Cattle hair as a biomarker of lead pollution in the region of the Shiraz oil and petrochemical industries in Iran

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Abstract

This survey aimed to evaluate the level of lead (Pb) pollution in cattle in the vicinity of the Shiraz oil and petrochemical industries using hair samples. Dairy farms located within 10 km of the Shiraz oil and petrochemical industries were identified and divided into four groups. Farms that were located in the radial zones of 0.5-1.5 km, 1.5-5 km, 5-7 km, 7-10.5 km were considered as groups A, B, C and D, respectively. Fifteen cattle from a farm that was located far from the polluting areas comprised the control group (E). Head hair samples were collected from fifteen age-matched cows from each of the five groups in each season round year. Cattle that were located closer to the oil and petrochemical industries had higher hair Pb concentration. In all groups, the hair lead concentrations of cattle that were reared near to the oil industry were significantly higher than of those reared in the region of the petrochemical industry ($p<0.05$); and showed pollution factors of about two folds when groups in the same distances of oil and petrochemical industries were compared. In this study, there was a declining trend in hair lead concentration from spring to winter from 8.3 to 2.6 ppm and from 4 to 2.2 ppm in cows located near to the oil and petrochemical industry plants, respectively.

Introduction

The evaluation and delineation of heavy metal contaminated areas have usually been associated with uncertainty, which makes decision making for future management strategies difficult (Goovaerts, 1997). Technological progress and various industrial activities have caused a significant increase in environmental contamination by heavy metals and have facilitated their entry into the food chain. Hair is a material that is easy to obtain, transport and store and is accessible for noninvasive sampling in individuals or population groups; it has been used to demonstrate exposure to toxic metals for many years in different areas. Lead (Pb) is a ubiquitous toxic metal, and assessments of lead exposure with the use of hair has been carried out in many epidemiological studies (Wilhelm *et al.*, 1989, 1994; Chlopicka *et al.*, 1998; Sana *et al.*, 2003; Barbosa *et al.*, 2005; Petra *et al.*, 2007; Stupar *et al.*, 2007).

Cattle production is one of the most important agricultural activities in the region of Shiraz, Iran. Cattle are predominantly reared on locally produced feeds and are exposed to heavy metal contamination because of their close proximity vicinity to sources of airborne contamination, such as oil and petrochemical industries. Although lead toxicity in animals is usually the result of licking lead-based paint, lubricants, and discarded batteries, grazing cattle are most likely to be exposed to lead if there is a regular source of airborne contamination (Chumbley and Unwin, 1982; Burren *et al.*, 2010). Ultimately, lead that is enriched in the body of humans through the food chain causes health problems, such as nervous system and brain damage, and studies of this kind can help to monitor the levels of exposure to lead from polluting industries.

One area that has been studied less intensively is regions that are in the vicinity of oil and petrochemical industries, which makes studies of pollution in these areas and the prediction of possible environmental and health hazards very important. In this study, we present data with regards to lead concentration in the head hair of cattle that graze in areas at different distances from the Shiraz oil and petrochemical industries over the period of a single year.

Materials and Methods

The areas that were selected for investigation were located within 10 kilometers from the Shiraz oil and petrochemical industry plants. This study examined stratified samples of head hair from randomly selected cattle in five different groups:

groups A, B, C and D consisted of farms that were located in the radial zones of 0.5-1.5 km, 1.5-5 km, 5-7 km and 7-10 km from the industrial source, respectively. None of these farms were close to other local sources of lead pollution. Group E consisted of cattle from the control farm, which was in a nonpolluted region in the east of Shiraz and was far from lead polluting sources and roads. Fifteen cattle were samples from each of the groups and samples were taken once in each of the four seasons over a single year. Approximately 2 g of head hair was collected from animals within the same age group. All samples were placed into labeled plastic bags and were sent to the Shiraz Veterinary School Central Laboratory. Hair samples were washed to ensure that the measured lead is indicator of endogenous metal (Bermejo-Barrera *et al*., 1997).

Lead concentrations were determined by a flame atomic absorption spectrometer (Unicam model 969) by the graphite flame 90 (GF 90) system with deuterium ground correction. During the standard preparation steps and the measurement of samples, a specific polyethylene sampler and atomic absorption system tube were used. Ammonium dihydrogen phosphate was used as the matrix modifier. All the operational conditions in the instrumentation manual were followed as shown in Table 1.

Table 1: Furnace Conditions for Pb measurement.

