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SUBJECT: EPA/CDC Survey for Heavy Metal Absorption by Children Living Near Smelters

ABSTRACT

This memo reports on a statistical analysis of blood and hair samples from children living close to nonferrous smelters. Included in this study are the assays of FEP (free erythrocyte protoporphyrin), Cd, Cu, Pb, and Zn in blood and As, Cd, and Pb in hair.

By the EPA's definition, Herculaneum is an area where "a serious problem of heavy metals absorption" exists. Monaca is not. However, Herculaneum does not show significantly higher average blood Pb or Cd values than Perryville, a control location in Missouri. Herculaneum does show a significantly higher FEP average than does Perryville.

Of the smelter locations tested, only Bartlesville, Oklahoma appears to have a really serious problem of heavy metals absorption.

Blood - EPA - Hair - Heavy Metals

DR 3403014

INTRODUCTION

Recently the Environmental Protection Agency (EPA) in conjunction with the Center for Disease Control (CDC) completed a sampling study on children living close to nonferrous smelters. The object of the study was to determine if such children showed evidence of undue heavy metal absorption.

Involved in the study were approximately 2250 children, 5 years of age and under, from 24 locations--4 control locations, 3 lead smelter locations, 5 zinc smelter locations, and 12 copper smelter locations. One control location and one copper smelter location are in Mexico. The rest are in the U.S. Of course, the study includes the areas surrounding St. Joe's Josephtown zinc smelter and Herculaneum lead smelter.

We report here on a statistical analysis of the data from blood and hair specimens. We do not report on urine specimens since none were taken (or at least none were reported) from the lead or zinc smelter locations. The assays reported, and here analyzed, are: FEP (free erythrocyte protoporphyrin), Cd, Cu, Pb, and Zn in blood; and As, Cd, and Pb in hair. The blood assays are in µg per 100 ml of blood. The hair assays are in µg per g of hair.

CONCLUSIONS

1. Neither the as-received data nor the logarithms of those data fit a normal distribution function very well--though, in general, the logarithms fit a normal distribution better than do the as-received data.

2. There are substantial differences in averages and in variation both between the control groups and between the smelter groups.

3. The data are influenced by some factor or factors unknown to us. The effect of those factors is to distort the probabilities associated with the usual statistical tests. Such factors must be identified and corrected for before we can make valid statistical tests.

4. Herculaneum is, by the EPA definition, an area where "a serious problem of heavy metals absorption" exists, in that 15% of the children tested in the area have FEP values greater than 50 µg/100 ml blood or Pb values greater than 30 µg/100 ml of blood, and in that the Pb in hair values are more than twice as high for those living within 1 mile of the smelter as for those living further away.

5. Of the blood assays, only FEP is "significantly" higher for Herculaneum and Monaca than in Perryville, Missouri (the control group most similar to Herculaneum and Monaca).

6. Hair Pb and Cd are significantly higher for both Herculaneum and Monaca than for Perryville.

7. Of the smelters tested, only Bartlesville, Oklahoma appears to represent a genuine problem area.

8. A number of correlations exist between the various components tested. Generally, these are weak and lack predictive capability. However, Pb in hair vs Cd in hair stands out as one correlation that is exceptionally strong.

SUMMARY STATISTICS

Tables A through H (at the end of this report) display the summary statistics for each of the assays, for each of the sampling locations. These tables contain statistics for the untransformed (as-received) data and for the logarithmically transformed data.

The statistics presented are:

- N - the number of reported assays
- $\bar{X}$ - the average of the reported assays
- S(X) - the estimated standard deviation of the assays
- P(X) - a probability value associated with the reported assays (discussed below)
- High - the largest reported assay for the group
- Low - the smallest reported assay for the group
- $\overline{\log X}$ - the average of the natural logarithms of the data
- S(log X) - the estimated standard deviation of the log transformed data
- P(log X) - a probability value associated with the log data (see below)
- Geo. Mean - the geometric mean of the data, which is the anti log of $\overline{\log X}$.

The probabilities values P(X) and P(log X) indicate how well the untransformed data or the transformed data, respectively, fit a normal probability distribution. A value of less than 0.05 indicates that the data are not likely to have come from a normal distribution.

Assumptions Implicit in Statistical Tests

At this point it is worthwhile to review the assumptions that underlie most statistical tests, and discuss the effect of violating those assumptions--because the EPA/CDC data do violate those assumptions. The assumptions concern the deviation of individual elements of data from estimated means or regression lines, and they are:

1. The deviations are normally distributed
2. The deviations come from distributions which have the same standard deviation, and
3. The deviations are independent of each other.

Table 1 contains data which comment on how much the first two assumptions are violated.

TABLE 1: Comparisons of Data Distributions

	BLOOD					HAIR		
	FEP	Cd	Cu	Pb	Zn	As	Cd	Pb
Number of groups	24	12	16	24	21	16	24	24
Number of groups for which P(X) >0.05	1	0	13	8	13	1	2	5
Number of groups for which P(log X) >0.05	10	5	9	18	14	15	22	21
Untransformed Data:								
Ratio of largest to smallest std deviation	9.0	8.4	5.4	5.2	4.3	447 (37)*	27.1	18.4
Largest γ_1	5.5	6.7	7.1	3.6	7.4	5.7	6.2	4.2
Smallest γ_1	0.3	1.1	-0.3	-0.1	-0.7	0.5	0.9	0.2
Largest γ_2	39.2	51.9	60.0	20.7	63.5	42.1	46.7	19.8
Smallest γ_2	-1.0	2.0	-0.6	-0.8	-0.9	-0.8	-0.7	-1.4
Log Transformed Data:								
Ratio of largest to smallest std deviation	2.6	3.0	2.3	3.0	1.9	2.1	1.9	1.6
Largest γ_1	2.0	1.3	2.5	0.7	1.6	1.8	1.0	0.7
Smallest γ_1	-0.1	-0.9	-2.5	-2.8	-3.1	-0.9	-0.8	-1.1
Largest γ_2	7.1	6.0	13.4	15.4	17.3	5.1	3.8	3.0
Smallest γ_2	-1.5	-0.7	-0.6	-0.6	-0.4	-0.8	-1.4	-1.4

*The number in parentheses excludes Anaconda data. The Anaconda data look suspiciously as though they suffer from a misplaced decimal point.

Failure to Fit a Normal Distribution

The data presented in Table 1 consistently show that they log transformed data fit the first two assumptions better than do the untransformed data. But, at least for some purposes, the fit is still inadequate. Of the 161 total groups of assays, 43 (27%) of the untransformed groups are fitted adequately by a normal distribution while 114 (71%) of the log transformed groups are adequately fitted by the normal.

We will be looking at two general types of statistical tests--those that seek to compare averages and those that seek to compare variation. Deviations from the underlying assumptions influence these two types of tests differently.

The general shape of a probability distribution is quantified by two statistics: γ_1 - the coefficient of skewness, and γ_2 - the coefficient of kurtosis. γ_1 measures the tendency of the distribution to be non-symmetric. A positive value of γ_1 indicates a long tail to the right of the mean, while a negative value indicates a long tail to the left. γ_2 is a measure of concentration of the distribution. A negative value indicates a large central mass with small or nonexistent tails, while a positive value indicates little central concentration and heavy tails.

For statistical tests concerning averages, the value of γ_2 seems unimportant--if the sample size is at least 10. However, large values for skewness (γ_1) indicate serious distortions in probability of ordinary tests unless the sample size is large. A sample size of 10 is "large" for a distribution whose γ_1 is less in magnitude than 1. A sample size of 30-50 is "large" if γ_1 is less in magnitude than 3, but only a sample size in the range of 100-200 can be considered large for γ_1 of magnitude 5.[1]

Since we have only 15 groups (8%) with sample sizes less than 30, and of those the largest value of γ_1 is 1.8 for log transformed data, we conclude that the shape of the distributions will not be an important factor for the tests of averages of the log transformed data. The same cannot be said for the untransformed data.

For statistical tests concerning variation between or within samples, γ_1 is unimportant, but γ_2 has great importance. This is because the standard deviation of squared sample standard deviations is:[2]

$$\left(\frac{2}{N-1} + \frac{\gamma_2}{N} \right)^{\frac{1}{2}} \sigma$$

where N is the sample size, and σ is the true population standard deviation. Since the usual tests for differences in variation depend on the underlying distribution being normal ($\gamma_2 = 0$), and since, even for the log transformed data we have many large positive values for γ_2, tests comparing variation can be very misleading. The tendency will be to show many "significant" results when none really exist.

Unequal Standard Deviations

As a result of the factors discussed above, we have no very good method to test if the standard deviations for an element vary from group to group. The usual tests give highly "significant" results. But, as explained above, the level of significance is likely overstated. However, with the ratios of largest to smallest standard deviations (for the log transformed data) ranging from 1.6 to 3.0, we must conclude the differences probably do exist between the standard deviations of the groups.

Such differences in standard deviations can have serious impact on the validity of comparisons of the averages between groups. If, in comparing such averages, the number of samples in each group is approximately equal, there is no serious problem. If, however, the group sizes differ by a factor of 2, and the ratio of standard deviations is about 2.2, then a test at the nominal 5% probability level has a true associated probability of 12% if the larger group has the smaller standard deviation, or 1.4% if the larger group has the larger standard deviation.[2]

This discussion is appropriate basically to between-group comparisons. Presumably the standard deviation within a group is constant.

Lack of Independence of Deviations

The third assumption listed above is that the deviations are independent of each other. We have strong, though indirect, evidence that this assumption is violated also.

In one series of calculations, to test the effect of distance from the smelter on heavy metal absorption, we assumed that sample sequence numbers were indicative of distance (we had no other information on distance at that time). We then divided each group into two halves based on the sequence numbers, and compared the averages for these two halves (on the log transformed data). Table 2 contains a summary of those comparisons.

TABLE 2: "Significant" Differences Between First and Second Halves of the Groups

	Number (%) of Positive Results	Number (%) of Negative Results	Total	Number of Tests
ALL CHILDREN				
Around Smelters	12 (9.6)	14 (11.2)	26 (20.8)	125
Control Groups	1 (3.1)	5 (15.6)	6 (18.8)	32
Total	13 (8.3)	19 (12.1)	32 (20.4)	157*
ONE CHILD PER FAMILY				
Around Smelters	11 (8.8)	11 (8.8)	22 (17.6)	125
Control Groups	2 (6.3)	6 (18.8)	8 (25.0)	32
Total	13 (8.3)	17 (10.8)	30 (19.1)	157*

*The total number of tests is less than 161 because, for one smelter (Corpus Christi), there were no blood samples among the first half groups.

In the above table, we list the number of times (and in parentheses, the percentage of times) the average level of an element tested significant by the usual t test at the 5% probability level. If there are no real differences, we would expect 2.5% positive results and 2.5% negative results due to chance causes. The positive results indicate that the children in the first half groups (presumably those closest to the smelters) have higher levels than those in the second half groups. Negative results indicate the opposite.

Without the large number of negative results and without the large number of "significant" results among the control groups, the large number of positive results around the smelters would indicate potentially serious problems. But the number of negative results exceeds the number of positive results, and it just doesn't make sense that children exposed to significantly higher concentrations of one element would be exposed to significantly lower concentrations of another. Also, we have roughly 20% "significant" results from the control groups. Thus, we must conclude that something about the data seriously distorts the probabilities of the tests.

According to earlier discussion, the shape of the sampling distribution should not have much effect on the probabilities providing that the numbers in the groups are large. (Of the groups that showed "significant" differences, the smallest contained 47 values.) To check on this, however, we performed similar tests except that the samples were assigned randomly to one of the two half groups, and repeated this procedure 10 times on both the transformed and untransformed data, giving 20 sets of 161 tests. The percentages of "significant" results ranged from 1.9% to 8.9% in the 20 sets, and averaged 4.5% for the untransformed data and 5.3% for the transformed data. We thus conclude that the shape of the distribution curves was not the cause of the distortion in probabilities.

We are thus left with non-independence of the data as the likely cause of the probability distortion.

Unfortunately, we do not have sufficient data to allow a detailed examination of sources of this non-independence. For the most part, we can only speculate on the causes. There is, however, one possible source we can check: differences in variation between children within a family versus children from different families. We performed the usual analysis of variance for this effect, and found 59 (36.6%) of the 161 groups showed "significantly" more variation between children of different families than between children within a family. However, because of the points made in the discussion of γ_2, these 59 "significant" results are open to question.

But, as a further check, we simply performed the first half groups versus second half group t tests using only one assay per family for each element. The summary of those t tests is included in Table 2. The results using only one child per family do not differ appreciably from the results using all children per family. We thus conclude that differences in variation between the children is not the major cause of the probability distortions.

We have exhausted the possibilities that we can examine with the data available to us, and can only speculate as to other possible causes.

One possible cause could be some sort of experimental drift or source of variation. For instance, an electronic instrument for automated analysis subject to electronic drift could be the explanation: a drift of less than 0.5 standard deviation could cause results similar to those reported here. A value of 0.5 standard deviation for Pb in blood, for instance, is equivalent to about 4 μg/100 ml of blood. Such a drift could be undetected by usual laboratory quality control procedures.

Another possible cause is some sort of racial, ethnic, socio-economic, dietary, or other such drift among the children sampled. Given other well known and documented physiological differences between various racial and ethnic groups, it is not unreasonable to assume some racial and ethnic differences in the absorption and elimination of heavy metals. Also, different racial and ethnic groups tend to have different dietary habits, and various foods contain differing amounts of heavy metals. The sampling was supposed to take place in a spiral pattern outward from the smelters. So, given the general tendency of neighborhoods to be segregated, it is very likely that the first halves of groups have substantially different racial or ethnic compositions than the second halves of groups.

To sum up, we have strong indications of serious problems with the data. We have insufficient information to pinpoint the causes of those problems. And, these problems cause us to question the results of any statistical tests performed with these data.

If the indicated drift is experimental, then it will not be possible to ever make valid statistical tests. If the drift is racial, ethnic, etc., then knowledge of the causal variables and correction for them will allow valid tests.

STATISTICAL COMPARISONS

In the following, we present results as though there were no statistical problems with the data. But bear in mind that we cannot say conclusively what is significant and what is not.

Average Concentrations

The average concentrations for each location are shown in Tables A-H in the appendix. These averages show no consistent patterns. Comparing either arithmetic or geometric means, for blood samples there is at least one smelter area that has a lower average than any of the control groups, and for hair samples there is at least one smelter area that has a lower average than at least one of the control groups.

Table 3 gives the F test results for differences in averages between various combinations of groups. F values of 3.1 (for the Pb smelters) to 1.6 (for all groups) would be significant if there were no data problems. All the F values reported are above the critical values for the usual significance level.

TABLE 3: F Values for Tests of Differences in Group Averages - Log Transformed Data

	BLOOD					HAIR		
	FEP	Cd	Cu	Pb	Zn	As	Cd	Pb
Control Groups	17.7	13.9	30.2	5.6	3.7	92.0	3.1	4.5
Pb Smelters	4.3	14.3		12.2			4.5	16.1
Zn Smelters	4.9	39.7		10.9	56.8		23.5	20.4
Copper Smelters	16.1		57.3	25.4	23.0	324.8	9.8	13.7
All Groups	11.8	26.6	53.1	18.9	27.1	325.1	35.1	34.3

Percentages of Groups Beyond Cut Limits

Part of the EPA's definition of "a serious problem of heavy metal absorption" is that 10% of the children tested exhibit "undue absorption." And "undue absorption" for the elements reported on here is defined as blood Pb level $\geq$30 μg/100 ml and/or FEP level $\geq$50 μg/100 ml or Cd blood level $\geq$1.0 ppm. The limit on Cd in blood gives us some reason to question the data presented. If the assays are truly in μg/100 ml, then the largest reported value (3.79) converts to approximately 0.038 ppm. Thus, none of the samples exceed 1.0 ppm. In Table 4, we present the percentages of each group which exceed the EPA's stated limits, except for Cd in blood, where we presume that the real limit is 1.0 in whatever units the data are presented in.

Also included in Table 4 is the fraction in each group that exceeds 40 μg Pb/100 ml blood (the more traditional indication of excess Pb absorption).

As can be seen from the table, only one smelter has more than 10% beyond the presumed Cd limit (Bartlesville). But 11 of the 20 smelters and 2 of the 4 control groups exceed 10% on the combined FEP-Pb limit--including Herculaneum, but not including Monaca.

The high variation between control groups (particularly with FEP) indicates strong influences of socio-economic/cultural/environmental differences. Unless a control group can be readily matched with a smelter group according to such factors, comparisons are meaningless.

The percentage of Pb in blood samples beyond 30 and beyond 40 μg/100 ml indicate a serious problem only at Bartlesville. A few other smelters (not including Herculaneum or Monaca) may be moderate problem areas. But even Bartlesville does not approach the magnitude of a problem indicated by the 1974 samples from Kellogg, Idaho where 87% of the children living within 2-1/2 miles of the smelter had blood Pb values greater than 40 μg/100 ml.[3]

Approximate Distance from the Smelter

Another part of the EPA's definition of "a serious problem of heavy metal absorption" is "when there is a two-fold decrease of that metal in any sample (blood, urine, or hair) from the children living closest to smelter to those living furthest away." As of this writing, we have actual distance information only for the Pb smelters--and that will be discussed in a later section. Here we show the results of dividing the groups into halves via sequence numbers. Table 5 shows the ratio of the geometric means of the first half group versus the second half group. The underlined values are those for which the t tests were "significant."

TABLE 4: Percentages of Children in Each Group Beyond Limits

	FEP ≥50	Pb ≥30	FEP ≥50 or Pb ≥30	Cd ≥1.0	Pb ≥40
Perryville, Mo.	1.2	4.7	5.8	2.3	2.4
Nogales, Mexico	17.9	2.8	19.8	0.9	0.9
Safford, Ariz.	3.3	3.3	6.5	1.1	0
Albuquerque, N. Mex.	6.0	4.8	10.7	0	0
All Control Groups	7.6	3.8	11.1	1.1	0.8
Herculaneum, Mo.	10.8	9.9	14.7	2.0	5.5
Glover, Mo.	8.7	0	8.7	0	0
Bixby, Mo.	16.7	0	16.7	0	0
All Lead Smelters	12.1	5.6	14.5	0.8	3.1
Monaca, Pa.	1.6	3.2	3.2	1.6	0
Amarillo, Tex.	8.4	15.8	22.1	0	4.2
Bartlesville, Okla.	6.7	39.1	38.9	10.4	21.8
Corpus Christi, Tex.	15.4	0	15.4	0	0
Palmerton, Pa.	15.0	4.4	15.9	3.5	0.9
All Zinc Smelters	9.1	15.1	20.9	3.6	6.5
Copperhill, Tenn.	1.1	5.7	6.9		1.1
Hayden, Ariz.	11.9	9.9	18.8		3.0
Anaconda, Mont.	3.1	3.1	6.2		1.5
McGill, Nev.	0	0	0		0
Hurley, N. Mex.	18.4	12.2	20.4		6.1
Douglas, Ariz.	12.5	12.5	19.8		2.1
White Pines, Mich.	0	5.8	5.8		1.4
San Manuel, Ariz.	3.0	3.0	5.9		0
Miami, Ariz.	7.1	6.1	12.1		1.0
Morenci, Ariz.	4.0	2.0	5.0		0
Aqua Prieta, Mexico	18.8	5.2	19.8		2.1
Ajo, Ariz.	0.9	0.9	1.9		0
All Copper Smelters	6.8	5.5	10.2		1.4
All Groups	7.9	7.0	12.8	2.1	2.4

TABLE 5: Approximate Effect of Distance

Ratios of average concentration in the first half group to average concentration in the second half group

	BLOOD					HAIR		
	FEP	Cd	Cu	Pb	Zn	As	Cd	Pb
Controls								
Perryville	1.05	0.74	1.00	0.92	1.03	0.72	0.85	0.70
Nogales	1.20	0.86	0.98	0.98	1.00	0.79	1.19	1.44
Safford	0.97	0.94	1.04	0.98	1.09	0.85	0.82	0.66
Albuquerque	1.10	0.88	0.99	0.84	0.98	0.85	0.93	1.01
Pb Smelters								
Herculaneum	1.29	1.56	-	1.14	-	-	1.47	1.45
Glover	0.79	1.42	-	0.93	-	-	1.08	1.12
Bixby	1.26	1.04	-	1.35	-	-	0.92	0.89
Zn Smelters								
Monaca	0.91	1.45	-	1.06	1.03	-	0.91	1.09
Amarillo	0.90	0.93	-	1.10	1.09	-	1.22	0.72
Bartlesville	1.38	0.51	-	2.34	0.92	-	1.44	1.23
Corpus Christi	*	*	-	*	*	-	1.22	1.07
Palmerton	1.07	0.77	-	1.06	1.00	-	1.70	1.61
Copper Smelters								
Copperhill	0.92	-	0.95	0.96	0.98	0.93	1.15	1.24
Hayden	0.83	-	0.87	0.87	0.84	1.18	0.98	1.06
Anaconda	1.03	-	0.98	1.35	1.00	0.90	0.79	1.09
McGill	0.95	-	0.91	1.02	1.01	1.69	1.71	1.68
Hurley	0.91	-	1.06	0.86	0.98	0.83	0.84	1.00
Douglas	1.18	-	0.97	1.31	0.91	0.99	1.10	1.22
White Pines	0.82	-	0.92	1.00	0.95	1.04	1.65	1.31
San Manuel	0.90	-	0.96	0.92	1.02	1.01	0.70	0.51
Miami	1.11	-	1.01	1.08	1.07	1.07	0.91	0.91
Morenci	0.75	-	0.94	0.78	1.07	0.71	1.10	0.90
Aqua Prieta	0.89	-	0.96	0.76	1.00	0.74	0.52	0.65
Ajo	1.00	-	1.04	0.94	0.99	1.06	1.04	0.79

*No blood samples in the first half group.

Only one group shows a two-fold decrease between the first half group and the second: Pb in blood at Bartlesville. Interestingly, the same location shows almost a two-fold increase in Cd in blood between the first and second half groups.

That the division of groups into halves gives an approximate distance relationship is demonstrated by the Pb smelter groups. Table 6 shows how the first and second half groups were actually divided according to distance.

TABLE 6: Distance versus Sequence Numbers

	First Half Group		Second Half Group	
	<1.0 mile	>1.0 mile	<1.0 mile	>1.0 mile
Herculaneum*	32	24	3	49
	<2.0 mile	>2.0 mile	<2.0 mile	>2.0 mile
Glover	4	14	3	16
Bixby	11	16	1	27

*1 sample from Herculaneum was unidentified as to distance and 3 were subsequently identified as coming from the persons taking the samples.

Glover and Bixby are, of course, sparsely populated areas, and Glover does not exhibit a good distance-sequence number correlation. However, Herculaneum, and Bixby do exhibit good distance-sequence number correlations.

Actual Distance from the Smelter

As mentioned previously, we do have actual distance data for the Pb smelters. Table 7 gives the ratio of geometric means and associated t values for the difference in means for various possible distance comparisons.

TABLE 7: Actual Effect of Distance for Pb Smelters

		BLOOD			HAIR	
		FEP	Cd	Pb	Cd	Pb
Herculaneum						
<1 m vs >1 m	Ratio	1.65	1.96	1.42	1.12	2.11
	t	3.74	2.60	3.71	0.77	4.01
<1½ m vs >1½ m	Ratio	1.39	1.64	1.16	0.84	1.42
	t	3.24	1.16	1.72	-0.77	2.00
Glover						
<2 m vs >2 m	Ratio	1.64	1.03	1.55	1.09	1.10
	t	2.21	0.08	1.56	0.20	0.29
Bixby						
<2 m vs >2 m	Ratio	1.45	0.67	1.29	0.86	0.93
	t	1.87	-1.73	1.05	-0.32	-0.14

The only ratios which show close to a two-fold decrease are the <1 m vs >1 m comparisons for Herculaneum. Cd in blood is nearly two-fold; Pb in hair is slightly more than twofold. The t values greater than 2.0 are usually considered significant.

Correlations Between Assays

Table 8 contains the correlation coefficients and associated t values for correlations between different types of assays. These were calculated for the log transformed data. The first five columns are within group comparisons, adjusted for group to group differences in averages. The last column is correlations between groups. The degree of correlation indicated is quite consistent for the different groupings of locations. Out of the 102 correlations reported, two show a significant negative value--about the expected result from chance causes. Many positive significant correlations show up, but these generally are rather weak and lack predictive power. (After all, given enough data extremely weak correlations will show up as significant.)

One set of correlations stands out as highly predictive: Cd in hair vs Pb in hair. One other is at an intermediate predictive level: As in hair vs Pb in hair. Why these hair results should be so strong when all the others are weak is difficult to explain unless the hair results are more indicative of exposure to the heavy metals than absorption of the heavy metals.

Of the between group correlations, only Zn in blood vs Cu in blood, As in hair vs Cd in hair, and Cd in hair vs Pb in hair are significant.

Herculaneum and Monaca Compared to Perryville

Perryville, a small town in southeastern Missouri, is the control group which probably matches both Herculaneum and Monaca best. Table 9 compares the data from Perryville with the data from Herculaneum and Monaca. Blood FEP is significantly higher at both Monaca and Herculaneum than at Perryville, while blood Cd is significantly lower at Monaca than Perryville. The hair data for both Herculaneum and Monaca are significantly higher than Perryville for both Pb and Cd.

Concerning the portion of samples exceeding certain threshold limits, Monaca is significantly lower in the portion of samples that exceed 30 μg/100 ml Pb in blood than Perryville, while Herculaneum is significantly higher than Perryville in the portion of samples that exceed 50 μg/100 ml FEP in blood.

TABLE 8: Correlations between Assays

		Control Groups		Pb Smelters		Zn Smelters		Cu Smelters		All Groups		Between Groups	
		r	t	r	t	r	t	r	t	r	t	r	t
Blood FEP vs Blood	Cd	-0.079	-1.52	0.114	1.24	-0.027	-0.50	-	-	-0.013	-0.39	0.140	0.45
	Cu	0.117	2.25	-	-	-	-	0.146	4.69	0.138	5.16	0.074	0.28
	Pb	0.136	2.61	0.311	4.12	0.274	5.45	0.251	8.21	0.245	11.01	0.273	1.23
	Zn	-0.114	-2.18	-	-	0.036	0.68	-0.046	-1.45	-0.040	-1.65	0.004	0.00
Blood FEP vs Hair	As	0.005	0.07	-	-	-	-	0.047	1.33	0.041	1.27	0.358	1.43
	Cd	0.062	0.86	0.289	3.00	0.125	1.96	-0.023	-0.63	0.052	1.88	0.161	0.77
	Pb	0.215	3.05	0.282	2.92	0.166	2.62	0.150	4.26	0.175	6.47	0.377	1.91
Blood Cd vs Blood	Cu	0.000	0.01	-	-	-	-	-	-	0.000	0.00	0.799	1.88
	Pb	0.023	0.44	0.142	1.55	0.065	1.22	-	-	0.070	2.04	0.229	0.75
	Zn	-0.075	-1.44	-	-	0.023	0.43	-	-	-0.013	-0.13	0.491	1.49
Blood Cd vs Hair	As	0.110	1.53	-	-	-	-	-	-	0.110	1.53	0.857	2.35
	Cd	0.027	0.38	-0.059	-0.47	0.104	1.59	-	-	0.056	1.23	0.199	0.64
	Pb	-0.051	-0.70	-0.039	-0.31	0.088	1.34	-	-	0.027	0.36	0.020	0.06
Blood Cu vs Blood	Pb	0.312	6.25	-	-	-	-	0.231	7.52	0.249	9.53	0.330	1.31
	Zn	0.292	5.80	-	-	-	-	0.270	8.91	0.274	10.53	0.726	3.95
Blood Cu vs Hair	As	-0.024	-0.34	-	-	-	-	0.009	0.24	0.002	0.07	0.330	1.31
	Cd	-0.059	-0.82	-	-	-	-	0.011	0.31	-0.005	-0.15	0.390	1.59
	Pb	-0.125	-1.75	-	-	-	-	0.026	0.74	-0.006	-0.17	0.483	2.07
Blood Pb vs Blood	Zn	0.209	4.08	-	-	0.047	0.89	0.225	7.34	0.178	7.51	0.423	2.03
Blood Pb vs Hair	As	0.099	1.38	-	-	-	-	0.057	1.60	0.063	1.97	-0.193	-0.86
	Cd	0.232	3.31	0.184	1.78	0.379	6.32	0.155	4.40	0.221	8.22	0.193	0.92
	Pb	0.237	3.38	0.216	2.10	0.396	6.64	0.222	6.41	0.264	9.93	0.218	1.05
Blood Zn vs Hair	As	-0.066	-0.91	-	-	-	-	-0.039	-1.11	-0.043	-1.35	0.340	1.35
	Cd	-0.026	-0.36	-	-	-0.089	-1.37	-0.042	-1.17	-0.050	-1.73	0.350	1.63
	Pb	-0.146	-2.04	-	-	0.000	0.00	-0.055	-1.54	-0.054	-1.90	0.389	1.84
Hair As vs Hair	Cd	0.226	3.47	-	-	-	-	0.221	6.90	0.221	7.70	0.652	3.22
	Pb	0.264	4.07	-	-	-	-	0.405	13.52	0.383	14.07	0.486	2.08
Hair Cd vs Hair	Pb	0.582	10.66	0.703	10.92	0.741	18.73	0.619	23.99	0.650	33.81	0.825	6.84

TABLE 9: Comparisons of Herculaneum and Monaca to Perryville, Missouri

Assay	Geometric Means			t Values for Difference Between Perryville and:	
	Perryville	Herculaneum	Monaca	Herculaneum	Monaca
Blood FEP	19.97	22.78	25.05	2.20	5.30
Blood Cd	0.196	0.227	0.164	1.00	-1.79
Blood Pb	15.83	17.12	13.76	1.33	-2.20
Blood Zn	367.	-	342.	-	-1.85
Hair Cd	0.67	3.04	1.46	9.94	5.27
Hair Pb	9.80	46.1	13.9	12.62	2.58
	Percent of Samples Beyond Limits			t Values for Difference	
Blood Pb >30	4.7	9.9	3.2	1.31	-2.23
FEP >50	1.2	10.8	1.6	2.69	0.22
Blood Pb >30 or FEP >50	5.8	14.7	3.2	1.97	-0.75
Blood Pb >40	2.4	5.5	0	1.06	-1.20
Blood Cd >1.0	2.3	2.0	1.6	-0.12	-0.32

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APPENDIX

TABLE A: FEP in Blood - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	20.9	8.3	0.00	80.0	13.1	2.994	0.272	0.01	20.0
Nogales, Mexico	106	37.1	38.5	0.00	348.0	12.4	3.398	0.565	0.00	29.9
Safford, Ariz.	92	23.2	11.6	0.00	89.4	11.0	3.063	0.369	0.00	21.4
Albuquerque, N. Mex.	84	26.1	12.8	0.00	91.4	12.2	3.183	0.365	0.01	24.1
All Control Groups	368	27.3	22.6		348.0	11.0	3.171	0.415		23.8
Herculaneum, Mo.	102	26.8	18.4	0.00	92.9	9.0	3.126	0.529	0.00	22.8
Glover, Mo.	23	22.2	13.4	0.00	63.7	10.9	2.974	0.478	0.04	19.6
Bixby, Mo.	48	33.9	24.8	0.00	125.0	11.3	3.341	0.570	0.02	28.3
All Lead Smelters	173	28.2	19.8		125.0	9.0	3.166	0.531		23.7
Monaca, Pa.	63	25.9	7.3	0.02	59.8	16.3	3.221	0.248	0.54	25.0
Amarillo, Tex.	95	28.8	17.8	0.00	122.0	12.2	3.244	0.444	0.00	25.6
Bartlesville, Okla.	90	26.5	17.0	0.00	107.0	12.0	3.150	0.467	0.00	23.3
Corpus Christi, Tex.	13	28.6	14.3	0.10	55.7	14.4	3.240	0.493	0.13	25.5
Palmerton, Pa.	113	35.5	25.2	0.00	185.0	15.1	3.415	0.504	0.00	30.4
All Zinc Smelters	374	29.8	18.8		185.0	12.0	3.269	0.443		26.3
Copperhill, Tenn.	87	18.5	5.8	0.00	51.8	9.9	2.876	0.274	0.30	17.7
Hayden, Ariz.	101	30.4	18.7	0.00	97.8	9.9	3.276	0.495	0.00	26.5
Anaconda, Mont.	65	26.8	13.9	0.00	107.0	14.2	3.207	0.374	0.00	24.7
McGill, Nev.	51	19.4	4.3	0.04	30.2	12.0	2.939	0.223	0.07	18.9
Hurley, N. Mex.	49	34.1	23.1	0.00	100.0	13.8	3.362	0.546	0.00	28.9
Douglas, Ariz.	96	30.1	19.6	0.00	146.0	11.1	3.273	0.480	0.00	26.4
White Pines, Mich.	69	17.4	4.7	0.02	31.3	10.1	2.822	0.256	0.28	16.8
San Manuel, Ariz.	101	23.8	11.0	0.00	90.4	10.7	3.095	0.367	0.08	22.1
Miami, Ariz.	99	27.1	15.7	0.00	123.0	10.0	3.198	0.419	0.05	24.5
Morenci, Ariz.	100	23.7	13.3	0.00	106.0	10.0	3.068	0.409	0.12	21.5
Aqua Prieta, Mexico	96	35.8	24.8	0.00	137.0	10.7	3.402	0.564	0.05	30.0
Ajo, Ariz.	106	22.1	10.0	0.00	99.8	10.8	3.035	0.331	0.21	20.8
All Copper Smelters	1020	25.9	15.3		146.0	9.9	3.135	0.411		23.0
All Groups	1935	27.1	18.0		348.0	9.0	3.170	0.430		23.8
Largest	113	37.1	38.5	0.10			3.415	0.570		30.4
Smallest	13	17.4	4.3	0.00			2.822	0.223		16.8

TABLE B: Cd in Blood - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	0.242	0.229	0.00	1.81	0.05	-1.628	0.583	0.00	0.196
Nogales, Mexico	106	0.293	0.220	0.00	2.20	0.07	-1.356	0.468	0.11	0.258
Safford, Ariz.	92	0.187	0.127	0.00	1.21	0.06	-1.786	0.425	0.06	0.168
Albuquerque, N. Mex.	84	0.210	0.103	0.00	0.55	0.05	-1.672	0.478	0.02	0.188
All Control Groups	368	0.235	0.180		2.20	0.05	-1.599	0.488		0.202
Herculaneum, Mo.	50	0.323	0.263	0.00	1.31	0.01	-1.481	0.943	0.14	0.227
Glover, Mo.	23	0.157	0.117	0.01	0.62	0.02	-2.052	0.667	0.01	0.128
Bixby, Mo.	48	0.118	0.073	0.00	0.31	0.01	-2.329	0.672	0.03	0.097
All Lead Smelters	121	0.210	0.181		1.31	0.01	-1.926	0.789		0.146
Monaca, Pa.	63	0.220	0.347	0.00	2.79	0.04	-1.809	0.627	0.00	0.164
Amarillo, Tex.	95	0.116	0.079	0.00	0.43	0.04	-2.352	0.634	0.00	0.095
Bartlesville, Okla.	77	0.502	0.535	0.00	2.68	0.01	-1.114	0.966	0.17	0.328
Corpus Christi, Tex.	13	0.162	0.064	0.05	0.35	0.11	-1.877	0.321	0.34	0.153
Palmerton, Pa.	113	0.373	0.452	0.00	3.79	0.05	-1.292	0.720	0.03	0.275
All Zinc Smelters	361	0.299	0.383		3.79	0.01	-1.645	0.731		0.193
Copperhill, Tenn.										
Hayden, Ariz.										
Anaconda, Mont.										
McGill, Nev.										
Hurley, N. Mex.										
Douglas, Ariz.										
White Pines, Mich.										
San Manuel, Ariz.										
Miami, Ariz.										
Morenci, Ariz.										
Aqua Prieta, Mexico										
Ajo, Ariz.										
All Copper Smelters										
All Groups	850	0.259	0.284		3.79	0.01	-1.665	0.646		0.189
Largest	113	0.502	0.535	0.05			-1.114	0.966	0.34	0.328
Smallest	23	0.116	0.064	0.00			-2.352	0.321	0.00	0.095

TABLE C: Cu in Blood - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log } X}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	92.3	20.7	0.12	133	43.3	4.497	0.245	0.00	89.8
Nogales, Mexico	106	104.0	23.1	0.00	221	49.1	4.621	0.213	0.01	101.6
Safford, Ariz.	92	77.4	20.5	0.22	130	33.3	4.313	0.276	0.38	74.7
Albuquerque, N. Mex.	83	99.1	18.9	0.24	156	25.3	4.575	0.227	0.01	97.0
All Control Groups	367	93.5	20.9		221	25.3	4.504	0.240		90.4
Herculaneum, Mo.										
Glover, Mo.										
Bixby, Mo.										
All Lead Smelters										
Monaca, Pa.										
Amarillo, Tex.										
Bartlesville, Okla.										
Corpus Christi, Tex.										
Palmerton, Pa.										
All Zinc Smelters										
Copperhill, Tenn.	87	97.8	16.5	0.34	156	57.1	4.568	0.170	0.78	96.9
Hayden, Ariz.	101	160.0	77.1	0.00	845	100.0	5.025	0.276	0.02	152.1
Anaconda, Mont.	65	90.0	21.4	0.38	149	26.0	4.466	0.282	0.02	87.0
McGill, Nev.	51	96.6	18.3	0.32	136	44.5	4.550	0.207	0.15	94.7
Hurley, N. Mex.	49	75.1	23.4	0.34	152	30.5	4.272	0.310	0.56	71.7
Douglas, Ariz.	96	94.6	14.2	0.65	132	65.1	4.538	0.153	0.49	93.5
White Pines, Mich.	69	106.2	18.5	0.40	162	42.1	4.649	0.190	0.15	104.4
San Manuel, Ariz.	101	106.4	18.3	0.01	163	57.5	4.653	0.176	0.04	104.9
Miami, Ariz.	99	126.2	28.7	0.17	234	63.4	4.814	0.222	0.55	123.2
Morenci, Ariz.	100	106.1	14.7	0.07	153	73.8	4.655	0.135	0.37	105.1
Aqua Prieta, Mexico	96	95.2	23.2	0.32	158	17.3	4.519	0.299	0.00	91.8
Ajo, Ariz.	106	105.3	16.6	0.59	145	51.5	4.644	0.165	0.13	103.9
All Copper Smelters	1020	107.5	30.5		845	17.3	4.638	0.216		103.4
All Groups	1387	103.8	28.3		845	17.3	4.603	0.223		99.8
Largest	106	160.0	77.1	0.65			5.025	0.310	0.78	152.1
Smallest	49	75.1	14.2	0.00			4.272	0.135	0.00	71.7

TABLE D: Pb in Blood - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	85	16.9	6.9	0.00	47.0	6.69	2.762	0.353	0.28	15.8
Nogales, Mexico	106	15.3	5.8	0.04	44.8	5.63	2.667	0.348	0.65	14.4
Safford, Ariz.	92	15.1	6.8	0.01	36.9	4.70	2.616	0.448	0.32	13.7
Albuquerque, N. Mex.	83	17.7	5.6	0.06	34.0	5.86	2.823	0.323	0.25	16.8
All Control Groups	366	16.2	6.2		47.0	4.70	2.712	0.370		15.0
Herculaneum, Mo.	91	18.8	8.6	0.00	44.0	6.05	2.840	0.426	0.40	17.1
Glover, Mo.	23	12.1	5.6	0.52	26.9	1.79	2.365	0.570	0.12	10.6
Bixby, Mo.	48	13.8	6.7	0.45	28.9	0.83	2.455	0.683	0.66	11.6
All Lead Smelters	162	16.3	7.7		44.0	0.83	2.659	0.531		14.3
Monaca, Pa.	62	14.9	6.4	0.00	36.0	4.46	2.622	0.400	0.17	13.8
Amarillo, Tex.	95	22.7	10.9	0.00	96.1	8.83	3.044	0.374	0.12	21.0
Bartlesville, Okla.	87	29.4	18.7	0.00	83.8	0.11	3.142	0.862	0.01	23.1
Corpus Christi, Tex.	13	19.6	5.1	0.87	27.4	9.90	2.939	0.285	0.86	18.9
Palmerton, Pa.	113	17.9	6.5	0.02	47.3	3.10	2.818	0.377	0.03	16.8
All Zinc Smelters	370	21.4	11.5		96.1	0.11	2.924	0.530		18.6
Copperhill, Tenn.	87	16.5	6.9	0.00	45.7	5.32	2.726	0.397	0.14	15.3
Hayden, Ariz.	101	21.2	8.5	0.00	58.5	6.96	2.991	0.349	0.09	19.9
Anaconda, Mont.	65	13.4	7.5	0.12	40.7	0.41	2.394	0.738	0.00	11.0
McGill, Nev.	51	9.1	3.6	0.05	16.8	0.78	2.111	0.522	0.03	8.3
Hurley, N. Mex.	49	17.1	11.2	0.00	55.7	2.16	2.665	0.600	0.17	14.4
Douglas, Ariz.	96	20.3	8.4	0.15	56.8	7.76	2.933	0.399	0.49	18.8
White Pines, Mich.	69	18.7	6.2	0.00	47.6	9.12	2.881	0.293	0.09	17.8
San Manuel, Ariz.	101	18.0	5.5	0.13	39.1	6.62	2.844	0.316	0.25	17.2
Miami, Ariz.	99	17.3	7.2	0.04	43.4	0.82	2.740	0.541	0.00	15.5
Morenci, Ariz.	100	13.9	5.5	0.01	32.2	4.13	2.556	0.387	0.68	12.9
Aqua Prieta, Mexico	96	19.6	7.0	0.02	53.0	1.43	2.910	0.410	0.01	18.3
Ajo, Ariz.	106	12.5	4.6	0.10	32.1	4.30	2.459	0.368	0.24	11.7
All Copper Smelters	1020	16.8	6.9		58.5	0.41	2.713	0.439		15.1
All Groups	1918	17.5	8.0		96.1	0.11	2.749	0.454		15.6
Largest	113	29.4	18.7	0.87			3.142	0.862	0.86	
Smallest	13	9.1	3.6	0.00			2.111	0.285	0.00	

TABLE E: Zn in Blood - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	373	69	0.41	561	215	5.904	0.189	0.68	366
Nogales, Mexico	106	350	80	0.02	783	179	5.835	0.215	0.18	342
Safford, Ariz.	92	345	83	0.08	632	185	5.816	0.238	0.51	336
Albuquerque, N. Mex.	83	368	68	0.78	513	214	5.891	0.193	0.12	362
All Control Groups	367	358	76		783	179	5.859	0.210		350
Herculaneum, Mo.										
Glover, Mo.										
Bixby, Mo.										
All Lead Smelters										
Monaca, Pa.	63	352	81	0.04	666	121	5.835	0.248	0.00	342
Amarillo, Tex.	95	371	157	0.00	1060	195	5.858	0.313	0.00	350
Bartlesville, Okla.	87	552	109	0.05	818	331	6.294	0.198	0.26	541
Corpus Christi, Tex.	13	295	56	0.44	386	203	5.671	0.192	0.74	290
Palmerton, Pa.	112	363	90	0.00	835	225	5.869	0.215	0.00	354
All Zinc Smelters	370	405	113		1060	121	5.953	0.244		385
Copperhill, Tenn.	87	346	70	0.19	517	64	5.819	0.260	0.00	336
Hayden, Ariz.	101	521	174	0.00	1610	247	6.213	0.277	0.24	499
Anaconda, Mont.	65	368	84	0.16	636	142	5.879	0.244	0.15	358
McGill, Nev.	51	352	84	0.45	522	94	5.830	0.283	0.13	340
Hurley, N. Mex.	49	383	111	0.00	853	230	5.914	0.250	0.00	370
Douglas, Ariz.	96	338	71	0.07	539	193	5.801	0.207	0.27	331
White Pines, Mich.	69	377	60	0.18	551	176	5.918	0.168	0.15	372
San Manuel, Ariz.	101	363	71	0.78	528	196	5.874	0.207	0.13	356
Miami, Ariz.	99	424	243	0.00	2600	192	5.983	0.321	0.03	397
Morenci, Ariz.	100	338	75	0.05	622	99	5.797	0.237	0.06	329
Aqua Prieta, Mexico	96	320	81	0.11	630	70	5.730	0.295	0.00	308
Ajo, Ariz.	106	372	86	0.15	624	150	5.892	0.241	0.15	362
All Copper Smelters	1020	377	116		2600	64	5.890	0.252		362
All Groups	1757	379	108		2600	64	5.897	0.242		364
Largest	112	552	243	0.78			6.294	0.321	0.68	499
Smallest	13	295	56	0.00			5.671	0.168	0.00	290

TABLE F: As in Hair - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	0.094	0.137	0.00	1.080	0.030	-2.661	0.623	0.00	0.070
Nogales, Mexico	66	0.391	0.336	0.00	2.510	0.080	-1.157	0.636	0.75	0.314
Safford, Ariz.	52	0.100	0.040	0.02	0.180	0.040	-2.380	0.409	0.32	0.093
Albuquerque, N. Mex.	23	0.112	0.110	0.00	0.600	0.040	-2.376	0.526	0.06	0.093
All Control Groups	227	0.184	0.202		2.510	0.030	-2.131	0.572		0.119
Herculaneum, Mo.										
Glover, Mo.										
Bixby, Mo.										
All Lead Smelters										
Monaca, Pa.										
Amarillo, Tex.										
Bartlesville, Okla.										
Corpus Christi, Tex.										
Palmerton, Pa.										
All Zinc Smelters										
Copperhill, Tenn.	92	0.138	0.093	0.00	0.490	0.030	-2.185	0.654	0.21	0.112
Hayden, Ariz.	105	2.067	1.488	0.00	7.850	0.040	0.457	0.804	0.08	1.579
Anaconda, Mont.	87	20.148	17.888	0.00	120.000	1.460	2.692	0.808	0.85	14.755
McGill, Nev.	47	0.358	0.296	0.00	1.550	0.050	-1.305	0.758	0.73	0.271
Hurley, N. Mex.	94	0.171	0.103	0.00	0.510	0.030	-1.942	0.614	0.12	0.143
Douglas, Ariz.	94	0.425	0.217	0.02	1.340	0.060	-0.984	0.524	0.27	0.374
White Pines, Mich.	78	0.421	0.823	0.00	5.920	0.040	-1.377	0.846	0.16	0.252
San Manuel, Ariz.	14	0.189	0.124	0.21	0.530	0.080	-1.828	0.574	0.45	0.161
Miami, Ariz.	78	0.470	0.460	0.00	3.240	0.070	-0.981	0.622	0.34	0.375
Morenci, Ariz.	97	0.333	0.318	0.00	2.900	0.060	-1.328	0.650	0.48	0.265
Aqua Prieta, Mexico	73	0.508	0.507	0.00	3.910	0.090	-0.943	0.697	0.46	0.389
Ajo, Ariz.	86	1.900	1.290	0.00	8.020	0.210	0.438	0.656	0.55	1.550
All Copper Smelters	945	2.498	5.446		120.000	0.030	-0.661	0.691		0.516
All Groups	1172	2.050	4.891		120.000	0.030	-0.946	0.669		0.388
Largest	105	20.148	17.888	0.21			-2.692	0.846	0.85	14.755
Smallest	14	0.094	0.040	0.00			-2.661	0.409	0.00	0.070

TABLE G: Cd in Hair - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	1.049	1.166	0.00	7.34	0.14	-0.407	0.936	0.09	0.666
Nogales, Mexico	66	0.880	0.747	0.00	4.19	0.30	-0.366	0.639	0.00	0.694
Safford, Ariz.	52	0.971	1.024	0.00	4.74	0.16	-0.441	0.887	0.06	0.643
Albuquerque, N. Mex.	23	0.487	0.350	0.00	1.20	0.14	-0.952	0.686	0.01	0.386
All Control Groups	227	0.925	0.959		7.34	0.14	-0.458	0.819		0.633
Herculaneum, Mo.	76	4.793	6.119	0.00	45.20	0.04	1.111	0.999	0.06	3.036
Glover, Mo.	30	6.379	5.111	0.12	19.80	0.47	1.480	0.973	0.41	4.392
Bixby, Mo.	20	7.933	6.335	0.15	28.20	0.83	1.785	0.817	0.41	5.960
All Lead Smelters	126	5.669	5.885		45.20	0.04	1.306	0.959		3.690
Monaca, Pa.	65	2.152	2.384	0.00	17.10	0.13	0.380	0.887	0.63	1.462
Amarillo, Tex.	40	3.560	4.838	0.00	24.10	0.31	0.716	1.043	0.66	2.046
Bartlesville, Okla.	79	8.063	9.500	0.00	66.20	0.14	1.605	1.051	0.53	4.977
Corpus Christi, Tex.	38	2.536	2.304	0.00	9.41	0.33	0.593	0.845	0.65	1.809
Palmerton, Pa.	74	7.236	7.884	0.00	44.00	0.37	1.566	0.902	0.37	4.789
All Zinc Smelters	296	5.240	6.651		66.20	0.13	1.076	0.947		2.933
Copperhill, Tenn.	92	2.718	4.129	0.00	36.40	0.11	0.484	1.024	0.05	1.623
Hayden, Ariz.	105	1.811	1.234	0.00	7.63	0.31	0.391	0.646	0.82	1.478
Anaconda, Mont.	87	1.963	1.669	0.00	9.42	0.10	0.360	0.839	0.24	1.434
McGill, Nev.	47	0.860	0.649	0.00	2.95	0.23	-0.410	0.721	0.08	0.663
Hurley, N. Mex.	94	1.475	1.347	0.00	6.91	0.15	0.030	0.879	0.60	1.030
Douglas, