Cows as a Biological Monitors of Surface Coal Mining Contamination of Biological Systems by Micro and Macro Element Toxins

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Project Summary

The focus of this project is to demonstrate efficient and profitable production of beef cattle on surface mined land in southwestern Virginia. A herd of forty-five beef cows and ten replacement heifers owned by Penn Virginia Coal are being maintained at the Powell River Project demonstration site in Wise County. The owners have provided pasture; day to day care and management, supplemental feed as needed, and labor to care for the cattle. Virginia Tech, through the co-investigators, has provided advice and assistance with breeding and health management, marketing, maintenance of pasture productivity, record keeping, selection of sires as needed and strategies for obtaining replacements over time. The overriding goal is sustainable beef cattle production with minimum inputs so that costs can be kept low enough to generate profit. The phase of the project here reported deals with an investigation into the healthiness and healthfulness of cattle raised near a mining site on reclaimed strip-mined pastures

Concerns of Toxicity

Concerns have been voiced from various sources concerning the healthiness and healthfulness of cattle raised near a mining site on reclaimed strip-mined pastures. Recently there has been concern about human health in the area associated with dust particles (called Particulate Matter 10 or PM10 in the literature) that pervade the areas associated with surface coal mining (Aneja, 2012; Aneja, 2009; Dubey, 2012).

Table 1 shows an analysis of dust collected in Wise County, VA in 2008. The dust was analyzed for a variety of elements. Note that the levels are reported as nanograms per milliliter, one one-thousandth the amount reported in tissues of cows.

Table 1. An analysis of dust collected in Wise County, VA in 2008. (Aneja, 2012)

Analyte	PM10 mass conc collected on quartz filter paper (ng/ m^{-3})	Time of exposure (h)	Normalized 24 h-Mass conc. (ng/ m-3) a
Site Campbell - Sample collected August 7, 2008.			
Antimony	1.83	23.67	1.856
Arsenic	0.958	23.67	0.971
Beryllium	0.067	23.67	0.068
Cadmium	0.263	23.67	0.267
Chromium	2.74	23.67	2.778
Cobalt	0.915	23.67	0.928
Lead	3.9	23.67	3.954
Manganese	34.1	23.67	34.575
Mercury	0.14	23.67	0.142
Nickel	3.04	23.67	3.082
Selenium	0.613	23.67	0.623
PM10 mass	183,432	23.67	185,990
Site Willis - Sample collected August 7, 2008.			
Antimony	1.81	23.5	1.849
Arsenic	0.72	23.5	0.735
Beryllium	0.041	23.5	0.042
Cadmium	0.09	23.5	0.092
Chromium	3.6	23.5	3.166
Cobalt	0.697	23.5	0.991
Lead	3.32	23.5	3.391
Manganese	19.4	23.5	19.813
Mercury	0.972	23.5	0.993
Nickel	14.3	23.5	14.604
Selenium	0.568	23.5	0.592
PM10 mass	96,853	23.5	98,914

Volumetric flow rate of ambient air through the quartz filter paper: 40 ft3 min-1
a PM10 mass collected on the filter normalized to 24 h exposure.

The implication of a number of reports is that coal dust pervades the environment of areas close to coal mining and hauling areas. The unintended ingestion and inhalation of these toxins might have significant health effects and even contribute to premature deaths in the area. (Aneja, 2012; Aneja, 2009; Dubey, 2012). Finkelman, R.B., 1995 , Gilbert, N., 2010 , Halverson, J.A. et al , Hendryx, M., 2008, Hykysova and Brejcha, J., 2009 , Onder, M. and Yigit, E., 2009 , Palmer, M.A., et al., 2010. Pless-Mulloli, T., et al. 2000.

Materials and Methods

The pastures on which the cattle have grazed throughout the thirteen years covered by this report were established by restoring land that had been strip-mined to a relatively level contour. As much top soil as was available was then placed on the surface. Finally, biosolids and wood shavings were placed on the surface to add organic matter to the soil and to increase soil fertility. Finally, a pasture seed mix was applied to the pastures that would grow into plants that were expected to thrive in the environment and provide forage for cows. The seed mix included ladino clover, tall fescue, orchard grass, red clover, sericia lespedeza and autumn olive.

