ACCUMULATION OF HEAVY METALS IN FORAGE ECOSYSTEM AND ITS IMPACT ON DAIRY COWS IN COIMBATORE, INDIA

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(Received 21st Dec 2023; accepted 19th Apr 2024)

Abstract. An investigation was carried out with 20 samples comprising soil, water, forage, blood serum and milk of cow to assess heavy metal contamination during 2018-19 and 2019-20 in Coimbatore district in Tamil Nadu, India. The results indicated that in soil, chromium residue 741.05 ppm and 1338.1 ppm, lead residue was 168.2 ppm and 164.2 ppm and cadmium 119.2 ppm and 76.14 ppm was in rural and urban areas, respectively. In water, chromium residue was 1.842 ppm and 2.192 ppm, lead residue was 0.816 ppm and 0.973 ppm and cadmium (Cd) was 0.586 ppm and 1.298 ppm in rural and urban areas respectively. In forages, chromium was 1159 ppm and 1712 ppm, lead residue was 341.6 ppm and 398.0 ppm and cadmium residue were 112.2 ppm and 1051 ppm in rural and urban areas, respectively. In the cow serum, chromium residue were 4463 ppm and 4283 ppm, lead residue was 421.3 ppm and 406.9 ppm, and cadmium residue was 409.2 ppm and 323.7 ppm and in the milk, the chromium residue were 101.4 ppm and 165.3 ppm, lead residue was 6.538 ppm and 6.593 ppm, and cadmium residue was 3.905 ppm and 11.23 ppm in urban and rural areas, respectively. The study indicated that heavy metal contamination in soil and water is transferred to dairy cattle and thus result in heavy metal accumulation in blood serum and milk.
Keywords: *contamination, sources, toxicity, food chain, quality*

Introduction

Pollution by heavy metals from waste water is a serious environmental and health issue due to the potential accumulation of heavy metals in biological ecosystems and their persistence, lasting for decades. The effluents and wastes are discharged randomly from the soil, rivers, lakes and roadsides without any treatment. These effluents are mainly deposited in soils and are mobilized either by leaching or through uptake by plants, where they enter the animal and human food chain. Due to the large-scale production, consumption and lack of regulations, heavy metals are discharged into the environment in large quantities through wastewater irrigation, solid waste disposal, sludge application, vehicular exhaust and atmospheric deposition. As a result, heavy metals are omnipresent in industrial, municipal and urban runoff. Environmental risks are related to the bioavailability of metals and depend on the metal speciation, soil characteristics and complex interactions between metals and the environment. The majority of heavy metals are toxic to living organisms, thereby affecting biochemical

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_31113121

processes, and even those considered essential can be toxic if present in excess (Khan et al., 2012). Food chain contamination by heavy metals has become a major issue in recent years because of the potential accumulation of heavy metals in biological systems through contaminated water and soil. Farm animals, especially ruminants, are very useful bio indicators of environmental pollution. Therefore, it is necessary to monitor and assess aggregate exposure to heavy metals in association with different environmental media and pathways to understand the relationships between the concentrations of trace elements in soils, plants, water and animal systems. Moreover, risk assessment seems to be particularly important because these elements can bioaccumulate and biomagnify in plants and animals, eventually facilitating human health through the food chain. Heavy metal consumption may lead to kidney failure, liver problems and blood-cardiac problems, all of which can ultimately lead to death. It is recommended that frequent monitoring of water should be enforced around the industrial hub, so that appropriate actions can be taken if present in excess (Mawari et al., 2022).

