Appendix E

Crustal Element Analyses for Following Soil Lead Transport

Measurements of the crustal elements iron and manganese in yard soils, entry mats, and dust were made as part of remedial investigation (RI) studies supporting the human health risk assessment (HHRA) of nonlead contaminants in the basin (URS Greiner Inc. and CH2M Hill 2001, Terra-Graphics et al. 2001). These data can be used to assess the sources of lead in indoor dust. Table 7-2 in the human health risk assessment (HHRA) presents a summary of the results of the residential sampling that shows that the concentrations of and in yard soils and entryway floor mats were essentially the same, with ratios of mat dust to surface soil of 0.94 and 0.97, respectively. In contrast, the ratios of vacuum dust to surface soil for the two elements were 0.57 and 0.53, respectively. The similarity in the concentrations of iron and manganese in the outdoor soils and indoor mats is consistent with tracking of soil into the houses sampled. In contrast, the elevated level of lead in mat dust compared with yard soils (described below) could be due to either indoor lead sources (lead-based paint) or the preferential tracking indoors of soil particles that have higher lead concentrations than the bulk soil samples processed using a 175 micrograms (μm) sieve. For example, lead concentrations on fine particles might be enhanced, whereas iron and manganese are crustal elements, so their concentrations would be expected to be independent of particle size—including those under 175 μm. Unfortunately, little is known about the particle sizes that are most effectively transported on footwear, and there is no clear physicochemical explanation for a particle-size-dependent concentration profile of lead in surficial soils—unless perhaps the ore processing methods and subsequent weathering processes of lead tailings preferentially produce lead in fine particles, or perhaps the majority of tracked particles are very fine lead particles deposited from air.

The dilution effect of indoor-derived organic-rich particles on the concentrations of crustal elements associated with tracked-in soils has been analyzed by Trowbridge and Burmaster (1997). For a series of crustal elements with no significant indoor sources (aluminum, cerium, iron, hafnium, lanthanum, manganese, sodium, phosphorus, scandium, samarium, thorium, and vanadium), the geometric mean (GM) dilution ratio (defined as the ratio of the concentration of the crustal element in house dust to its concentrations in yard soil) was 0.42, with a geometric standard deviation (GSD) of 1.44. A ratio of 1 would indicate that indoor dust is entirely of outdoor origin, whereas a ratio of 0 implies that outdoor soil does not contribute to indoor dust. The U.S. Environmental Protection Agency (EPA) default value for this ratio in the IEUBK model (defined as the M_{SD} parameter, or the mass fraction of soil in dust, grams [g] of soil/g of dust) is 0.70 (EPA 1998), which is higher than the apparent dilution values noted above. However, IEUBK model runs conducted in support of the HHRA (Tables 6-11a-h) used measured concentrations of lead in household dust and yard soil.

As a means of further exploring the relationships between the crustal elements and lead in soil and dust, we evaluated the analytical results of the sampling campaigns that included measurements of iron, manganese, and lead in yard soils, entryway mats, and vacuum bag dust (data provided by the Idaho Department of Health and Welfare from FSPA06). The data included residences in the towns of Kingston, Osburn, Mullan, Silverton, and Wallace, along with residences in the Side Gulches, Nine-Mile, and Burke. To minimize the potential impacts of different sampling techniques and geographical regions on the exploratory analysis, we restricted the evaluation to the basin towns and used only the top surface-soil samples (0 to 0.08 feet) from the borehole samples of the yards (thereby excluding surface grab samples and hand auger samples). The soil concentration, assumed to be representative for the multiple yard samples obtained at each residence, was calculated as the GM of the samples. A total of 37 residences had paired measurements of the crustal elements and lead in the soil, mat, and vacuum bag media. Three residences included data outliers for one or more of the soil constituents and therefore were removed from the analysis, leaving 34 residences for the analysis. The resulting concentration data for the soils, mats, and vacuum bags were then used to calculate ratios for mat/soil, vacuum bag/mat, and vacuum bag/soil. These ratios are presented in Table E-1.