Water sources have been and continue to be a source of challenge for the cattle operation. Originally, cavities were scooped into the surface and compacted designed to become pools from water runoff. Many of these eventually filled with silt and became unusable. A tank was installed associated with the barn on the site to capture rain water and this was routed to the waterers for a few years but this proved unsustainable. For several years water was pumped from water filled deep mines below but eventually the electric source was removed. Next, when ponds were dry, water was hauled from the river and placed in watering tanks. Finally in 2012 completion of a well drilling project has resulted in a long-term, dependable, high quality water source for the cattle.

Potential sources of contamination of cattle are the biosolids that were applied to the land when the pastures were established. As the area has continued to be mined, especially from above levels on the site, blasting has occurred and trucks have hauled coal on a road that runs adjacent to all cattle pastures. There is the potential that dust from the coal trucks or from blasting used to loosen rock and coal on adjacent mining sites has contaminated the forages that cattle have consumed. It should be noted that roads are kept aggressively sprinkled to minimize dust. Water contaminated by mining might be an additional source of contamination.

Virginia Coal personnel carry out a management and breeding plan for the herd which has involved almost continuous grazing of the site where cows are grazed at present. The cows and calves are grazed on the property throughout the year with only supplemental feeding when there is severe snow cover during the calving season.

Virginia Coal personnel have developed a management and breeding plan for the herd which is being grazed at present. The cows and calves are grazed on the property throughout the year with only supplemental feeding when there is severe snow cover during the calving season. Calves are sold between September 15 and November 1. Calving commences about March 1of each year.

Records collected over a fourteen year period of time were summarized and data is plotted to show trends in cow numbers, success of breeding and calf survival and calf weaning weights.

Two cows which were slated be culled in 2011 were humanely slaughtered and liver, kidney and muscle tissues were collected. These tissues were frozen at -40 degrees C until shipping.

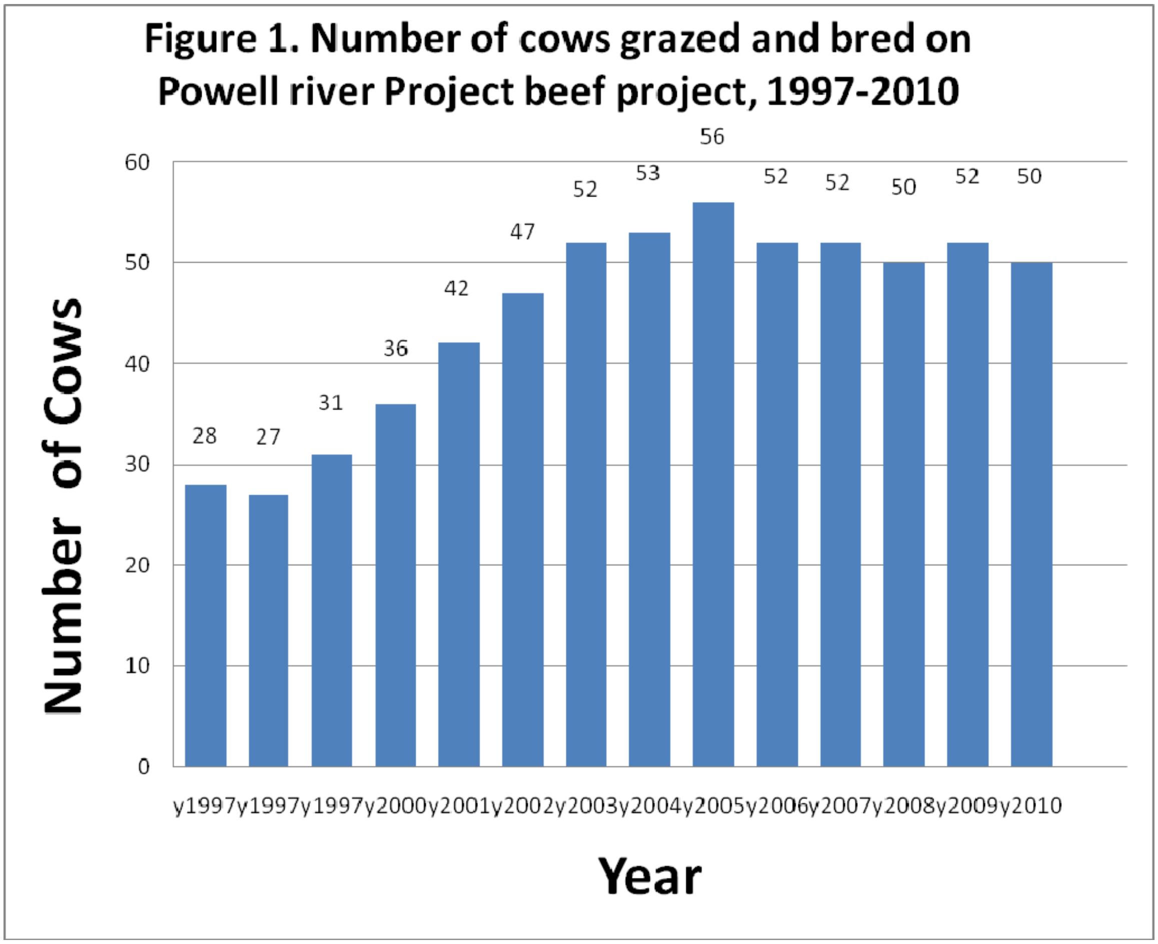
Samples were then shipped to the Diagnostic Center for Population and Animal Health at Michigan State University. The following elements were analyzed on a toxicity panel: Antimony, Arsenic, Barium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Molybdenum, Phosphorus, Potassium, Selenium, Sodium, Thallium, and Zinc. This panel is designed to detect toxic levels of the reported elements and is the default panel for large tissue samples for all species.

Cow number 1 was a fifteen year old cow that was part of the original group of cows brought to the project in 1997. She had therefore grazed these reclaimed surface mined lands for 14 years. She was still classified as healthy but was designated as a cull because she had failed to become pregnant during the 2011 breeding season.

Cow number 214 was born at the Powell River Project site March 20, 2002. She was therefore nine years old at the time of slaughter and had never grazed any other pastures than those on reclaimed surface-mined lands adjacent to active coal mining operations.

Results

Figures 1- 3 demonstrate the progress made in production of cattle from 1997 through 2010. Figure 1 shows the number of cows that were grazed and bred on the project from year 1997 through 2010.



Note that a maximum number of cows was reached in the mid-2000's. It was concluded that running more than about 50 cows wouldresult in the need to buy considerable outside feed for winter needs. It was judged more economical in both dollars and labor to keep the herd numbers near 50 and allow stockpiled grass that grows in the summer and flall to meet most wintering needs.

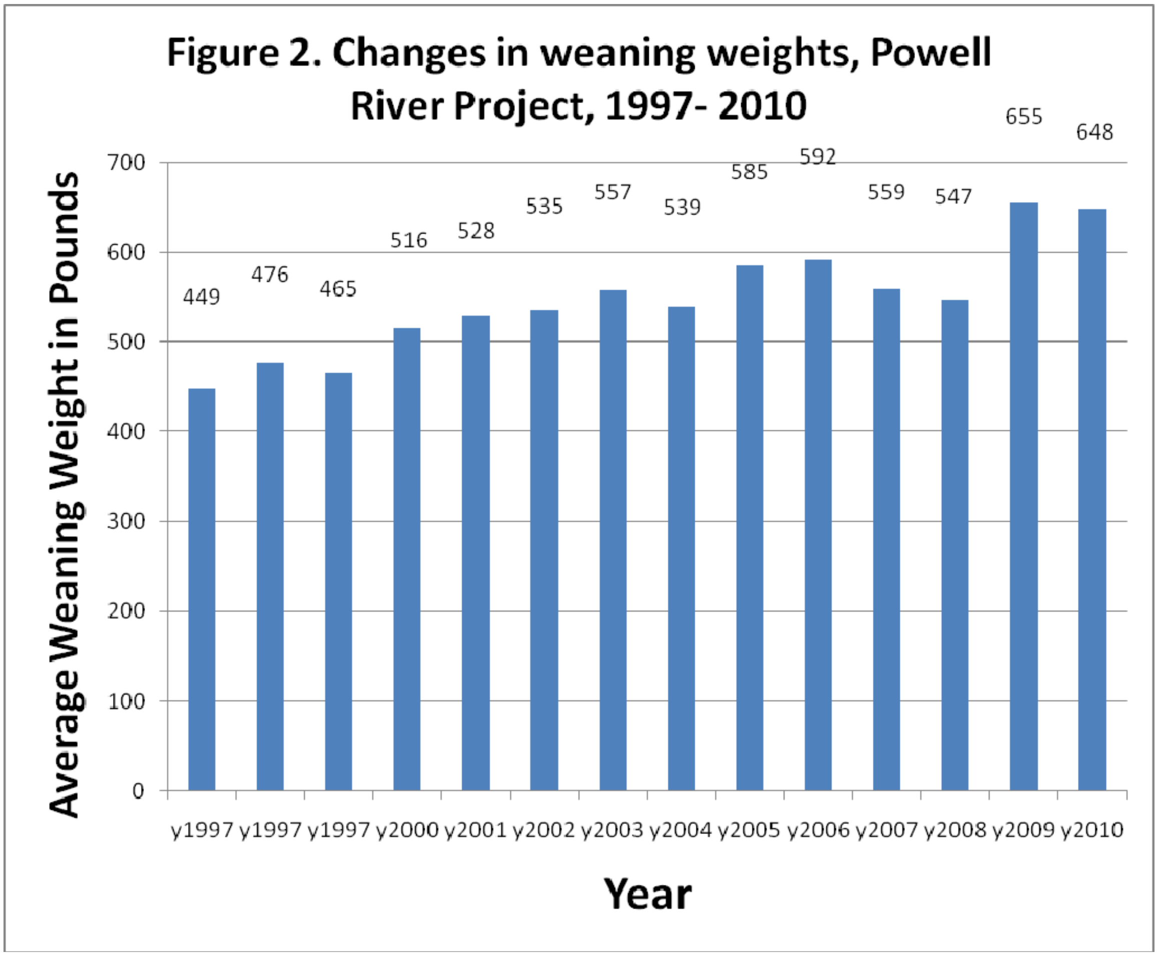
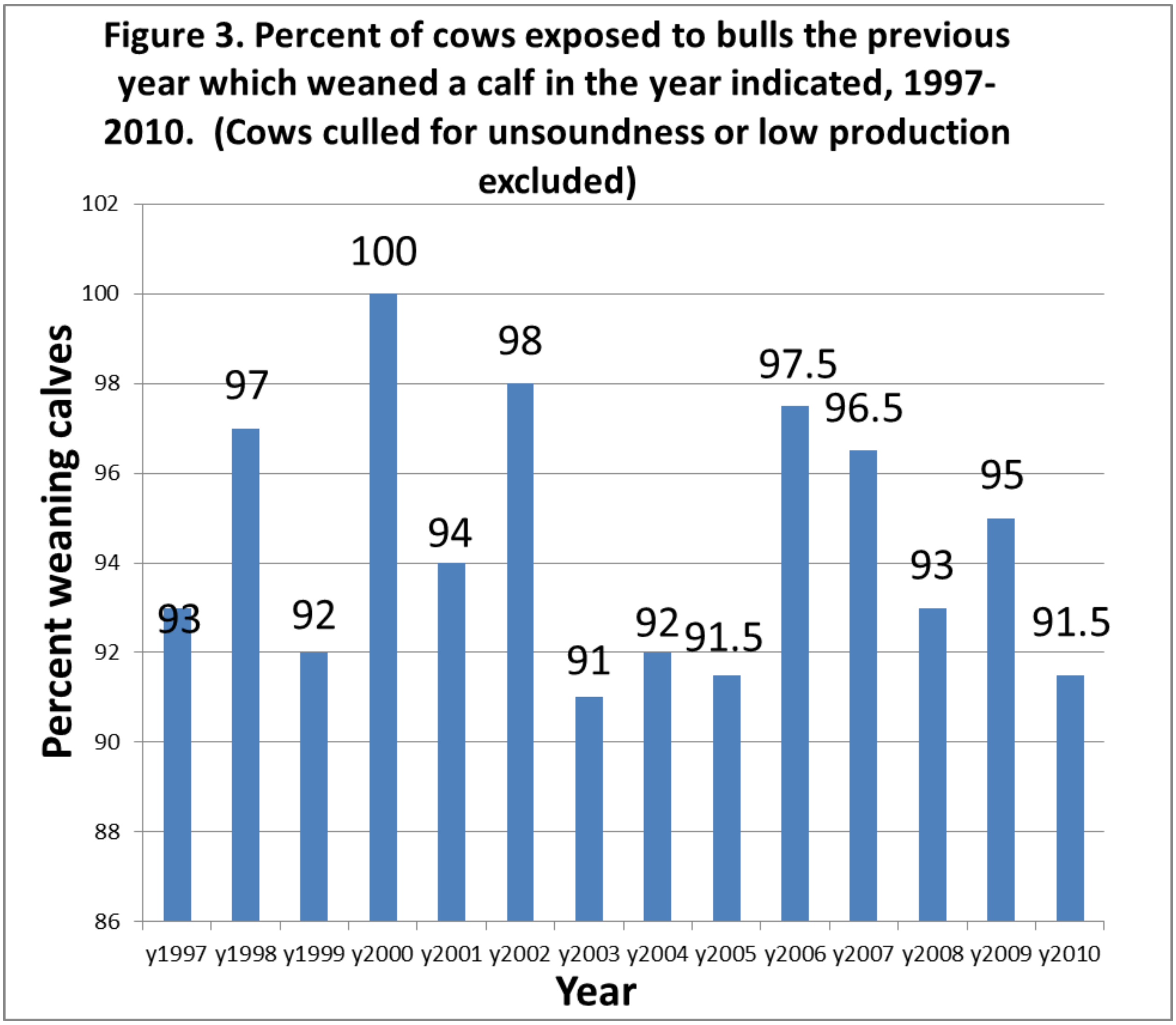


Figure two shows that weaning weights have been continually improving throughout the project. Weights have decreaased during a few years beacause of dry condtions. Use of superior sires, natural and Artificial Insemination, continual development of pastures, use of dewormers and growth-promotant implants and better grazing has allowed for the contiula improvement in weaning weights.

Figure three shows that calves weaned per cow exposed has varied somewhat during the project but rates have always been acceptable. When rates have been lower it has typically been because of calf death losses, for example in 2010 because of severe weather conditions at the time of calving.



These figures demonstrate a clear trend in optimizing production of beef on reclaimed strip-mined land. On the same acreage female numbers have been increased, weaning weights have been augmented and although there is some variation, reproductive performance has been maintained. During these years the cattle have been observed for any signs of toxicity and none have been observed. Cows continue to be productive for a typical production span of eight to twelve years unless culled for infertility, low production or other unsoundness.

Even though it is obvious that levels of toxins have not been sufficient to hurt cattle production, it must be assured that toxic substances that might be harmful for those who consume these cattle as beef have not accumulated.

Tables 2 to 4 show the levels of a number of elements in the tissues of the two cows who had spent many years grazing the pastures at the Powell River Project. The only element which has been reported to be toxic in cattle or humans that was present at the level of sensitivity at which testing was done was cadmium. However, it was present in levels far below toxicity for cattle and below acceptable levels for human consumption as established by USDA.

Table 2. Levels of elements present in the kidneys of two cows grazed extensively on reclaimed surface-mined lands adjacent to active surface mining operations in Wise County, VA.

Mineral	**Cow # 1 Kidney ppm**	**Cow # 214 Kidney ppm**	**Acceptable Kidney ppm**
Antimony	<1.0	<1.0	<1.0
Arsenic	<0.50	<0.50	<0.50
Barium	0.16	0.20	0.20
Boron	<1.00	<1.00	<1.00
Cadmium	0.71	0.61	<15
Calcium	58	96.1	30-200
Chromium	<0.20	<0.20	<0.20
Cobalt	<0.10	<0.10	<0.10
Copper	4.3	3.5	25-150
Iron	52	50	45-300
Lead	<0.50	<0.50	<1.0
Magnesium	154	135	100-200
Manganese	1.24	0.9	2.5-4.0
Mercury	<2.00	<2.00	<2.00
Molybdenum	0.42	0.35	0.14-1.40
Phosphorus	2719	2402	1500-4100
Potassium	2494	2382	1200-3300
Selenium	<2.0	<2.0	0.1- 0.9
Sodium	1667	1853	600-1900
Thallium	<2.50	<2.50	<2.50
Zinc	23	16	25-200

Table 3. Levels of elements present in the livers of two cows grazed extensively on reclaimed surface-mined lands adjacent to active surface mining operations in Wise County, VA.

Mineral	**Cow # 1 Liver ppm**	**Cow # 214 Liver ppm**	**Acceptable Liver ppm**
Antimony	<1.0	<1.0	<1.0
Arsenic	<0.50	<0.50	<0.50
Barium	<0.05	<0.05	0.20
Boron	<1.00	<1.00	<1.00
Cadmium	0.13	0.09	<0.15
Calcium	41.10	39.1	30-200
Chromium	<0.20	<0.20	<0.20
Cobalt	<0.10	<0.10	<0.10
Copper	4.60	28.7	25-150
Iron	91	60	45-300
Lead	<0.50	<0.50	<1.0
Magnesium	181	154	100-200
Manganese	4	3.08	2.5-4.0
Mercury	<2.00	<2.00	<2.00
Molybdenum	1	1.16	0.14-1.40
Phosphorus	4332	3860	1500-4100
Potassium	2906	2502	1200-3300
Selenium	<2.0	<2.0	1.5-2.5
Sodium	737	1017	600-1900
Thallium	<2.50	<2.50	<2.50
Zinc	50	36	25-200

Table 4. Levels of elements present in the muscle of two cows grazed extensively on reclaimed surface-mined lands adjacent to active surface mining operations in Wise County, VA.

Mineral	Cow # 1 Muscle ppm	Cow # 21 Muscle ppm	Acceptable Muscle ppm
Antimony	<1.0	<1.0	<1.0
Arsenic	<0.50	<0.50	<0.50
Barium	0.16	0.20	0.20
Boron	<1.00	<1.00	<1.00
Cadmium	0.71	0.61	<0.15
Calcium	58	96.1	30-200
Chromium	<0.20	<0.20	<0.20
Cobalt	<0.10	<0.10	<0.10
Copper	4.3	3.5	25-150
Iron	52	50	45-300
Lead	<0.50	<0.50	<1.0
Magnesium	154	135	100-200
Manganese	1.24	0.9	2.5-4.0
Mercury	<2.00	<2.00	<2.00
Molybdenum	0.42	0.35	0.14-1.40
Phosphorus	2719	2402	1500-4100
Potassium	2494	2382	1200-3300
Selenium	<2.0	<2.0	0.1- 0.9
Sodium	1667	1853	600-1900
Thallium	<2.50	<2.50	<2.50
Zinc	23	16	25-200

Discussion

Cadmium, mercury, and lead are toxic to humans and animals. Although cadmium and inorganic mercury toxicities occur in humans, they have not been observed in domestic livestock under practical conditions. In contrast, cattle, especially young calves, are extremely susceptible to lead toxicity. Apparently, cattle are more tolerant of cadmium than are other animal species. Due partially to higher absorption and longer retention times in the body, the alkyl mercuries, especially methyl mercury, are more toxic than inorganic mercury compounds. Inorganic forms of cadmium, mercury, and lead are poorly absorbed from the intestine. However, due to lack of effective homeostasis, after absorption retention time is long. Injected cadmium, mercury, and lead are metabolized differently from that naturally absorbed. Most cadmium and mercury are in kidney and liver (50 and 23% of total body in goats); but highest total load of methyl mercury is in muscle (72% in cows). With low to moderate body burden, most lead is retained in the skeleton. However, beyond a certain point, the kidney accumulates large quantities. Only minute amounts of cadmium and mercury are secreted into milk, but milk is only moderately well protected from dietary lead. Likewise, little cadmium and inorganic mercury pass the placental barrier whereas lead and methyl mercury pass more readily. (Neathery et al 1975)

Cadmium (Cd), mercury (Hg), and lead (Pb) are toxic elements with no evidence of essentiality. When introduced into the body by ingestion or inhalation in sufficient quantities, they cause various toxic effects. These effects arise when biochemical reactions are altered sufficiently and adversely. It seems, however, that in

Generally, highest cadmium (Cd) concentrations are in kidney, followed by liver. However, initially, with low intake, liver may have more Cd than kidney. The liver, which is much larger than kidneys, contains more total Cd (67). Of the total body burden of radioactive Cd, the kidney and liver contained 73% in goats (69) and 42% in cows 14 days after oral dosing (78) (Table 1). Tissues and contents of gastrointestinal tract contain a substantial amount (Table 1). Although they represent a large proportion of body mass, muscles contain a relatively small part of the total body Cd. Thus, muscle meat is well protected from ingested Cd.

182 samples of bovine musculature and 183 samples of bovine liver obtained from the sanitary slaughters in the North Moravian region, mostly at Frýdek-Místek, over the February and March 1978, were examined for the lead content by the method of atomic absorption spectrophotometry. The lead content in the examined samples of musculature ranged from 0 to 0.80 mg per kg (average value 0.28 mg per kg) and in the examined samples of liver from 0 to 1.23 mg per kg (average value 0.39 mg per kg); in 2.2 per cent of liver samples the level of lead was higher than 1.0 mg per kg. (Majeck et al , 1980.)

The overriding conclusion of this report supports the safety of mining practices in the Wise county area. Cows would be expected to have a much greater exposure than humans to any elements because they not only are in open spaces cintinuously where they would breath contaminated articles, but virtually all of their ingested feed for many years would be subject to contamination by dust particles. The finding that none of the elements of concern had accumulated in these cows represents strong support for a lack of contamination of the environment with these elements.

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