Coimbatore exhibits rapid technical evolution in the state of Tamil Nadu, India. It is the second largest industrial center of the state. The major industries include textile, dyeing, electroplating, motor, pump set, foundry and metal casting. In fact, the present scenario edifies nearly 500 textile industries, 300 electroplating industries, 300 dyeing units and 300 foundries in and around Coimbatore. Industrial effluents and municipal wastes contain medium or maximum amounts of heavy metals such as chromium (Cr), iron (Fe), arsenic (As), mercury (Hg), and cadmium (Cd). Apart from these industries, approximately twenty thousand sewers (Malarkodi et al., 2007) run through various zones and finally discharge into the sewage farm located in Ukkadam. The presence of Pb is high in Velangulam lake, Ukkadam lake, and Sungam lake. The presence of Cr is high at Ganapathy and the X-cut road and is 3.6 and 3.5 ppm, respectively, because of electroplating industries.

The district has a total geographical area of 367,097 ha with net cultivated area of about 165,260 ha. Coconut is the major plantation crop cultivated in an area of about 85,831 ha. The other agricultural crops cultivated are millets, pulses, oilseeds, cotton and sugarcane. Food chain contamination by heavy metals has become a major issue in recent years because of the potential accumulation of heavy metals in biological systems through contaminated water and soil. Farm animals, especially ruminants, are very useful bio indicators of environmental pollution. To adopt any type of remedial measure, it is necessary to determine the heavy metal load in the contaminated soil. Against this background, it is necessary to analyze the heavy metal concentrations in and around Coimbatore, Tamil Nadu. Hence, the present study was designed to determine the extent of exposure of dairy cattle to heavy metals by drinking water, dietary intake from soil, water, plants and feed; and rearing around contaminated rural and urban areas of industries in Tamil Nadu.

Materials and methods

Study area

The Coimbatore is located at 11°01’N, 77°97’ E and 426.7 m above sea level and has an area of approximately 7,469 km^2 in the northwestern Tamil Nadu region, very close to the Western Ghats, India. The Coimbatore is surrounded by mountains on the west and the Nilgris biosphere reserve on the northern side. Fodder grass cumbu napier

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_31113121

(CO4) grown for cattle and taken for study purpose. In this study, samples of soil, water, forage, serum, and milk from dairy cows were collected from urban and around (rural) Coimbatore for heavy metal contamination (*Fig. 1*).

