2.0. Lead and Other Elementals in the Environment

The overwhelming majority of exposures of living things in the Coeur d'Alene River Basin to toxic substances such as lead and cadmium are apparently benign. Under exceptional circumstances excessive exposures occur and harmful biologic effects (see 1.1., 1.2., 3.1. - 3.7.) may occur. There is no doubt that potentially excessive levels of lead and cadmium are present in the Basin. Processes and pathways which make the elementals available for absorption by plants, animals, and humans are not well described. Knowledge of mechanisms might enable development of land management strategies which minimize exposures.

The data reported in the subsequent sections provide evidence that the exposure potential is lower today than in times past.

The studies are not presented as a comprehensive study of Basin lead. The work was limited in scope and was done to better understand the potential exposures of animals.

2.1. Soils

A recent USEPA report (Hornig et al. 1988) lists lead, cadmium and zinc levels in Coeur d'Alene Basin sediments (Table 21). Levels for the North, Central, and South parts of the Lake are included as well as Anderson and Thompson Lakes. The latter contained 2492 and 3386 ug lead/g, respectively. Data shown in Table 22 show similar lead levels for various sites including Thompson River (3177 ug/g), Killarney Lake Channel (4522 ug/g), Hidden Island Channel (7376 ug/g) and Blue Lake River (2576 ug/g). Those levels measured during 1985 are typical of values recorded during other aspects of the study. They represent the amounts of lead present in the upper part (zero to six inches) of the soil column.

No attempt was made to sample a particular soil horizon and in general soils were dark and heavy. Lighter colors were observed lower in the soil column in areas where digging had occurred.

Flood sediment. Analyses of flood sediment collected from boat launches near Thompson Lake and Swan Lake show that the River is carrying substantial amounts of lead solids (Table 22). In 1985, the deposits contained 4109 ug/g (mean, N=3) and 3572 ug/g, respectively, at Thompson and Swan Lakes. Spring flood sediments might be profitably monitored over time to obtain information about current movements of lead in the Basin.

The Bunker Hill Superfund Task Force reported lead, cadmium and zinc levels in yard soils and house dusts. Amounts measured usually range over an order of magnitude. The yard soils lead levels at Superfund sites (Table 24) are similar to lead levels in Basin sediments (Table 21) reported by Hornig et al. (1988) and in various measurements made during this work (Table 22 and others). The higher levels (lead 30,000 ug/g; cadmium 205 ug/g) reported in the Task Force report have not been observed and may be characteristic of conditions not present in the sediments of the land along the River.

Probably no part of the basin environment is without detectable and relatively elevated lead levels. The ubiquitous nature of this persistent environmental pollutant hardly needs reconfirmation. Similarly, lead is well know as a "toxic heavy metal" in excessive amounts. Dose-response relationships are established for a variety of toxicological endpoints including neurotoxicity, renal toxicity and immunotoxicity. The risks associated with the various hazards known to be linked to excessive lead exposure will be determined by dose. Dose, in turn, will be determined by the availability of lead in sediments (soil), water, plants and even salt incrustations.

Table 21. Summary of Lead, Cadmium, Zinc Levels in Coeur d'Alene Basin Sediments

Location	Sedimentary Elements (ug/g) Lead	Cadmium	Zinc
Lake Coeur d'Alene Northern Part	1146-5732	7-8	16-87
Central Part (Coeur d'Alene River Delta)	4158	8	3680
South Part	10-367	0.6-10	77-1310
Lateral Lakes			
Anderson Lake	2492	10	2180
Thompson Lake	3386	9	2560
Lower Coeur d'Alene River	2310-3992	5-8	50-90
South Fork Coeur d'Alene River	298-7897	3-5	0.1-232
U.S.A. Median (Lyman et al. 1987)	16	1	4
95 Percent of U.S.A. sediments below	199	12	39

Hornig et al., USEPA, 1988

Table 22. 1985 Sedimentary Lead Levels

Sample	Sedimentary Lead (ug/g)	Mean
CDA River WMA #7	3489	2853
	2447	
	2624	
Thompson River Bank #6	4405	3177
	2281	
	2845	
Hidden Island Channel River Bank #2	6130	7376
	7287	
	8712	
Killarney Lake Channel #1	4857	4522
	5502	
	3207	
Blue Lake River Bank #5	2447	2576
	2688	
	2594	
Blessing Slough #3	3223	3499
	3279	
	3996	
Swan Lake Channel #4	4145	3814
	3993	
	3305	
Osprey #1	3073	3117
	3555	
	2724	
Springston #1	5803	6525
	7116	
	6654	
Springston #4	15	15
	14	
	16	

Idaho Department of Fish and Game

Samples analyzed by the Washington Animal Disease Diagnostic Laboratory, Toxicology Section, Washington State University and University of Idaho.

