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Cadmium, Lead, and Zinc in Reclaimed Phosphate Mine Waste Dumps in Idaho

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Southeastern Idaho contains the major portion of the western phosphate field and accounts for about 35% of the U.S. phosphate ore reserves. Since 1945, the phosphate ore in this area has been surfaced mined and processed. In 1975, over 4.8 million metric tons of phosphate ore were produced by the five mines in this area (U. S. GEOLOGICAL SURVEY 1978). Surface mining consists of open-pit mining of phosphate ore and production of large amounts of waste rock. Present phosphate ore mining operates on a waste rock to ore ratio of 3:1. Therefore, in 1975 over 14 million metric tons of waste rock were generated. This accumulation of waste rock has a significant impact on the land. Large waste dumps are constructed using the waste rock and efforts are underway by the mining companies to reclaim these waste dumps. Some waste dumps have been terraced and revegetated with alfalfa and a variety of grasses. Reclaiming these waste dumps provides aesthetic value, erosion protection and possible forage land for livestock and wildlife.

Phosphate ore mined in southeastern Idaho contains significantly high levels of certain trace elements such as cadmium and zinc. The average concentrations of cadmium and zinc in the ore are 90 and 250 ppm, respectively (U. S. GEOLOGICAL SURVEY 1978). The actual levels of trace elements in the reclaimed waste dumps and their effects on the environment are not known. This study was designed to investigate the distribution of cadmium, lead, and zinc in the soil and in vegetation grown on the reclaimed phosphate waste dumps.

Two adjacent mines, the Ballard mine and the Henry mine, located about 32 kilometers northeast of Soda Springs, Idaho, were studied in the summer of 1977. The Ballard mine has over 160 hectares of waste dumps; most of them have been reclaimed. Samples were collected from six waste dumps representing different years of reclamation (from 1970-74 including a prior 1970 waste dump) at this mining site. Another waste dump reclaimed in 1976 and a control site at the Henry mine were also sampled. The control site consisted of an approximate 9 hectare area originally marked as a waste dump with its top soil removed. This site was later rejected as a waste dump and the top soil was replaced. The control site was revegetated with the same plant species as the other waste dumps. Soil samples consisting of the top 25 centimeters of soil were collected randomly

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from each reclaimed waste dump at 10-15 sites. Two types of plants, alfalfa and grass species (brome, crested, orchard, and timothy) were sampled at each site when present. Alfalfa is the predominant species found in the reclaimed waste dumps. The top 30 centimeters of alfalfa and the entire grass plant (stem and leaves) were collected for chemical analysis. No distinction was made between the different grass species.

The soil samples were dried in an oven at 105°C, ground with a mortar and pestle and then sifted through a U. S. No. 80 standard testing sieve. Plant samples were washed with distilled water, dried in an oven at 80°C, and ground with a blender. Cadmium, lead, and zinc in soil (less than 80 mesh size fraction) and vegetation were analyzed by an atomic absorption spectrophotometer. Procedures of atomic absorption analysis are described elsewhere (HUTCHISON 1978).

Heavy metal concentrations (Cd, Pb, and Zn) for soil and vegetation at Ballard and Henry mine reclaimed waste dumps are shown in Table 1. Values are in parts per million (ppm) with two standard errors of the mean ($p = 0.05$). Average cadmium concentrations in soil from different reclaimed waste dumps vary from 14.5 ± 6.8 ppm to 38.8 ± 8.5 ppm. These average values are an order of magnitude higher than the cadmium concentration in soil found in the control plot (1.0 ± 0.3 ppm). Zinc concentrations in soil of the waste dumps average 443 ± 210 ppm to 1112 ± 124 ppm which are also high compared with those found in the control plot (54 ± 16 ppm). Contrary to cadmium and zinc, average lead concentrations in waste dump soil which vary from 20.1 ± 5.2 ppm to 35.0 ± 2.5 ppm are not significantly higher than those in the control plot (15.4 ± 0.8 ppm). Elevated cadmium and zinc levels in the reclaimed waste dumps are expected because of their high concentrations in the phosphate ore. Lead, however, is not significantly enriched in the ore and does not appear in high concentration in the waste dumps. Soil heavy metal contents do not seem to correlate with the year of reclamation. However, the plot reclaimed prior to 1970 was found to contain lower levels of cadmium and zinc.

Average cadmium concentrations in vegetation from the reclaimed waste dumps vary from 1.1 ± 0.9 ppm to 5.9 ± 0.9 ppm in alfalfa and from 0.7 ± 0.3 ppm to 1.8 ± 0.6 ppm in grass. In the control plot, average cadmium in alfalfa and in grass are 0.4 ± 0.1 ppm and 0.1 ± 0.1 ppm, respectively. Cadmium levels in alfalfa grown on the phosphate waste dumps are about 3 to 15 times higher than those found in the control plot. Grass shows a similar trend; waste dumps grass cadmium levels are about 7 to 18 times higher relative to the control plot. Although cadmium levels in vegetation show considerable fluctuation, it is interesting to note that alfalfa in general contains several times higher cadmium than grass.