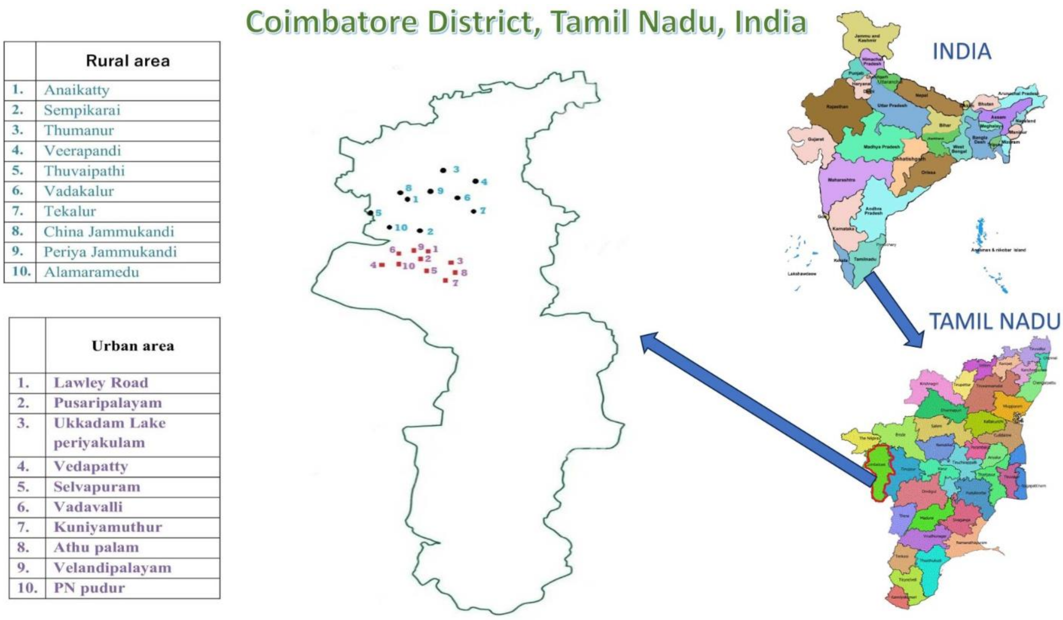

Figure 1. *Locations of study area map*

Sample collection

The soil samples were collected randomly in a zig-zag pattern from three places in each field of study (*Fig. 2*). Each sample was collected by pushing the blade of a garden trowel, shovel, or spade into the soil to a shallow depth of 15 cm. A triangular wedge of soil was cut and set aside (to be replaced after sampling). The blade was subsequently allowed to slide into the soil again through a thin (half inch) slice from one side of the hole. Using a knife, the slice was trimmed to approximately a 1-inch strip of soil down the center of the spade top to bottom. The samples were collected in a polythene bag and labeled. The water samples were collected from lakes (Velangulam Lake Ukkadam, and at the Sungam Lake) using sterile, clear plastic sample bottles 100 ml in volume. The plastic sample bottles were rinsed with the sample to be collected before collection. For lake water samples, water was collected from the subsurface without disturbing the surface layer of the lake water. For irrigation water or tap water samples, water samples were collected by letting the water for 10 min before collection. Approximately 60-70 ml of water was collected per sample. The bottles were then labeled. The samples were stored at 4°C until processing. The leaves of the forage crops fed to the cows under study were collected randomly in a zig-zag pattern. The leaves should not be too young or mature. The leaves collected were not damaged or diseased. The leaves were collected randomly from different forage crops in the field. The collected leaf samples from a field were mixed, collected in a plastic cover and labeled. Three dairy cows per area were selected for serum sample collection. The neck region of the dairy cows was disinfected with mild antiseptic lotion, i.e., spirit, to avoid pathogenic microbial infection during blood collection. With digital pressure, the jugular vein is raised in the neck region. Eighteen-gauge sterile needles were used to pierce the jugular vein to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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collect blood. A sterile, clean test tube was used to collect blood, which was kept at the slope angle without disturbance for a few minutes. The test tube was subsequently centrifuged for 2 min at 2000 rpm for efficient collection of serum. The clear, yellow, transparent supernatant fluid was obtained from the serum, collected with a 1 ml pipette, placed in a serum storage tube and stored in a deep freezer at -18°C. A clear sterile dry plastic container was used to collect milk. The first few strips of milk from each quarter were left, after which the milk was directly stripped into the milk container. Fifty milliliters of milk per cow was collected, 4% formalin was added, and the sample was stored in a deep freezer at -18°C.

Figure 2. *Sample collections from the study area*

Digestion and analysis of the sample

The soil sample was digested using 20 ml of aquaregia for every 0.5 g of sample analyzed. The samples were digested overnight. The next day, the samples were placed in a water bath for 3 h until the sample solution became clear. The samples were then filtered using Whatman number 42 filter paper, after which the filtrate was collected. The volume of the filtrate was adjusted to 100 ml using distilled water. The other samples water, forage, blood serum and milk were digested using triacid extraction, and the same procedure described above was followed for analysis. The water, forage, blood serum and milk samples used for analysis were 100 ml, 0.5 g, 0.1 ml and 20 ml, respectively.

Heavy metal analysis

The collected samples were digested as per the standard protocol for analyzing heavy metals through an atomic absorption spectrophotometer (AAS). The determination of heavy metals in all samples was done using atomic absorption spectroscopy. Hollow cathode

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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lamps for Cr, Cd, and Pb were used. The total content of heavy metals in the digest was measured via an atomic absorption spectrophotometer (AAS, Varian Spectra AA 200) using an acetylene flame. After analyzing all the samples for heavy metals, the data were analyzed according to standard statistical methods and safe limits of heavy metals (*Table* 1).

