrations in cow milk were significantly higher than in buffalo milk, although both exceeded the WHO limit in some samples. Lead contamination was highest in cow milk, with a concentration of 0.16 ppm.



Conclusion

The analysis of 120 milk samples from various locations in Peshawar revealed contamination by four heavy metals—cadmium, chromium, lead, and zinc—in both buffalo and cow milk. The study highlights the contamination of milk by environmental heavy metals in Peshawar, which can pose serious health risks, particularly for infants and children. Lead, a potent neurotoxin, and cadmium, a carcinogen, were detected in levels that exceed the WHO guidelines in some milk samples. The presence of these heavy metals in milk may be attributed to pollution from industrial activities, agricultural runoff, and the use of contaminated water sources.

Zinc, although essential for human health, was found at higher concentrations in all samples compared to other metals. While zinc is crucial for growth and development, excessive intake can lead to adverse health effects, particularly in children. Chromium, although present at lower concentrations, also poses health risks when consumed in large quantities over extended periods.

The findings call for stricter monitoring of milk quality in Peshawar, particularly in urban areas where industrial pollution is prevalent. Regular testing of milk for heavy metals and more stringent regulatory measures to limit environmental pollution are crucial to ensuring the safety of milk for consumption.

Conclusion: The study provides valuable insights into the contamination of milk by heavy metals in Peshawar, highlighting a potential public health risk. Zinc, cadmium, chromium, and lead were detected in both buffalo and cow milk, with some samples exceeding permissible limits for cadmium and lead. This underscores the urgent need for improved monitoring and regulation of environmental pollutants to safeguard milk quality and protect public health, particularly vulnerable populations like infants and children.

The presence of these contaminants calls for more stringent monitoring and efforts to reduce environmental pollution to safeguard public health.

Recommendations

- Regular monitoring of heavy metals in milk and other food products should be implemented.
- Efforts should be made to control industrial emissions, agricultural runoff, and other sources of contamination.
- Public awareness programs should educate consumers about the risks of consuming contaminated milk and dairy products.

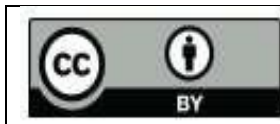
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