The normal cadmium level in soil has not been clearly defined but is probably less than 1 ppm. WARREN et al. (1971) suggested that the background concentration of cadmium in soil is 0.5 ppm.

TABLE 1

Ballard Mine	Cd	Pb	Zn
	Metal Concentration (ppm)		
Prior 1970			
Soil	14.5 ± 6.8 (15)	20.3 ± 5.7 (15)	443 ± 210 (15)
Alfalfa	1.1 ± 0.9 (6)	2.1 ± 1.3 (6)	41 ± 12 (6)
Grass	1.4 ± 0.7 (10)	0.6 ± 0.4 (10)	70 ± 26 (10)
1970			
Soil	33.4 ± 8.9 (15)	33.7 ± 2.7 (15)	1112 ± 124 (15)
Alfalfa	4.6 ± 2.0 (15)	3.7 ± 0.6 (14)	63 ± 13 (15)
Grass	1.8 ± 0.6 (14)	1.7 ± 0.7 (14)	96 ± 24 (14)
1971			
Soil	33.7 ± 11.5 (15)	35.0 ± 2.5 (15)	1023 ± 129 (15)
Alfalfa	5.0 ± 2.7 (13)	4.8 ± 0.9 (13)	73 ± 17 (13)
Grass	1.5 ± 2.1 (4)	<0.5 (4)	84 ± 68 (4)
1972			
Soil	15.1 ± 5.9 (15)	20.1 ± 5.2 (9)	633 ± 104 (15)
Alfalfa	3.0 ± 2.1 (15)	3.2 ± 0.8 (14)	37 ± 8 (15)
Grass	0.7 ± 0.3 (14)	2.5 ± 1.0 (14)	29 ± 11 (14)
1973			
Soil	27.2 ± 7.9 (15)	24.9 ± 2.5 (15)	837 ± 215 (15)
Alfalfa	2.9 ± 0.9 (13)	3.5 ± 0.9 (13)	61 ± 14 (13)
Grass	1.4 ± 0.6 (15)	2.6 ± 0.7 (15)	41 ± 16 (14)
1974			
Soil	38.8 ± 8.5 (15)	30.8 ± 1.7 (15)	973 ± 115 (15)
Alfalfa	2.6 ± 0.7 (13)	3.9 ± 0.8 (13)	88 ± 29 (13)
Grass	1.2 ± 0.4 (11)	0.9 ± 0.5 (11)	57 ± 20 (11)
Henry Mine			
1976			
Soil	29.0 ± 6.3 (10)	20.6 ± 1.8 (8)	1112 ± 239 (10)
Alfalfa	5.9 ± 0.9 (10)	2.6 ± 0.6 (10)	148 ± 38 (10)
Grass	1.6 ± 1.2 (10)	0.9 ± 0.5 (10)	131 ± 25 (9)
Control			
Soil	1.0 ± 0.3 (15)	15.4 ± 0.8 (8)	54 ± 16 (15)
Alfalfa	0.4 ± 0.1 (13)	2.2 ± 0.7 (13)	34 ± 19 (13)
Grass	0.1 ± 0.1 (15)	2.6 ± 0.4 (14)	30 ± 17 (15)

*Parentheses indicate number of samples analyzed.

The concentrations of cadmium in alfalfa from environments presumed to have normal levels of cadmium were estimated to be in the range of 0.02-0.2 ppm on a dry weight basis (SHACKLETTE 1972). In environments having greater than normal cadmium levels, the estimated range of cadmium in alfalfa is 0.2-2.4 ppm. The average cadmium levels in soil and in alfalfa from the control plot of this study are slightly above the suggested "normal" cadmium levels. This higher than normal soil cadmium background is likely the result of mineral formation of this area.

Zinc concentrations in vegetation from the reclaimed waste dumps are also high with respect to the control plot. The concentration factor of zinc in the former is about a factor of 4 or less relative to the latter. Lead in vegetation shows little difference between the waste dumps and the control plot.

Various studies have shown detrimental effects of cadmium, lead, and zinc on calves and horses (NEATHERY & MILLER 1975, WILLOUGHBY *et al*. 1972). Elevated levels of cadmium and zinc in reclaimed phosphate waste dumps may create a problem for these animals. It appears that the effects of long-term feeding of alfalfa and grasses, inhalation of dust and soil ingestion by animals should be investigated before releasing these waste dumps for animal feed and use.

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