Table 1. *Guidelines for safe limits of heavy metals (ppm)*

Sample	Chromium	Lead	Cadmium
Soil	100-200	85-300	0.8-3.0
Water	0.05	0.1	0.01
Plant	20	2.5	1.5
Serum	0.006 – 0.066	0.012 – 0.02	0.001 – 0.040
Milk	0.008 – 0.250	0.001 – 0.003	0.005 – 0.2

Data processing methodologies

Simple correlation studies were carried out with the analytical data on various chemical properties enumerated to establish the relationship between different parameters of samples using the methods described by Gomez and Gomez (1984). The data collected on various characters of the samples were analyzed based on the procedure given by Federer (1963). Wherever the treatment differences were significant, critical difference were worked out at 5 per cent probability level.

Results

The heavy metal content in the soil and water samples in the rural and urban areas of Coimbatore, Tamil Nadu is presented in *Table 2*. Whereas *Table 3* illustrates the presence of heavy metals in forage and blood serum samples. The research mainly investigated the presence of three heavy metals: chromium (Cr), cadmium (Cd) and lead (Pb). The reason behind collecting the samples from different rural and urban localities was to identify the extent to which industrial practices impact dairy farming activities. The data yielded the following outcomes:

Heavy metal concentration in soil

The chromium content of rural samples ranged from 390.4 ppm to 1104 ppm and urban samples from 517.8 ppm to 5334 ppm, cadmium content of rural samples ranged from 32.2 ppm to 230.4 ppm and urban samples from 42.2 ppm to 183.8 ppm, lead content of rural samples ranged from 111.8 ppm to 207.4 ppm and urban samples from 129.8 ppm to 210.0 ppm. The soil samples collected from the rural and urban areas, the mean content of chromium residues in rural soil was 741.1 ppm. On the contrary urban soil had a higher amount of chromium climbing to 1338 ppm. Some of the common reasons behind the elevated levels of chromium content in urban soil include industrial processes such as dyeing, electroplating, marble and tile polishing. The maximum content of cadmium residues was found in rural soil with the mean concentration being 119.2 ppm. On the contrary, urban soil had a relatively lesser presence of cadmium at 76.1 ppm. Cadmium contamination in rural and urban localities could be attributed to industrial emissions from electroplating, pigments and battery production activities. The presence of lead residues in rural soils was measured at a mean value of 76.1 ppm.

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Simultaneously the concentration of lead residue in urban soil was calculated at 168.3 ppm.

Heavy metal concentration in water samples

The chromium content of rural samples ranged from 1.129 ppm to 2.512 ppm and urban samples from 1.762 ppm to 2.946 ppm, cadmium content of rural samples ranged from 0.298 ppm to 0.989 ppm and urban samples from 0.240 ppm to 4.611 ppm, lead content of rural samples ranged from 0.596 ppm to 1.396 ppm and urban samples from 0.654 ppm to 1.176 ppm, The mean concentration of chromium residue in rural water samples was found at 1.842 ppm whereas the concentration was significantly higher in the urban water (2.192 ppm). This poses immense threats to the inhabitants of urban localities has chromium-contaminated water could harm the aquatic ecosystem as well as the food chain. The mean concentration of cadmium residue in rural water was found to be 0.586 ppm whereas the concentration in urban water was 1.298 ppm indicating a significantly higher contamination of cadmium in urban waters. Cadmium pollution in water could cause major health problems relying on the aquatic ecosystem and hinder the food chain. The mean concentration of lead residue was calculated at 0.816 ppm in rural water ppm while that of urban water sample was 0.974 ppm.

Heavy metals in forages

In *Table 3* the chromium content of rural samples ranged from 798.6 ppm to 2192 ppm and urban samples from 1245 ppm to 2476 ppm, Cadmium content of rural samples ranged from 22.0 ppm to 556 ppm and urban samples from 446 ppm to 2981 ppm, lead content of rural samples ranged from 153.0 ppm to 188.2 ppm and urban samples from 136.6 ppm to 564.2 ppm. The mean concentration of chromium residue in rural was calculated at 1159 ppm whereas the concentration was significantly higher in the urban forages with a mean concentration of 1712 ppm. The increased level of chromium in urban plant samples could be due to its heavy concentration in soil and water bodies. The mean concentration of cadmium residue was calculated at 112.2 ppm in rural forages while urban plant samples had a mean concentration of 1051 ppm. The increased level of cadmium in urban forages could be due to industrial emissions and toxic waste discharges into the surrounding environment. The presence of lead residue in plant samples was calculated at 341.6 ppm in rural areas whereas urban forages was 398.1 ppm.