Step	Temp(C^o)	Ramp Time	Hold time	Internal flow	Gas type
1	110	15	50	250	Normal
2	130	25	50	250	Normal
3	560	20	20	250	Alternate
4	560	20	20	250	Normal
5	850	10	20	250	Normal
6 (Result reading step)	1600	0	5	0	Normal
7	2450	0	3	250	Normal

The effects of lead pollution on hair lead concentration in the examined cattle were compared by an assessment of the pollution factor (PF). PF was calculated as the ratio of metal levels in the industrialized area to metal levels in the control rural area, as previously described (Miranda *et al*., 2005). Additionally, the effect of Pollution factor (PF) in the hair of cattle around Shiraz oil and petrochemical industries was shown in Table 3.in examined cattle was compared by PF (Table 3).

Results were analyzed by Sigma stat software with a one way ANOVA (Holm-Sidac) test for the comparison of hair lead concentration of different groups in each season. The level of statistical significance (p-value) was set at 0.05.

Table 3: Pollution factor (PF) in the hair of cattle in the region of the Shiraz oil and petrochemical industries. Farms located in the radial zone of 0.5-1.5 Km (A), 1.5-5 Km (B), 5-7 Km (C) and 7-10 Km (D).

Group	Oil industry				Petrochemical industry			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
A	5.93	4.42	3.81	3.86	2.86	2.37	1.73	1.29
B	5.36	4.14	3.5	3.71	2.78	2	1.73	1.29
C	3.86	4.14	3.5	3.78	2.14	1.62	1.73	1.29
D	1.86	1.78	1.31	2.07	2	1	1.26	1.23

Results

Cattle that were located closer to the potential contamination sources were found to have higher hair lead concentrations (Table 2). In all groups, hair lead concentrations of cattle which were reared in proximity to sites of oil industry were significantly higher than of those reared near petrochemical industrial plants ($p<0.05$). Almost all farms near to oil industry plants showed PF ratios that were approximately two-fold more than farms near petrochemical industries when compared with the corresponding groups in the same season (Table 3). Hair lead concentration showed a declining trend from spring to winter, from 8.3 to 2.6 ppm and from 4 to 2.2 ppm in regions close to oil and petrochemical industries, respectively. In each season there were statistically significant differences between the control group and groups A, B and C in those regions near to oil industry ($p<0.05$). In cattle that grazed close to the petrochemical industrial plants, there were significant differences between the control group and groups A, B and C in spring and between the control group and groups A and B in summer (Table 2).

Discussion

The results of this study revealed that

Table 2: Lead concentrations (ppm) in the cattle hair from animals living within different zones in the vicinity of the Shiraz oil and petrochemical industries. Farms were located within the radial zone of 0.5-1.5 km (A), 1.5-5 km (B), 5-7 km (C), 7-10 km (D), and E (control farm).

Group	In the region of oil industry (mean ± SD)				In the region of petrochemical industry (mean ± SD)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
A	$8.3±1.2^{cde}$	$6.2±1.0^{de}$	$6.1± 1.3^{de}$	$5.4± 0.9^{de}$	$4.0± 1.1^{e}$	$3.8±1.0^{de}$	2.6±0.7	2.2±0.8
B	$7.5±1.1^{cde}$	$5.8±0.8^{de}$	$5.6±1.0^{de}$	$5.2±0.7^{de}$	$3.9±0.9^{e}$	$3.2±0.8^{de}$	2.6± 0.8	2.2±0.7
C	$5.4±0.8^{abde}$	$5.8±0.9^{de}$	$5.6±1.1^{de}$	$5.3±0.8^{de}$	$3.0±0.9^{e}$	2.6±0.7	2.6±0.7	2.2±0.8
D	$2.6±0.5^{abc}$	$2.5±0.5^{abc}$	$2.1±0.6^{abc}$	$2.9±0.5^{abce}$	2.8±0.7	$1.6±0.9^{ab}$	1.9± 0.4	2.1±0.6
E	$1.4±0.3^{abc}$	$1.4±0.5^{abc}$	$1.6±0.4^{abc}$	$1.4±0.6^{abcd}$	$1.4±0.3^{abc}$	$1.6±0.4^{ab}$	1.5± 0.4	1.7±0.4

a, b, c, d, e Statistical significant differences of lead concentrations among groups A, B, C, D and E, respectively ($p<0.05$).

environmental contamination close to oil and petrochemical industrial plants in Shiraz had a significant effect on head hair lead concentration in cattle. Similar reports have been released previously with regards to different heavy metals in different tissues from cattle in other polluted environments, including areas in the vicinity of zinc refineries (Spierenburg *et al.*, 1998), metalliferous areas (Antoniou *et al.*, 1989; Antoniou *et al.*, 1995; Farmer and Farmer, 2000; Koh and Judson, 1986; Zantopoulos *et al.*, 1990), and areas in which pastures receive wastewater (Sedki *et al.*, 2003).