Table 23. Coeur d'Alene River Lead During Spring Flood, 1985

Sample	1985	River Lead Nanograms/ml
1	3/17	10
2	3/21	40
3	4/06	10
4	4/12 (Early Flood Stage)	-[a]
5	4/14	230
6	4/16	50
7	4/18	-
8	4/20	-
9	4/22	-
10	4/24	-

Surface water samples collected by the Idaho Department of Fish and Game near boat launch near southwest outlet of Thompson Lake.

Grab samples of surface water were stored in plastic bags.

[a] - MDL approximately 10 ng/g assuming 1g/ml water.

Analyzed by the Washington Animal Disease Diagnostic Laboratory, Toxicology Section, Washington State University and University of Idaho.

Table 24. Elementals in Yard Soils and House Dusts at Bunker Hill Superfund Site

	Lead (ug/g)	Cadmium (ug/g)	Zinc (ug/g)
Yard Soils	2,500-30,000	28-205	999-8109
House Dusts	1,800-36,000	19-602	1118-20545

Presentation to Bunker Hill Superfund Task Force, July 28, 1988

2.2. Water

Water from a small pond on the southeast edge of Thompson Lake was analyzed for lead. The sample contained 20 ppb or less. Sediment in close proximity contained 2488 ug/g. The pond was tested because there was a very large amount of sediment in contact with standing water. In spite of the apparent close contact, there was not extensive accumulation of lead in the small pond. Plans to sample the invertebrates in the pond were not further developed on the basis of the low amount of lead present in the water.

During the March-April period of 1985 when the River was high, John Nigh, Idaho Department of Fish and Game collected a series of water samples. We were interested to see whether those flood waters would cary high levels of lead. Nine samples from March 17, 1985 to April 24, 1985 were analyzed and found to contain zero (MDL about 10 ug/ml) to 230 ug/ml (Table 23). This series of samples provides inadequate evidence of elevated lead associated with the spring flood even though the two highest levels were found during the early part of the flood period. The data are very limited in scope and extent and certainly do not rule out short term changes that could be biologically or environmentally significant. More extensive time-concentration data could clarify the relationship between flooding and lead.

A site investigation conducted for the Bureau of Land Management in 1988 reported a remarkably high level of lead in Thompson Lake. A sediment sample contained 2730 ug/g and the water sample 7 mg/liter. The report states: "The water sample contained lead and zinc above the analytical detection limit - 7.0 mg/L and 0.246 mg/L respectively." It seems unusual to refer to such an extremely high number as being "above the analytical detection limit" unless reference to the upper limit is intended. As noted in the draft report, the value is 350,000 times above the proposed recommended maximum contaminant level, 5,384 times the chronic toxicity criteria, and 206 times the acute toxicity criteria. A sampling or analytical error seems likely.

Due to the extremes reported and the seeming incompatibility with earlier findings, a preliminary survey of water levels was made in July 1989. Results listed in Table 25 include distilled water purchased in the Basin, Killarney Lake, Thompson Lake, Coeur d'Alene River near the boat launch near Thompson Lake, Wildwood Ranch (well) near Thompson Lake, Harrison City Hall, St. Joe River in St. Maries, and the Titus residence in Saint Maries. The levels found in Thompson Lake were less than one-one thousandth (<1/1000) of those reported in the report. Levels were at or near the minimum detectable levels in the distilled water, Wildwood Ranch well water, and in the pair of samples from St. Maries. Killarney Lake (0.013 ug/ml) and Thompson Lake (0.006 ug/ml) waters contained less than Coeur d'Alene River water (0.055 ug/ml).

A carefully developed surface water sampling plan could provide useful management data concerning the magnitude of seasonal changes in water lead and other elementals. A sampling program has recently been initiated by the Bureau of Land Management (Fortier, personal communication).

The discussion of Thompson Lake lead and the single datum reported are not adequate. More analyses may be indicated but not based on that piece of information.

2.3. Plants

There are several observations which lead to my opinion that elementals in the sediment have very low mobility and bioavailability.

1. Very high lead levels exist in the sediments in stable form as evidenced by the massive expanse of contaminated sediments that have been deposited over decades.

2. The lead sediments are not being mobilized in substantial amounts by plants such as horsetail Equisetum sp. Note: Lead-contaminated soils may be physically moved by wind and water erosion onto plant surfaces in insignificant amounts under natural conditions. Sampling of vegetation may be complicated or compromised by transfer of soil to plant surfaces.