Heavy metals in blood serum samples

In *Table 3* the chromium content of rural samples ranged from 1144 ppm to 9295 ppm and urban samples from 1219 ppm to 9400 ppm, Cadmium content of rural samples ranged from 75.5 ppm to 1131 ppm and urban samples from 122.0 ppm to 920 ppm, lead content of rural samples ranged from 207.5 ppm to 687.5 ppm and urban samples from 52.92 ppm to 256.2 ppm. The blood serum samples, chromium residues were measured at 4463 ppm, slightly lower at 4283 ppm was recorded in urban areas. The mean concentration of cadmium residue in rural serum samples was calculated at 409.2 ppm whereas the concentration was relatively low in the urban blood serum at 323.8 ppm. Similar to chromium, the potential sources of cadmium in the blood serum samples could be contaminated water and soil. The presence of lead residue in blood serum was calculated at 421.3 ppm in rural areas whereas that of urban blood serum samples was slightly lower at 406.9 ppm.

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DOI: http://dx.doi.org/10.15666/aeer/2204_31113121

Table 2. *Concentration of different heavy metals (ppm) in the soil, water and plant samples*

Sample	Soil						Water					
	Chromium (ppm)		Cadmium (ppm)		Lead (ppm)		Chromium (ppm)		Cadmium (ppm)		Lead (ppm)	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
1	390.4	2082	48.20	42.20	179.0	143.4	1.696	1.960	0.487	0.688	1.396	0.757
2	1045	632.0	220.6	183.8	207.4	204.6	2.249	2.320	0.603	4.611	0.786	1.016
3	509.6	5334	259.4	83.60	124.0	189.4	2.215	2.007	0.989	0.942	0.828	0.952
4	BDL	517.8	32.20	65.40	143.6	135.6	2.420	2.168	0.193	1.003	0.684	0.943
5	937.2	739.3	116.2	61.30	111.8	143.1	1.129	2.207	0.429	2.520	0.720	1.020
6	1104	840.1	BDL	84.40	165.6	129.8	1.784	2.008	0.576	0.998	0.596	1.124
7	782.4	520.6	67.20	78.20	178.5	143.6	1.176	2.946	0.763	0.472	0.746	1.143
8	945.1	660.6	230.4	82.60	195.2	178.9	1.348	2.006	0.832	0.240	0.647	0.954
9	692.4	890.9	97.90	120.3	203.1	210.0	1.896	2.541	0.298	0.670	0.923	1.176
10	1004	1165	120.5	79.90	174.5	165.1	2.512	1.762	0.698	0.836	0.834	0.654
Max.	390.4	2082	259.4	42.2	124.0	210.0	2.512	2.946	0.989	4.611	1.396	1.176
Min.	1104	517.8	32.20	183.8	207.4	135.6	1.129	1.762	0.193	0.240	0.596	0.654
Mean	741.1	1338	119.2	76.10	168.3	164.4	1.843	2.193	0.587	1.298	0.816	0.974
SEd	**19.82**	**51.08**	**3.23**	**2.11**	**3.84**	**3.80**	**0.04**	**0.055**	**0.015**	**0.044**	**0.020**	**0.024**
CD (0.05)	**41.64**	**107.33**	**6.79**	**4.45**	**8.07**	**7.99**	**0.09**	**0.115**	**0.032**	**0.093**	**0.042**	**0.052**

BDL - below the detected level

Table 3. *Concentration of different heavy metals (ppm) in serum and milk samples*

