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Cadmium Level in Blood and Milk from Animals Reared Around Different Polluting Sources in India

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Cadmium is a well known ubiquitous environmental and industrial toxicant distributed widely in the environment. It is a cumulative poison having no beneficial biological role, but is highly toxic to both human and animals. The common sources of cadmium are combustion of coal and mineral oil, smelter, alloy processing, mining, discarded paints and incinerators (Sharma and Street, 1980). Cigarettes smoke is also a source of cadmium into the environment (Hossn et al. 2001). These anthropogenic activities and automobile exhaust contributes to the entry of cadmium into human and animal food chain (WHO 1992, Okada et al. 1997). Animals may gain access to excess of cadmium from water, soil and vegetation contaminated with industrial and automobile emissions, and its toxicities have been reported in animals reared around different polluted areas. Higher cadmium levels in milk and blood of dairy cattle have been reported from urban localities (Swarup et al. 1997). Earlier reports from India indicate presence of higher concentration cadmium than the maximum allowable limits in water, vegetation and food chain in certain areas (Agarwal and Raj 1978, Khandekar et al. 1980) and higher blood levels of lead and cadmium in cows and buffaloes near a primary lead-zinc smelter in India (Dwivedi et al. 2001).

The cadmium residues in milk from animals exposed to environmental pollutant have serious public health concern. Cadmium is poorly secreted into milk (Neashery and Miller 1975), but milk can be a significant source of cadmium and lead for infants if the level exceeds the acceptable limit for human consumption (MRS 1987). Cadmium levels in human milk are 5 to 10% of its level in blood. The poor excretion of cadmium in milk as compared to lead is possibly due to inhibited transfer from blood because of metallothionein binding of cadmium in blood cells (Radisch et al. 1987). However, appreciable cadmium residues in milk have also been recorded in cows in a polluted locality (Swarup et al. 1997). The present work was conducted to examine blood burden of cadmium and its transfer into milk with respect to blood cadmium levels in lactating cows reared in areas around different industrial activities in India.

MATERIALS AND METHODS

The study sites are located at various parts of India with different industrial activities such as mining or processing factories. Lactating cows reared in these

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areas within 2 km radius from the industrial unit and allowed to graze on pasture within 2 km distance from the factories were used for this study. The industrial units included steel processing unit (n=22), zinc manufacturing factory (n = 21), aluminum processing plant (n=25), rock phosphate mining area cum phosphate fertilizer plant (n=21), coal mining areas (n=46) and ex-lead processing plant cum presently zinc smelting unit (n=14). A random 52 samples were collected from lactating cows reared in non-polluted areas to serve as control.

Respective blood and milk samples were collected from each of the lactating cows (n=201). Blood samples were collected in nitric acid washed glass vials using heparin as anticoagulant, and milk samples were collected in to plastic vials. Environmental samples such as stool, feed and fodder were collected in polythene bags for further processing in the laboratory.

Fodder samples were washed in de-ionized water to remove dust and superficial contamination. The washed environmental samples, blood and milk were wet digested with nitric acid and perchloric acid mixture (Kolmer 1951) and the cadmium concentration in digested samples was estimated using atomic absorption spectrophotometer (Electronic Corporation of India Limited) at the wave length of 229.5nm with 6ma current and the values were expressed in μg/ml of blood or milk and μg/g of soil, feed or fodder.

The data were analyzed using one-way analysis of variance to find out the statistical difference among the mean values. The blood cadmium concentrations irrespective of the site of collection were grouped into 7 frequencies (Table 2). The mean cadmium excretion in milk within a particular range of blood cadmium level was analyzed by sorting the corresponding values. The overall correlation between blood and milk cadmium were analyzed using standard statistical methods (Snedecor and Cochran 1989).

RESULTS AND DISCUSSION

Table 1 depicts mean (±SE) blood and milk cadmium concentration in lactating cows, reared in different polluted areas. Significantly ($P<0.05$) higher mean blood cadmium level was recorded in animals reared around steel manufacturing plant (0.232 ± 0.016 μg/ml) followed by aluminum processing plant /thermal power plant (0.044±0.001 μg/ml) and phosphate fertilizer manufacturing cum mining areas (0.044 ± 0.002 μg/ml). The lactating animals reared around lead-zinc smelter (0.033 ± 0.002 μg/ml), coal-mining areas (0.032 ± 0.001 μg/ml) had statistically comparable ($P>0.05$) blood cadmium levels to those from non-industrialized areas, supposed to be free from pollution (0.028 ± 0.002 μg/ml). The lowest blood cadmium level (0.028 ± 0.002μg/ml) was recorded in milk animals around closed lead cum operational zinc smelter and the value was comparable ($P>0.05$) with that from non-industrialized areas (0.028±0.002 μg/ml).

The highest mean milk cadmium level (0.264 ± 0.019 μg/ml) was recorded in animals with the highest blood cadmium level (0.232 ± 0.016), and these animals were reared in the vicinity of steel manufacturing plant. The mean milk cadmium levels in lactating cows from other areas with different industrial activities except around aluminum processing units (0.087 ± 0.003 μg/ml) was statistically comparable to mean value recorded for control animals. Sorting all the results from 201 lactating cows into 7 different ranges (Table-2) based on blood cadmium concentrations, 180 animals had level (Group 1 to 6) below 0.100 μg/ml and the remaining 21 animals (Group 7) had levels above this limit. Comparison of blood cadmium level and its excretion in milk revealed a positive significant correlation ($r=0.722$ at $P<0.01$). The cadmium excretion in milk remained relatively constant up to the blood cadmium level from non-detectable to 0.020 μg/ml, showed increasing trend form 0.021 to 0.051 μg/ml, and significantly higher cadmium excretion in milk as compared to that of control animals was recorded with blood cadmium level ≥ 0.051 μg/ml.

Table 1. Residues of cadmium in blood and milk from animals reared in polluted areas.

	Place	N	Blood Cd (μg/ml)		Milk Cd (μg/ml)	
			Range	Mean ±SE	Range	Mean ±SE
1	Unpolluted areas	52	0.00-0.05	$0.028±0.002^{ab}$	0.00-0.07	$0.033±0.002^{ab}$
2	Steel manufacturing Plant	22	0.09-0.41	$0.232±0.016^{c}$	0.11-0.39	$0.264±0.019^{d}$
3	Aluminum processing plant/ Thermal power plant	25	0.03-0.07	$0.044±0.001^{b}$	0.06-0.12	$0.087±0.003^{c}$
4	Phosphate fertilizer and mining areas	21	0.02-0.07	$0.044±0.002^{b}$	0.00-0.09	$0.034±0.004^{a}$
5	Lead-zinc Smelter	21	0.01-0.05	$0.033 ± 0.002^{ab}$	0.02 - 0.27	$0.078 ± 0.014^{bc}$
6	Coal mining areas	46	0.01-0.07	$0.032 ± 0.001^{ab}$	0.00 - 0.10	$0.057±0.002^{ab}$
7	Closed lead-operational zinc smelter	14	0.00 - 0.05	$0.026 ± 0.003^{a}$	0.03-0.09	$0.055 ± 0.004^{ab}$

N- Number of animals from which blood, milk and hair samples were collected. Means (±S.E.) with different superscripts vary significantly at 0.05.

Cadmium is a persistent non-biodegradable, toxic heavy metal pollutant in the environment. Its burden has steeply escalated in the environment due to industrial evolution. Anthropogenic activities such as mining, smelting operations, use of phosphate fertilizers, electroplating, pigments and automobiles have significantly contributed to the entry of cadmium into human and animal food chain (WHO

1992). Long term exposure to lower levels of cadmium in air, food or water leads to a build up of cadmium in the kidney, resulting in possible kidney diseases (ATSDR 1999). Higher concentrations of cadmium than the maximum allowable limits in water, vegetation and food have been reported in certain areas from India and, in tissues from animals (Agarwal and Raj 1978, Khandakar et al. 1980, Amido and Fiora 1987). Lead/ zinc smelters have been attributed to cause varying degrees of lead, cadmium and zinc poising in animals (Radostits et al. 2000). Amodio and Fiora (1987) reported tissue cadmium concentrations in animals in Campania, Italy, which varied between 0.038 and 0.342 mg/kg in cattle, 0.048 and 0.666 mg/kg in pig, 0.178 and 1.035 mg/kg in lamb and 0.021 mg/kg in milk. There values were lower than the levels to be considered free from pollution. However, the authors recommended monitoring of lead and cadmium levels in the feed stuff as higher levels were detected in other provinces.

Normal concentration of cadmium in blood was <0.01 μg/ml, while in exposed workers the whole blood cadmium level ranged between 0.01 to 0.1 μg/ml (Friberg et al. 1974). Hogan and Jakson (1986) opined that acute cadmium administration transiently increases its level in blood plasma. In India, Swarup et al (2000) reported considerably higher cadmium concentration in blood from urban dogs as compared to their rural counterparts. In the present work, maximum cadmium level was recorded in cows reared in the vicinity of steel and aluminum manufacturing plant. A higher concentration of cadmium in arable soil and in tissues from dairy cows has been recorded in number of regions in Russia that resulted through atmospheric deposition and use of phosphate and mineral fertilizers (Shaproshnikov and Prisnyi 2001, Olsson et al. 2001).

The present finding of higher blood cadmium levels in animals around these industries might be due to higher cadmium emission from these industrial units leading to enhanced cadmium levels in aerosol and fodders as the cadmium uptake by plants is highly and positively related to soil cadmium concentration (Burgat et al. 1996). This might have resulted in continual higher intake of cadmium through ingestion of contaminated fodder. This was substantiated by the present finding of higher cadmium concentration in fodder and soil samples collected from these industrial areas (32.00 ± 30.524 μg/g (n=3) and 168.91 ± 0.00 (n=1) μg/g, respectively) than those from non-industrialized area (0.152 ± 0.014 μg/g (n=8) and 1.203 ± 0.007 μg/g (n=3), respectively.

Milk cadmium concentration is a potential public health concern, especially to children as the young absorb more cadmium than adults. Milk production mobilizes accumulated cadmium from liver and kidney and enhances its excretion in milk (Olsson et al. 2001). Cadmium clearance in milk averaged 2.0 to 4.9% of blood clearance in an experimental cadmium exposure in ewes (Houpert et al. 1997). However, cadmium passage from mother to child through placenta is not uncommon (ATSDR 1999). Higher cadmium and lead levels were reported in milk of urban cattle from India (Swarup et al. 1997). However, there appears to have no literature on cadmium excretion in milk from lactating cows reared around different industrial areas with continual exposure to environmental pollutants. In the present study, significantly higher cadmium excretion was recorded in animals reared around steel-manufacturing plant and aluminum processing plant in comparison to control (unpolluted) area. However, milk from animals reared around other industrial areas did not have significantly ($P>0.05$) higher milk cadmium excretion as compared to control animals, although there was a trend of increased cadmium excretion in milk. Cadmium and zinc in mammary gland is positively related to age and milk production. Lactation reduced the mean kidney cadmium concentration, and cadmium and zinc in kidney was related to age and production related parameters but not to the farming system, conventional or organic, in lactating cows revealed mobilization of cadmium and its higher excretion in milk (Olsson et al. 2001). The present finding of higher cadmium level in animals around different industrial units has serious public health concern, and potential hazard, if such milk is regularly consumed in quantities that lead to daily intake of cadmium more than the permissible limit.

Table 2. Milk cadmium (µg/ml) excretion in respect to blood cadmium concentration in lactating cows.

	Levels in µg/ml (N)	**Blood Cadmium Level**	**Milk Cadmium Level**	
		Mean ± SE	*Range*	*Mean ± SE*
1.	0.000– 0.010 (7)	0.004 ± 0.001	0.04 – 0.06	0.045 ±0.005[a]
2	0.011 – 0.020 (16)	0.016 ± 0.001	0.00 – 0.07	0.036 ± 0.004[a]
3	0.021–0.030 (41)	0.026 ± 0.001	0.02 – 0.14	0.051 ± 0.04[ab]
4	0.031– 0.040 (69)	0.035 ± 0.001	0.00 – 0.27	0.054 ± 0.005[ab]
5	0.041–0.050 (33)	0.045 ± 0.001	0.01 – 0.17	0.063 ± 0.006[ab]
6	0.051– 0.100 (14)	0.061 ± 0.002	0.02– 0.30	0.079 ± 0.019[b]
7	> 0.100 (21)	0.238 ± 0.015	0.11 – 0.39	0.262 ± 0.020[c]

The lactating cows were grouped into 9 different group based on blood cadmium concentrations. N- Number in parenthesis indicates the number of animals with blood cadmium level falling in that particular range

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