3. Equisetum sp. removed from the proventriculus of swans at necropsy apparently contained high lead levels. Follow-up studies using plants grown in high lead soils in a variety of growth stages did not contain high lead residues. The elevated levels in the necropsy materials likely resulted from surface contamination within the proventriculus rather than from environmental sources per se.

4. Water potatoes Sagitarea cuweata are common throughout the Basin and they are among the plants eaten by muskrats. Since data concerning liver levels in muskrats were obtained, a series of water potatoes were also analyzed. Lead, cadmium, and zinc were tested in potatoes and the sediment in which they were growing.

An additional concern was the possibility that humans would consume water potatoes as part of their diet. Some relevant experimental data were obtained to determine the relationship between plant and soil levels of lead.

The potatoes were washed free of all visible sediment in the laboratory using a light brush. In our judgement, normal food preparation of vegetables taken from the ground would have involved similar cleaning. Nine samples of sediment and six potatoes were analyzed from each of the nine sites.

The levels of lead, cadmium, and zinc showed considerable variability (Table 26). Elevated lead levels were present in all soil and potato samples. Individual potato samples ranged from <4.7 to 810 ug/g lead. The range of cadmium concentrations was less extreme.

These data indicate a high relative exposure potential associated with muskrat feeding or human eating of water potatoes, however, risk can not be established because of the extent of actual exposure. The fact that muskrat livers contained modestly elevated liver levels of lead may indicate either limited ingestion and/or limited availability of lead. It would be of interest to monitor muskrat kidneys to determine status of cadmium -- the toxic elemental that is stored in kidney.

Native Americans have formally consumed substantial amounts of water potatoes. During earlier times of extreme pollution of the Basin, the potatoes acquired an unacceptable "metallic" taste and could not be eaten. The extent of current risk would require a complete understanding of their status in the diet and methods of preparation.

Most plants will absorb some elements to excess if present in an available form in the soil (Table 27). Any process such as microbial activity or acidic water seeps that might make an elemental such as lead more available could more heavily thus contaminate plants growing in the same environment. Although no evidence of such an occurrence was found in the course of sampling to date, the unlikely possibility that plants *per se* could be important in particular episodes of waterfowl poisoning must remain open.

The concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, and a number of trace elements including lead were determined in bracken fern *Pteridium aquilinum* fronds and rhizomes. Considerable differences were found among the trace elements. Generally, the trace element concentration increased during the growing season. Lead, for example, increased from 5.1 (ppm in dry matter) to 10.7 ppm from May 15 to October 5. Our sampling of horsetail fern usually occurred in the summer, intermediate between the test periods in the earlier studies with bracken.

Our studies with horsetail at later times during the year showed higher levels of lead, but not toxic ones *per se*. *Equisetum* does not have a propensity to absorb large amounts of lead. Certain forms of lead, perhaps even fine particles of lead sulfide, made be readily adsorbed to plant surfaces. That mechanism is known and probably accounts for the high leads registered on the necropsy samples, some plant samples, and *Equisetum* (Tables 27 and 29) and wild rice (Tables 27 and 30).

Toxicological research on the lead-plant relationship is important. On the one hand, contamination of plant samples can lead to unreliable data concerning the concentrations of elementals. At the same time, the laboratory artifact can be pointing the way to mechanism of particle adsorption by food plants.

The subject deserves further study to define how important this transfer process could be, particularly under conditions where the soil has been disturbed.

Mitchell and Reith (1966) have also reported a marked seasonal difference in the lead concentration of pasture plants. During rapid early growth, plants contained 0.3 to 1.5 ppm. In the case of *Equisetum* in the present study, only early season growth has been considered a potential lead source based upon observations of equisetum in the proventriculus of poisoned swans at necropsy. That early season growth is less likely to contain high lead concentrations as a result of absorption. Waterfowl exposure to adsorbed lead on plant surfaces is likely but its quantitative importance can not be ascertained with available data and insight.

A series of *Equisetum* shoots were collected by John Nigh, Idaho Department of Fish and Game, along the southeast edge of Thompson Lake to determine whether lead was loosely associated with plant surfaces (Table 27). Young *Equisetum* shoots had been collected from the proventriculus of a swan necropsied in 1985. The shoots (five sets each) were either washed or unwashed to determine whether lead was adhering to the plant cuticle. Unwashed plants contained 108 ug lead/g dry weight (range 57 to 175) and washed plants also contained 108 ug lead/g dry weight (range 61 to 214). A second tap water washing was performed on a third set of plants and the mean lead content was 89 ug/g dry weight (59 to 104). Surface soil at the site contained 2488 ug/g lead. Dried _Equisetum_ at the same site contained 179 ug/g perhaps indicating more prolonged contact with environmental lead or breakdown of plant parts not containing lead. The lead levels of _Equisetum_ collected at five other places were 78, 69, 42, 17, and 38 ppm.

Since _Equisetum_ is a potentially important foodplant, it is important to summarize observations concerning its lead content. The hardy marsh plants thrives in soils that contain several thousand ug/g lead. Roots apparently washed free of adhering soil still contained extremely high lead levels, but lead was not apparently transported to the aerial parts of the plant to an appreciable extent. Dried plant parts had higher lead levels due to loss of water. There is no evidence that _Equisetum_ has a special capacity to concentrate and transport lead. Since contaminated soils can adhere to the plant under certain conditions, it is possible that some plants might expose foragers to elevated and even toxic lead levels. This possibility is hypothetical but warrants consideration when _Equisetum_ is discovered by necropsy of waterfowl or other wildlife.

Table 25. Preliminary Water Levels (July 1989) of Lead from Coeur d'Alene River Basin

Sample	Preliminary Lead (ppm) 1	2	3	Mean
Distilled water	0.004	0.003	0.004	0.003
Killarney Lake[a]	0.015	0.014	0.009	0.013
Thompson Lake[b]	0.006	0.006	0.006	0.006
Coeur d'Alene River[c]	0.060	0.056	0.048	0.055
Wildwood Ranch[d]	0.000	0.008	0.001	0.003
Harrison City Hall[e]	0.000	0.000	0.000	0.000
St. Joe River[f]	0.000	0.000	0.000	0.000
Titus residence[g]	0.000	0.002	0.000	0.001

Krieger, 1989

Levels of 0.005 ug/ml are near limit of detectability (approximately 0.002 ug/ml). All samples obtained in triplicate July 24, 1989. ppm = ug/ml.

[a] Public boat launch (Township 49N Range 2W Sec 10, 11, 13, 14: Boise Meridian).
[b] Midpoint along north shore (49N 3W 21).
[c] 100 yards upstream from boat launch on channel from Thompson Lake.
[d] Well approximately 300' up mountain from site (3); about 1/4 mile from Thompson Lake shore.
[e] Harrison, Idaho.
[f] St. Maries, Idaho. Public boat launch in Aqua Park.
[g] Two miles west of St. Maries; 250 foot well (46N 2W 20).

Table 26. Lead, Cadmium, and Zinc in Water Potato and Corresponding Sediments

Sample		Tissue Elements (ug/g) Pb	Cd	Zn
Water Potatoe				
1	Mean ± SD	411 ± 220	3.2 ± 1.4	367 ± 127
2		463 ± 236	1.2 ± 0.7	242 ± 93
3		30 ± 23	1.4 ± 1.0	155 ± 155
4		121 ± 97	1.2 ± 0.6	165 ± 77
5		18 ± 16	2.6 ± 3.6	150 ± 134
6		14 ± 6	0.5 ± 0.3	28 ± 6
7		254 ± 131	1.3 ± 0.7	272 ± 99
8		104 ± 79	1.3 ± 0.8	79 ± 39
9		19 ± 14	1.1 ± 0.5	45 ± 25
1	Median	397	3.0	358
2		460	0.9	240
3		33	1.1	116
4		88	1.3	159
5		11	0.9	97
6		13	0.4	25
7		248	1.4	284
8		84	1.2	78
9		17	1.0	46
Sediment				
1	Mean ± SD	6364 ± 834	52.5 ± 19.7	4336 ± 549
2		5551 ± 577	32.1 ± 7.6	4259 ± 731
3		868 ± 366	13.5 ± 3.9	1076 ± 263
4		2596 ± 1399	18.6 ± 9.9	1907 ± 870
5		342 ± 115	5.6 ± 0.8	272 ± 108
6		327 ± 136	7.4 ± 1.4	305 ± 125
7		407 ± 45	83.6 ± 18.6	620 ± 227
8		2125 ± 48	30.4 ± 13.7	243 ± 60
9		617 ± 307	8.5 ± 1.7	593 ± 212
1	Median	5975	50.6	4254
2		5559	33.3	4215
3		911	12.4	1035
4		2863	16.5	1916
5		329	5.7	234
6		327	7.2	296
7		413	32.6	716
8		406	26.8	238
9		612	7.9	618

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Bureau of Indian Affairs

Table 26. Lead, Cadmium, and Zinc in Water Potato and Corresponding Sediments - (Continued)

Median Values		Water Potato	Sediment
Regression Output:		**Lead**	
		397	5975
Constant	240.6148	460	5559
Std Err of Y Est	1302.725	33	911
R Squared	0.723306	88	2863
No. of Observation	9	11	329
Degrees of Freedom	7	13	327
		248	413
X Coefficient(s)	11.27273	84	406
Std Err of Coef.	2.635233	17	612
		Cadmium	
		3	50.6
Constant	0.296566	0.9	33.3
Std Err of Y Est	9.913833	1.1	12.4
R Squared	0.634868	1.3	16.5
No. of Observations	9	0.9	5.7
Degrees of Freedom	7	0.4	7.2
		1.4	32.6
X Coefficient(s)	16.99383	1.2	26.8
Std Err of Coef.	4.871076	1	7.9
		Zinc	
		358	4254
Constant	-182.955	240	4215
Std Err of Y Est	1143.097	116	1035
R Squared	0.572235	159	1916
No. of Observations	9	97	234
Degrees of Freedom	7	25	296
		284	716
X Coefficient(s)	10.81154	78	238
Std Err of Coef.	3.533081	46	618

Table 27. Preliminary Soil and Plant (Dry) Survey at Thompson Lake, 1985

Sample		Lead (ug/g)			Mean
Site 1 Springston					
Mud/silt		1980	1627	1245	1618
Reed/Grass (not identified)		1.9	1.3	1.3	1.5
Site 2 Springston					
Deep roots and silt "a little silt"		3443	3167	3533	3381
Equisetum	roots		349		349
	upper parts	5.1	5.0	3.9	4.7
Site 1 Osprey					
Silt/roots		2076	3000	1815	2297
Equisetum	roots	1992	2112	2049	2051
	upper parts	13	13	12	13
Reed/Grass (not identified)		12	7	8	9
Rice cutgrass (Leersim oryzoldecs)		39	30	25	31
Site 2 Osprey					
Silt/roots		2486	3347	3734	3222
Equisetum	roots	1573	2207	2003	1928
	upper parts	2.3	2.7	2.4	2
Wild rice	roots	2.8	3.6	1.5	3
	upper parts	638	833	992	821
Site 3 Osprey					
Silt/roots		2551	2302	2497	2450
Equisetum	roots		not sampled		
	upper parts	10	6	7	8
Wild rice	upper parts	2.2	1.9	2.4	2

Collected and analyzed by the Washington Animal Disease Diagnostic Laboratory, Toxicology Section, Washington State University and University of Idaho.

Table 28. Vegetation (Dry Weight) and Soil Lead From Deltas of St. Maries and South Coeur d'Alene Rivers, 1986

Sample		Vegetation Lead (ppm)	Soil Lead (ppm)
St. Maries River			
A	Grass-1	<4	NA
		<4	
		<4	
B	Reed	<4	NA
		<4	
		<4	
C	Grass-2	<4	29
		<4	35
		<4	44
South Coeur d'Alene River			
D	Grass-3	20	3193
		19	2316
		15	2814
E	Grass-4	21	NA
		18	
		20	
F	Grass-5	24	NA
		43	
		72	
G	Grass-6	35	1743
		141	2147
		48	2113
H	Grass-7	17	2813
		12	3638
		112	3280
I	Grass-8	12	3501
		9	3181
		8	3558
J	Grass	6	2613
		12	2121
		13	2434
K	Reed	<4	2763
		<4	2617
		5	3222
L	Reed	4	2695
		9	2947
		9	3062

Idaho Department of Fish and Game

Analyzed by the Washington Disease Diagnostic Laboratory, Toxicology Section, Washington State University and University of Idaho.

Table 29. July 1989 Survey of *Equisetum* at Thompson Lake

Sample	Collection Depth (inches below surface)	Lead (ug/g) Wet	Lead (ug/g) Dry
1[a]	6	11	116
2[a]	18	7	26
3[a]	18	2	8
4[b]	26	2	7
5[b]	36	1	16
6[b]	30	3	30
7[b]	32	10	85
8[a]	12	3	1
9[a]	12	3	1
10[a]	6	2	16

Krieger, 1989

[a] Sample collected by John Nigh, Idaho Department of Fish and Game, four to six inches above marsh bottom.
[b] Samples collected 12 inches below water surface in deeper water.

Table 30. July 1989 Survey of Wild Rice at Thompson Lake[a]

Sample	Lead (ug/g) Wet	Lead (ug/g) Dry
1	0.4	3.8
2	0	0
3	8.5	28.5
4	1.1	4.5
5	0.7	14.4
6	0.2	1.7
7	4.2	64.0
8	1.5	25.8
9	1.3	28.5
10	1.9	12.5

Krieger, 1989

[a] Samples collected by John Nigh, Idaho Department of Fish and Game.