Sample	Forages						Blood serum					
	Chromium (ppm)		Cadmium (ppm)		Lead (ppm)		Chromium (ppm)		Cadmium (ppm)		Lead (ppm)	
	Rural	Urban	Rural	Rural	Urban	Rural	Rural	Urban	Rural	Rural	Urban	Rural
1	933.4	1245	40.20	446.0	18.82	170.8	1144	7310	718.0	285.5	315.0	235.0
2	2192	2104	55.60	1636	153.0	136.6	6185	1894	81.00	164.0	874.0	687.5
3	1361	1042	83.0	583.6	178.4	251.8	2323	1219	256.0	215.5	207.5	574.0
4	1061	2476	22.0	BDL	168.0	158.4	4479	1855	494.0	920.0	284.0	640.0
5	843.3	1871	39.1	2981	173.1	788.5	5160	3403	1131	494.5	358.5	217.0
6	984.2	1347	92.0	724.3	186.3	920.9	5445	7555	337.0	184.0	338.0	436.0
7	1006	1567	76.5	893.8	165.0	343.7	2553	1626	75.50	290.0	389.0	515.5
8	798.6	2311	66.9	1020	181.0	564.2	4051	5375	340.0	301.5	568.5	174.5
9	1453	1249	48.7	679.4	157.4	167.7	9295	9400	443.0	260.5	400.5	509.0
10	956.4	1906	97.9	1548	171.8	478.0	4002	3143	216.5	122.0	478.0	584.0
Max	2192	2476	BDL	2981	18.82	920.9	9295	9400	1131	920	874	687.5
Min	798.6	1042	22.00	446.0	153.0	136.6	1144	1219	75.50	122.0	207.5	174.5
Mean	1159	1712	112.2	1051	341.6	398.1	4463	4284	409.2	323.8	421.3	406.9
SEd	**27.78**	**42.82**	**1.591**	**40.09**	**4.059**	**13.10**	**119.7**	**116.52**	**15.68**	**11.19**	**10.03**	**11.70**
CD (0.05)	**58.38**	**89.96**	**3.344**	**84.23**	**8.529**	**27.52**	**251.5**	**244.8**	**32.95**	**23.51**	**21.07**	**24.59**

BDL - below the detected level

Heavy metals in milk

In *Figure 3* the chromium content of rural samples ranged from 52.92 ppm to 256.2 ppm and urban samples from 63.18 ppm to 257.0 ppm, Cadmium content of rural samples ranged from 0.44 ppm to 15.11 ppm and urban samples from 0.04 ppm to 68.60 ppm, lead content of rural samples ranged from 0.39 ppm to 11.36 ppm and urban samples from 1.35 ppm to 14.47 ppm. The mean concentration of chromium residues in rural milk samples was measured at 101.4 ppm. which significantly increased to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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165.3 ppm in urban milk samples. Chromium contamination in milk can lead to adverse health risks to animals and humans. The mean concentration of cadmium residue in rural milk samples was measured at 3.905 ppm whereas the concentration was significantly higher in the urban milk samples at 11.23 ppm. Long-term exposure to cadmium-contaminated milk could lead to serious health conditions and pose significant risks to consumers. The concentration of lead in rural milk was measured at 6.538 ppm. while in urban milk it was slightly higher at 6.593 ppm. Lead is a rather toxic heavy metal which could especially impact the health and well-being of children and cause long-term implications on the nervous system of consumers.

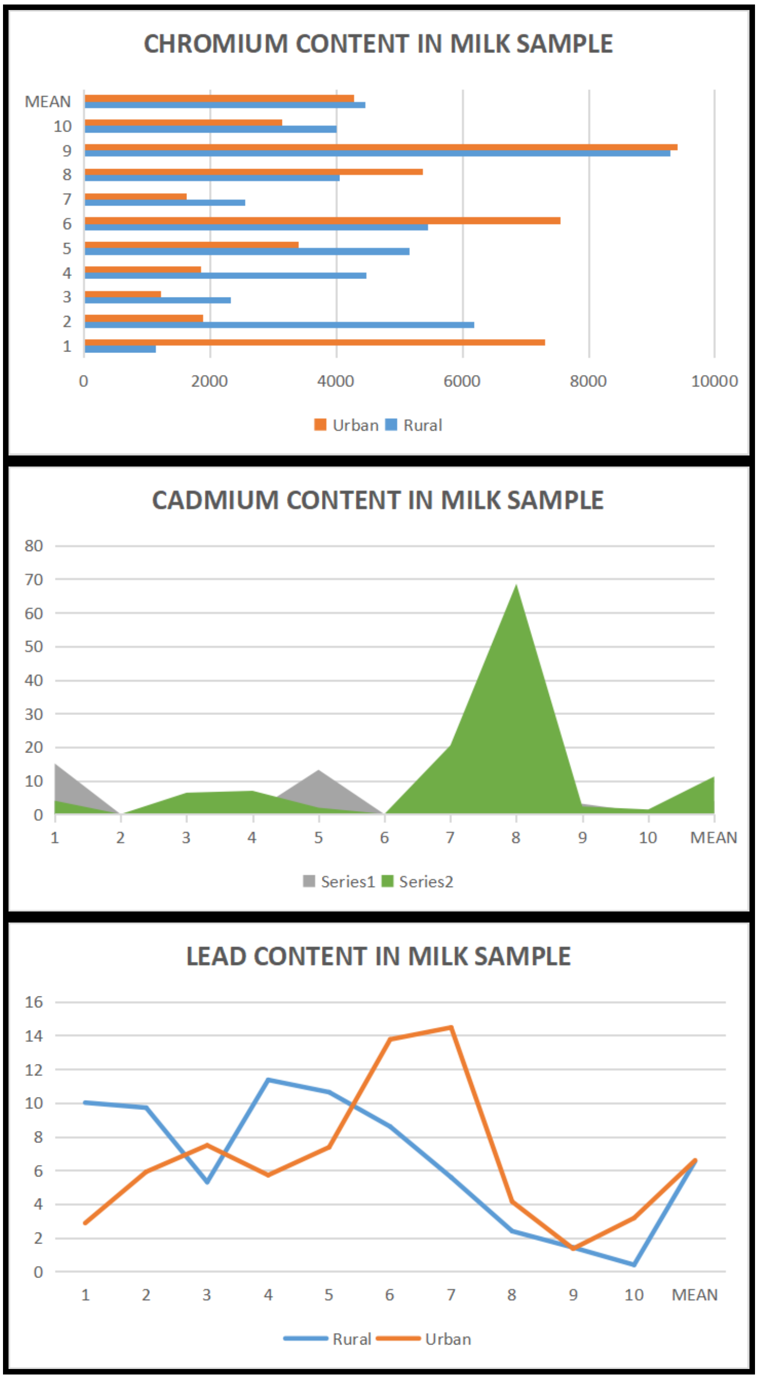

***Figure 3.** Heavy metal concentration (ppm) in milk samples in rural and urban*

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DOI: http://dx.doi.org/10.15666/aeer/2204_31113121

Discussion

Based on the empirical findings it can be gathered that heavy metal contamination in soil and water bodies can have adverse health impacts to the water ecosystem, dairy cattle and eventually to humans through the food chain. The results of the study reveal that the cattle are majorly impacted by heavy metal pollution in soil and water leading to reduced milk quality and shelf life. Some of the major facilitators of heavy metal contamination in the above-mentioned samples are linked to industrial contamination with the main sources of heavy metals being inadequately discharged in sewage water and industrial discharges from dyeing electroplating and textile industries. Heavy metals and metalloids (HMs) are environmental pollutants. When it accumulate to beyond critical levels in soils, these heavy metals adversely affect soil and also agricultural productivity. These findings were accordance with the findings of Rashid et al. (2023) and Zhao et al. (2022). Metals in milk and dairy products are probably sourced from the contaminated environment around the farm, feed, and packing materials (Yan et al., 2022).

Water is precious resources for all living organism in the world. Heavy metal pollution presence in the aquatic system is mainly due to the due to industrialization and urbanization (Koser et al., 2023). Considering the environmental impacts of heavy metal distribution it can be argued that the indiscriminate discharge of industrial pollutants into rivers lakes roadsides and soils are serious threat to the health of humans and the overall environment. Increased amounts of heavy metals in the environment could have adverse impacts on a variety of creatures and cause significant health hazards to humans (Ogututucu et al., 2021). Coimbatore, a major industrial hub of India Coimbatore poses some serious problems in terms of heavy metal pollution in rural as well as urban areas. The increased amounts of wastewater and sewage discharges add to the height and levels of cadmium chromium and lead contamination in the surrounding eco system.

Being a toxic heavy metal, elevated lead concentration cause serious health complications among animals including reproductive problems and impaired functionality of the nervous system. Adverse levels of chromium in the blood stream could have adverse health implications on animals with potential sources being contaminated by both water and soil. Hence the urban soil has a higher concentration of lead residues which can lead to detrimental consequences on the quality of soil, crops and overall human health outcomes. Some major facilitators of lead emission in water bodies include industrial emissions from lead acid batteries and foundries. Similar trend on heavy metal concentration in pasteurized and sterilized milk was noticed in Pakistan, Brazil, Egypt, Slovakia, and Turkey by Alinezhad et al. (2024). Pb, As, Cr, and Cd were also discovered by Zhou et al. (2019) in cow milk, water, silage, and soil. additionally according to him, there is a significant association between the amount of protein in milk and the presence of heavy metals in silage, which may be a contributing factor to milk contamination. According to Zhang et al. (2024), eating habits can also affect the amount of heavy metals in human milk.

The generally accepted level of lead in forages, according to the World Health Organisation (WHO), is 2 ppm (Ogututucu et al., 2021). The heavy metal contamination in soil and water gets transferred to dairy cattle and finally to humans through food chain and thus causes serious health issues. Similar views were expressed by Sarsembayeva et al. (2020). Cow milk from analysis had minimal levels of hazardous heavy metals and a good mineral makeup. The milk samples revealed modest levels of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_31113121

chromium, lead, and cadmium that did not surpass the permitted levels in Coimbatore. Similar trend was observed by Sarsembayeva et al. (2019) the Almaty region, Kazakhstan and Sidawi et al. (2023) in the Kvemo Kartli Region, Georgia. The findings of the study highlighted the need for waste management procedures and pollution prevention strategies to protect the overall ecosystem. Therefore, there is a need to develop nano technological and nanomedicine should be developed to treat heavy metal toxicity (Mitra et al., 2022). The probiotic *Lactobacillus rhamnosus* helps reduce the amount of lead and cadmium in dairy products (Elafify et al., 2022).

Conclusion

From the present study, the following conclusions are drawn for mitigating the negative ill effects of heavy metal pollution in dairy and forage plants, thereby minimizing the health hazard among people through safe milk and milk product consumption. The concentration of heavy metals in milk is dependent on the relative level of exposure of cattle to contaminated soil, water and forage. Forage and water play key roles in determining the level of heavy metals in milk. Toxic elements (Pb and Cd) were translocated and magnified more in the biological system of dairy cattle from forages and water. Special attention must be given to the constant assessment and monitoring the quality of soil and water bodies. To prevent health risks to the population through the consumption of milk samples need to be screened regularly. Plant breeders may be advised to evolve suitable fodder varieties that can nullify the concentration of heavy metals, thereby avoiding accumulation and translocation into the human food chain. Similarly, high yielding flower crops that can utilize sewage water may also be grown in the study areas as a potential phytoremedial measure. Animal nutritionists may be advised to formulate feeds with low chromium contents, particularly during the summer season.

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