Dorn *et al.* (1974) reported that reductions in lead exposure were reflected more rapidly in blood than in hair concentrations. They also emphasized these results demonstrate the value of using bovine hair samples in the surveillance of environmental contamination, as well as other ecological, epidemiological, and mineral metabolism studies.

Only broad comparisons can be made between the results of the present study and data reported previously. This is principally because there is considerable variation among studies in the way in which average values are presented, in limits of detection, and in the value assigned to subdetectable concentrations. All three factors are very important when samples do not show a normal distribution and/or many samples have metal levels close to or below the limit of detection (Barbosa *et al.*, 2005). The age of animals is also an important factor for bioaccumulative metals, such as cadmium (Antoniou *et al.*, 1989; Dorn *et al.*, 1974). Therefore, we removed the effect of the age of the animals in our study via sampling of head hair in age-matched animals.

Hair lead concentrations in cattle reared within the radius of 1 to 5 km of Shiraz oil industry (5.8-6.2 ppm in summer) were considerably lower than the mean lead concentration reported previously in cattle from Isfahan, another polluted area of Iran (Pourjafar *et al.*, 2008). This same previous study also reported that cattle reared within 1 to 5 km of oil industrial plants in Isfahan had a mean hair lead concentration of 9.22-10.42 ppm in summer.

Studies on heavy metals in animals may be an indicator of pollution in human beings; therefore, the interpolation and comparison of data in animal studies with human data could be important. This is supported by study of Hayashi *et al.* (1981). They showed that the concentrations of heavy metals in dogs are consistent with those in humans. Reports from human revealed higher amount of hair lead concentration in comparison with our results in other countries (Chlopicka *et al.*, 1998; Esteban *et al.*, 1999; Leukouch *et al.*, 1999; Sanna *et al.*, 1995).

In recent years, there has been a remarkable decline of more than 10-fold in lead concentrations in animal tissues throughout the developed world (Jorhem *et al.*, 1996; Skalicka *et al.*, 2002; Tahvonen and Kumpulainen, 1994), which has been attributed to the phasing-out of leaded petrol (Belle´s *et al.*, 1995; Rodamilans *et al.*, 1996).

Puls (1988) stated that the normal hair lead content of cattle was within the range of 0.5-5 ppm. He reported that 10-100 ppm of hair lead content is considered as a high and toxic level. Therefore, the reported lead values in our study were mostly within the normal range.

Pollution factors (PF) are calculated as the ratios of metal levels in the industrialized area under study to metal levels in control rural areas (Miranda *et al.*, 2005). The effects of pollution on the toxic metal levels in our study could be compared with data reported elsewhere on the basis of PFs. PF values have been widely used in monitoring studies (Fernandez *et al.*, 2000; Sedki *et al.*, 2003) that allow the estimation of the proportion of tissue metal content with anthropogenic origin. The most marked effect of pollution on lead concentrations was seen in the vicinity of oil industry plants in spring (PF: 5.93, 4.42, 3.81 and 3.86 in groups A, B, C and D, respectively), and to a lesser extent near petrochemical industries in the winter (PF: 1.29, 1.29, 1.29 and 1.23 in groups A, B, C and D, respectively). This result is in accordance with the report of Sanna *et al.* (2003) on the PF of hair lead concentrations in boys and girls.

In this study, the hair PF of lead (PF=3.86-5.93 near oil industry plants and PF=1.29-2.86 near petrochemical industry plants), as compared with the hair PF of lead in schoolchildren who live in a wastewater spreading field of Morocco (PF=3.32) (Leukouch *et al.*, 1999), show a higher effect of anthropogenic interference in environmental pollution. Although toxic lead levels in cattle from the industrialized area of Shiraz were low, cows that were located closer to potential contamination sources were found to have higher hair lead contents.

It is important to note that the lead was found in all the samples in this current study, which demonstrates that a permanent source of pollution exists in this region; the cumulative effect of the metal can eventually lead to dangerous levels, which adversely affect human and animal health. The detection and monitoring of lead levels in the hair of cattle can be a useful method for the estimation of possible lead hazards.

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