Cadmium, Copper, Lead and Zinc in Bovine Hair in the New Lead Belt of Missouri[1]

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Hair is a stable, easily collected biological material that can be used in evaluating the magnitude of environmental contamination by heavy metals (HAMMER, et al., 1971; KLEVAY, 1973; SORENSON, 1973). Bovine hair has been studied in bovine mineral research by a number of investigators (HARTMAN, 1967; MILLER, et al., 1965; ANKE, 1971; HALL, et al., 1971; NOUGUES and LAMAND, 1972). Investigations of radioactive fallout (O'MARY, et al., 1969) and endemic nephritis (IVANOV, et al., 1962) also used hair obtained from cattle. RÜSSEL and SCHÖBERL (1970) measured lead storage in hair of cattle with chronic lead poisoning. The purpose of this communication is to report the concentrations of cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) measured in hair of cattle sublethally exposed to multiple sources of contamination in a lead mining and smelting area.

MATERIALS AND METHODS

An exposed farm, subsequently called the test farm, was located approximately 800 meters north of a lead smelter and on a highway that was used for trucking lead ore concentrate from the mines in the New Lead Belt in southeast Missouri (WIXSON and BOLTER, 1972; HEMPHILL, et al., 1973; DORN, et al., 1973). Four cows were identified on this farm for sample collections in October 1971 (fall), January 1972 (winter), April 1972 (spring) and July 1972 (summer). The test cows included a 7-year-old Jersey, two Hereford-dairy crossbred cows (3 and 5

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years of age) and a 10-year-old Holstein. All of these cows originated outside the New Lead Belt and were placed on the test farm 1-2 weeks before the first sample collection.

A control farm, free of exposure to production sources of contamination, was located outside the New Lead Belt. The cows selected for study on this farm were a 3-year-old Holstein, a 3-year-old Guernsey, a 6-year-old Guernsey-milking shorthorn crossbred cow and a 10-year-old Holstein that was a half-sister of the Holstein on the test farm. None of the control cows had been moved from the farm so they had never been exposed to production sources of heavy metals.

Approximately 10 gm of hair was clipped in equal amounts from 4 different areas of the cow's body: head, shoulder, trunk and rear leg. Equal amounts of pigmented and non-pigmented hair were collected from the dual color haircoats. The hair was split into duplicate samples and placed in polyethylene bags for transport and storage. The samples were washed with 1% Snoop* solution, a low trace element containing soap. The hair was then rinsed twice with deionized-distilled water, air dried and wet ashed in Kjeldahl flasks using a hot and cold mixture (5 parts nitric acid : 1 part perchloric acid). The analyses were performed using a Perkin Elmer 403 atomic absorption spectrophotometer. The hair sample values were calculated on a dry weight basis; the blood and milk were calculated on a wet weight basis.

The blood and milk determination procedures and statistical analysis using analysis of variance were previously described (DORN, et al., 1973). The data were normalized by log transformation to satisfy necessary assumptions for analysis of variance.

RESULTS

The concentrations of Cd and Pb in the washed hair of the four cows on the test farm were significantly different than the concentrations in hair of the four control cows (Tables 1 and 2). The mean Cd concentration in the terminal summer sample from the test cows' hair was approximately 12 times higher than that of the control cows' hair, and the Pb concentration in the test cows' hair was approximately 75 times higher than that of the control cows' hair.

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*Applied Laboratories, Inc.

The hair concentrations of Cd, Pb and Zn were significantly affected by season (Tables 1 and 2). Only Cu and Zn hair concentrations varied significantly among the cows on each farm. None of the interactions had a significant effect on the levels of the four elements observed in this study.

The relationship between lead concentrations in blood and hair of cows on the test farm is shown in Figure 1. The correlation coefficient calculated from these data was not significant. The hair and blood cadmium levels were very low on the control farm, so correlation analysis was not attempted.

TABLE 1

Mean Values of Elemental Components In Test and Control Cattle Hair by Season

Source and Season	Mean Value (ug/g)*			
	Cd	Cu	Pb	Zn
<u>Test Farm</u>				
Fall	1.29	8.26	94.13	104.50
Winter	1.74	7.76	87.50	134.88
Spring	2.80	6.94	96.50	130.50
Summer	0.67	7.99	66.00	93.30
<u>Control Farm</u>				
Fall	0.06	7.25	2.19	93.75
Winter	0.13	7.84	3.92	115.88
Spring	0.05	6.81	2.13	101.88
Summer	0.04**	7.41	0.88	82.59

* Mean of 8 samples (2 from each cow) except as indicated.

**One value below lower detectable limit was excluded.

DISCUSSION

The possibility that washing does not remove all exogenous Cd and Pb was a concern in interpreting these results. NISHUYAMA and NORDBERG (1972) reported that Cd adsorbed on human and mouse hair was incompletely removed by different treatments. The most complete removal of cadmium was by using a sufficiently strong solution of an acid; however, the different treatments were not effective for separate analysis of exogenous and endogenous cadmium in hair.

Therefore, analysis of hair concentrations of Cd and Pb may not truly represent body accumulation, depending upon the amount of airborne exposure. In the present study airborne exposure was negligible on the control farm and uniformly high on the test farm. The higher hair Cd and Pb concentrations on the test farm than those on the control farm, therefore, may reflect both the increased lead and cadmium assimilation by the cattle and the adsorption of excess amounts of airborne Cd and Pb onto the hair. In any event, the high hair concentrations of both

TABLE 2

Sums of Squares and Levels of Significance Of Elemental Components of Test and Control Cattle Hair

Source	d.f.	Sum of Squares			
		Cd	Cu	Pb	Zn
Farm	1	163.19**	0.05	233.54**	0.10
Season	3	11.33**	0.18	7.41*	1.69**
Cow within farm	6	1.58	0.54	4.32	0.64*
Farm - season	3	3.21	0.04	2.79	0.02
Season - cow within farm	18	6.93	0.08	5.37	0.49
Duplicate analysis error	32	3.00	0.36	6.27	2.02

* $p<0.05$

**$p<0.001$

elements truly reflected high airborne concentrations on the test farm. The hair lead concentrations were higher than the concentrations of any of the other biological samples tested (DORN, et al., 1973); this supports the use of cattle hair as a sensitive indicator of airborne lead contamination.

RÜSSEL and SCHÖBERL (1970) have pointed out that lead blood levels reflect only lead intake within the last few days, while the hair lead content reflects the intake of at least six months. It is

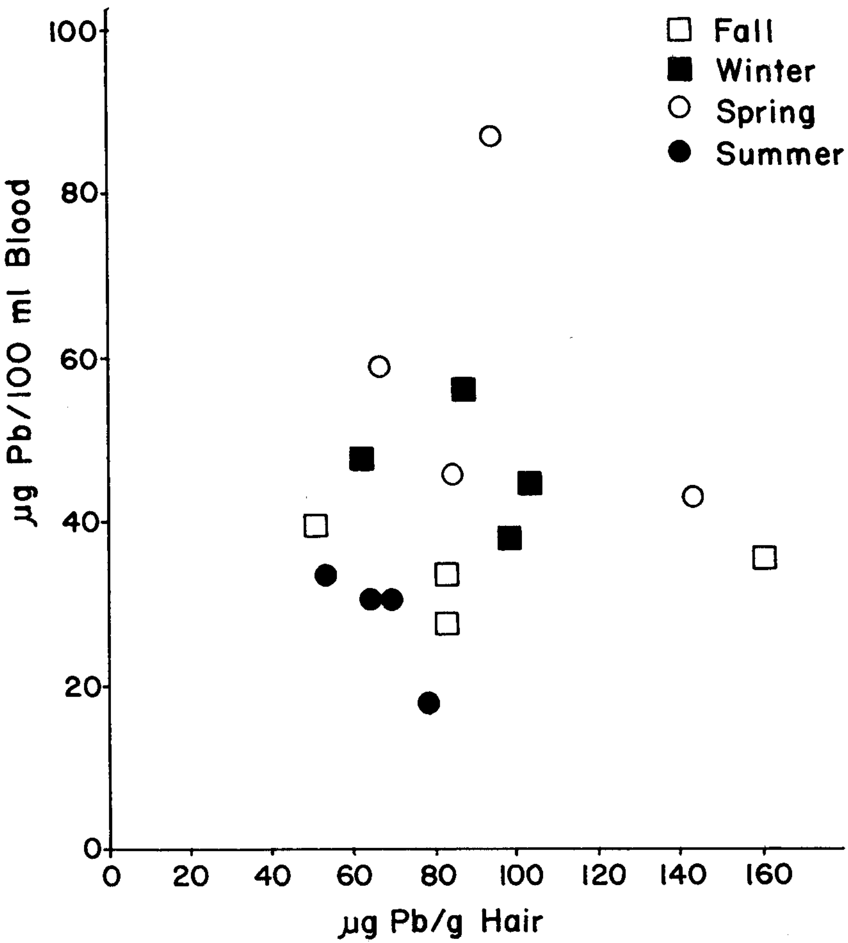

Figure 1. Relationship Between Lead Concentrations in Blood and Hair of Cows on Test Farm

apparent in Figure 1 that the reduction in blood lead levels between spring and summer were greater than the corresponding reduction for hair lead concentrations. Therefore in an area of continuous contamination from multiple sources, seasonal and other temporal changes may be revealed in an examination of hair and other biological samples of exposed cattle. Where cattle are present in an area of contamination, they can serve as both a sentinel of quantitative changes in the amount of available toxic materials and a subject for comprehensive epidemiologic and ecologic studies.

The lack of correlation between blood and hair lead levels in this study might be expected due to the small numbers of observations compared with the study by RÜSSEL and SCHÖBERL (1970) in which a significant correlation was obtained using 25 observations. In addition, their cases were lead poisoning due, probably, to ingestion of lead containing materials, while the cows on the test farm were exposed to primarily airborne sources of lead which contribute to lead ingestion, inhalation and adsorption in the hair surface.

SUMMARY

The levels of Cd, Cu, Pb and Zn were determined in washed hair samples from four test cows exposed to multiple lead production sources of contamination and four control cows that were not exposed. Cadmium and lead were found in significantly higher concentrations in the hair collected from the test cows than in the hair of the control cows. The mean concentration of Cd in the summer sample from the test cows' hair was approximately 16 times higher than that of the control cows, and the Pb concentration in hair of the test cows was approximately 75 times higher than that of the control cows. The hair concentrations of Cd, Pb and Zn were significantly affected by season and Cu and Zn concentrations varied significantly among the cows on each farm. There was no relationship between hair and milk lead concentrations. Reduction in lead exposure was reflected more rapidly in blood than in hair concentrations. These results demonstrate the value of using bovine hair samples in surveillance of environmental contamination, as well as other ecologic, epidemiologic and mineral metabolism research.

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