

Flin Flon Speciation Data Summary

The speciation analyses were completed using electron microprobe analysis (EMP), conducted at the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado, in Boulder, Colorado, USA. The standard operating procedure (SOP) for EMP analysis at this laboratory is available at <http://www.colorado.edu/geolsci/legs/speciation1.html>. The method generates percent relative mass and percent linear frequency of occurrence of the mineral phases in each dust sample. The latter is simply the frequency of occurrence of a given mineral phase in the sample, whereas relative mass indicates which metal-bearing phase in a sample is likely to control the bulk metal concentration in the sample. Of these two types of output, relative mass percent is typically the most useful. This is because linear frequency of occurrence is influenced by particle size, wherein minerals with a large particle size will produce a high percentage value for this parameter, but may not necessarily contribute significantly to the bulk dust concentration of a given metal.

Tables summarizing the percent linear frequency of occurrence and percent relative mass for the major mineral phases of lead and arsenic are provided below. For comparison purposes, the corresponding bulk dust concentrations of lead, arsenic and tin are also provided in these tables for each dust sample, from both Bodycote (BC) and Testmark (TM) laboratory analyses. Minor mineral phases (as shown by 0 or very low percent linear frequency and/or percent relative mass) for lead and arsenic are not included in these tables.

Data Analysis

The analysis of the dust speciation data for lead and arsenic was limited to examining broad trends in the data.

Table 1: % linear frequency in major mineral phases

Sample	PbMO	PbMSO4	Cerussite	Slag	PbSiO4	Anglesite	SbMO	SnMO	FeOOH	Galena	ZnMO	CuMO	Arsenopyrite	Phosphate	FeSO4	Clay	Paint-cr	Brass	MnOOH	PbTiO2	Bulk Lead (Pb)		Bulk Arsenic (As)		Bulk Tin (Sn)		
																					BC	TM	BC	TM	BC	TM	
aads	0.39	0.39	4.65	18.6	14.34	5.43	0.78	2.71	7.36	1.16	6.2	7.36		0.78	2.71	27.13						153	111	36.2	30.3	9	6.83
ajds		1.41	0.6	48.49					18.91		6.44			0.8	1.21		22.13					347	186	65.7	42.5	57	8.47
awds	8.28	1.91	8.92	7.64	0.64				51.59			3.82	5.1		2.55			9.55				96.7	74.2	55.8	48.9	18	13.3
rsd		2.21	0.32	12.3	0.63				53.31	3.15	5.05				5.36			7.89	9.78			1290	175	73	57.2	660	11.5
sds			30.17				42.46												25.14	2.23		1060	422	41.7	31.6	374	16.5

Table 2: % relative mass lead of major mineral phases

Sample	PbMO	PbMSO4	Cerussite	Slag	PbSiO4	Anglesite	SbMO	SnMO	FeOOH	Galena	ZnMO	CuMO	Arsenopyrite	Phosphate	FeSO4	Clay	Paint-cr	Brass	MnOOH	PbTiO2	Bulk Lead (Pb)		Bulk Arsenic (As)		Bulk Tin (Sn)		
																					BC	TM	BC	TM	BC	TM	
aads	1.14	1.16	17.73	0.51	47.8	17.4	0	0.06	0.44	5.62	0.3	0.71		1.44	0.3	5.38						153	111	36.2	30.3	9	6.83
ajds		27.51	14.98	8.58					7.33		2.03			9.75	0.87		28.96					347	186	65.7	42.5	57	8.47
awds	37.81	7.8	46.27	0.28	2.58				4.34			0.5	0		0.38			0.03				96.7	74.2	55.8	48.9	18	13.3
rsd		8.35	4.02	1.12	6.29				10.42	51.04	0.82				1.98			0.06	15.9			1290	175	73	57.2	660	11.5
sds			88.68				0.03												8.66	2.63		1060	422	41.7	31.6	374	16.5

Table 3: % relative mass arsenic in major mineral phases

Sample	PbMO	PbMSO4	Cerussite	Slag	PbSiO4	Anglesite	SbMO	SnMO	FeOOH	Galena	ZnMO	CuMO	Arsenopyrite	Phosphate	FeSO4	Clay	Paint-cr	Brass	MnOOH	PbTiO2	Bulk Lead (Pb)		Bulk Arsenic (As)		Bulk Tin (Sn)		
																					BC	TM	BC	TM	BC	TM	
aads	13.63	10.22	0	0	0	0	3.89	0	39.85	0	0	0		5.24	27.16	0						153	111	36.2	30.3	9	6.83
ajds		23.66	0	0					65.18		0			3.47	7.7		0					347	186	65.7	42.5	57	8.47
awds	7.34	2.21	0	0	0				5.81			0	83.52		1.12			0				96.7	74.2	55.8	48.9	18	13.3
rsd		40.86	0	0	0				49.67	0	0			9.47			0	0				1290	175	73	57.2	660	11.5
sds			0				100												0	0		1060	422	41.7	31.6	374	16.5

As shown in Tables 1, 2 and 3, a variety of mineral phases were identified in the dust samples that underwent speciation analysis. The focus of this analysis was on the major mineral phases that contribute the most to relative mass percent of lead (Table 2) which is a more meaningful parameter than linear frequency of occurrence in terms of the contribution of mineral phases to the measured bulk dust concentrations). The most predominant phases in Table 2 include PbMSO₄ (lead metal sulfates), cerussite, and PbMO (lead metal oxides), and perhaps PbSiO₄ (lead silica oxide). Both PbMSO₄ and PbMO are consistent with atmospheric deposition of smelter emissions. PbSiO₄ may be naturally occurring or associated with smelting emissions, depending upon the characteristics of the ore being processed. Cerussite is present in all samples, and is present in a higher relative % mass in sample SDS, compared to the other samples (88 % relative mass of lead, compared with 46 – 4%; Table 2). Cerussite is also known as lead carbonate (PbCO₃), which is a naturally occurring form of lead, and was widely used as a pigment in lead-based paints, amongst other industrial applications. Since it is naturally occurring, and has historic anthropogenic uses, its presence in these samples could be related to any number of sources. The 4 dust samples with lower cerussite concentrations (AADS; AJDS; AWDS and RSD) all have indications of a smelter signature, in that PbMSO₄ is present in these samples. Sample SDS is clearly missing a smelter signature, in that no PbMSO₄ or PbMO is present, and its general speciation characteristics are not in keeping with those seen in the remaining samples (see Table 2 and 3). The likelihood of lead in this sample being related to smelter operations is considered low, based on the speciation data presented. In this same sample, the % relative mass of arsenic is related to SbMO (an antimony-metal-oxide complex), and does not match the profile presented in the remaining 4 samples in Table 3, further supporting that this sample is likely related to another source.

Slag is also identified as being present in 4 of the 5 samples analyzed. While the % relative mass for lead is low, the presence of slag also suggests a smelter-signature, albeit non-atmospheric. Despite slag being present in a reasonable % linear frequency (Table 1), relatively little of the relative mass percent of lead or arsenic is contributed by the slag phase (Table 2 and 3). This appears to be a logical finding in that the smelting process is extracting metals from concentrate, thus pure slag should not be a major source of lead or arsenic.

Paint is clearly identified in sample AJDS (Table 2), in addition to smelter contributions, which suggests multiple sources in this particular sample.

Anglesite (PbSO₄), manganese and iron oxyhydroxides, galena are all natural mineral phases that are reasonably common in soils.

In summary, the speciation data suggest the presence of a smelter-signature in 4 of the 5 samples analyzed, with the 5th sample (SDS) being markedly different in terms of the metal-phases present.