The concentrations of iron and manganese in yard soils exhibit less variability than that of lead, which is reasonable given that the crustal

TABLE E-1 Summary Statistics for the Concentrations of Iron (Fe), Lead (Pb), and Manganese (Mn) in Yard Soils, Entryway Mats, and Vacuum Bags as Well as Computed Concentration Ratios for a Sample of 34 Residences in the Coeur d'Alene River Basin

		Elements					
		Fe		Pb		Mn	
Parameter	Units	GM	GSD	GM	GSD	GM	GSD
Yard soil	μg/g	19924	1.24	542	1.95	892	1.46
Entry mat	μg/g	19627	1.41	1029	2.09	904	1.43
Vacuum bag	μg/g	11841	1.96	626	2.48	516	2.17
Mat/soil ratio	Unit less	0.98	1.39	1.90	1.52	1.01	1.37
Bag/mat ratio	Unit less	0.60	1.92	0.61	2.03	0.57	1.95
Bag/soil ratio	Unit less	0.59	1.95	1.16	2.08	0.58	2.05

Abbreviations: GM, geometric mean; GSD, geometric standard deviation.

elements are from weathered soils, whereas soil lead in these communities is the result of complex transport processes from the many sources (for example, redistribution of flood sediments and mine tailings). Levels of iron and manganese are essentially the same in yard soils and mat dust samples, but lead is about a factor of two higher in the mat dust than yard soils, as seen also in the results of the Agency of Toxic Substances and Disease Registry (ATSDR)-funded study (ATSDR 2000). Nevertheless, the linear correlation coefficient, r, between the concentrations of lead in yard soils and mat dusts was 0.87, compared with 0.30 and 0.74 for iron and manganese, respectively. The r value for iron concentrations in mat dusts and soils, though, increases to 0.65 after removing three data sets in which iron levels in mats might have been sampling/analysis artifacts. The strong correlation between lead in soils and mats indicates that the apparent particle fractionation-enrichment process between yard soil and mats occurs in a systematic fashion among the sampled residences. We also calculated correlation coefficients of 0.71 between soil manganese and soil lead and 0.52 between soil iron and soil lead. Although more analyses are warranted, the congruence between the concentrations of crustal elements in soil and residual lead indicates that waste ore/tailings mixed with host soils have also changed the elemental composition of soils.

The vacuum bag/entry mat dilution ratios for iron and manganese have geometric mean values of 0.60 and 0.57, respectively, with geometric standard deviations (GSDs) of nearly 2, which are greater than the GSD of 1.44 reported by Trowbridge and Burmaster (1997) in their review of other studies. The Ln-transformed iron and manganese concentrations are highly correlated, as shown in Figure E-1, with $r = 0.93$. The dilution ratios are also substantially higher than the value of 0.42 reported by Trowbridge and

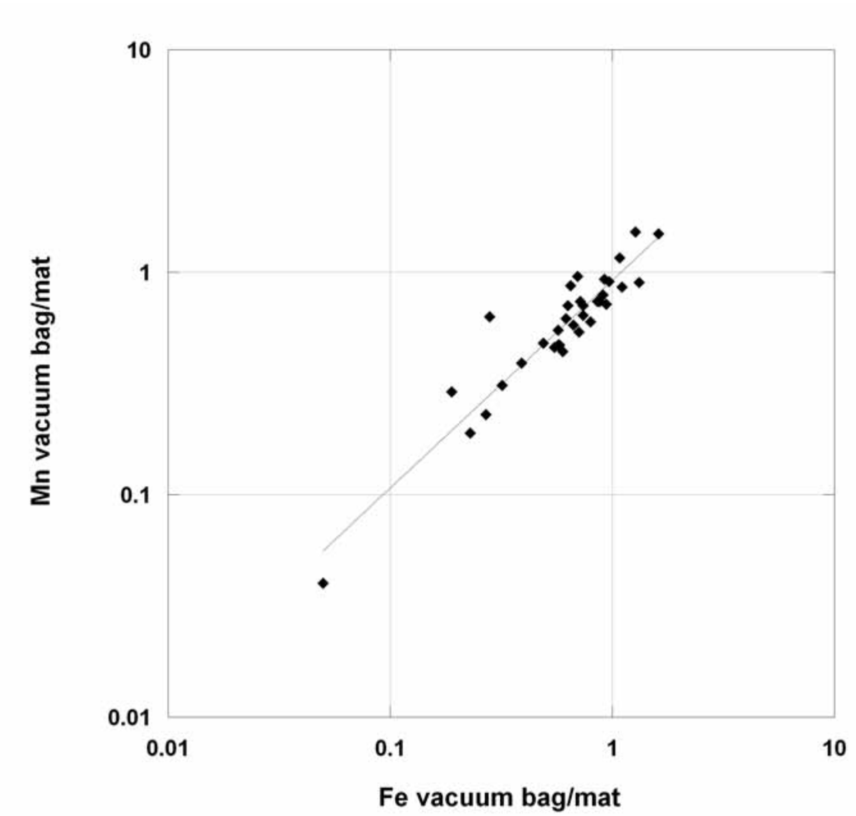

FIGURE E-1 Correlation between 1n-transformed concentrations of iron (Fe) and manganese (Mn) in vacuum bags and entryway mats for 34 basin residences. The correlation coefficient between the log-transformed concentrations is 0.93.

Burmaster (1997)—an indication that outdoor soils may be a more significant component of the indoor dusts in these communities. However, four of the vacuum bag/mat dilution ratios for iron were above 1, whereas three of the manganese ratios exceeded 1, suggesting that there were indoor sources of these elements (or possibly analytical artifacts). Other crustal elements may in fact be better tracers for characterizing the migration of soil lead to the indoor environment and in-house dilution processes in this mining region (Fe and Mn were targeted for sampling in the RI for human health considerations—not to study contaminant transport processes). Interestingly enough, the concentration reduction of lead between mat samples and vacuum bag samples is about the same as for iron and manganese. The correlations, though, between the log-transformed concentrations for lead and iron and lead and manganese (r values of 0.66 and 0.75, respectively) are lower than the correlation between the iron and manganese ratios (r = 0.93). Possible explanations are the presence of indoor lead sources such as lead-based paint particles and the differential transport of indoor lead due to particle-size-dependent processes of resuspension, deposition, and tracking.

We compared the vacuum bag/mat concentration ratios for manganese and lead by dividing the lead ratio by the manganese ratio to determine the potential extent of indoor lead sources. Figure E-2 presents a log probability plot of the resulting ratios. The GM of the ratios is 1.07, with a GSD of 1.61. More than half the ratios are greater than 1, which indicates that lead in vacuum dust may have nonoutdoor sources, such as lead-paint particles. This is particularly so for the many houses in the basin that were built before the phase out of lead-based paints.

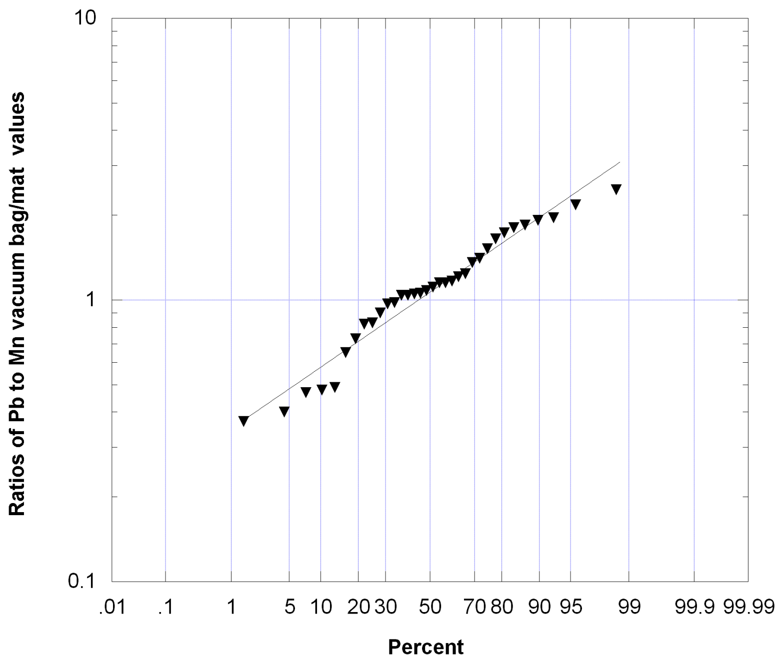

FIGURE E-2 Log probability plot of the ratios lead (Pb) vacuum bag/mat to manganese (Mn) vacuum bag/mat for 34 basin residences. The GM of the ratios is 1.07 with a GSD of 1.61.

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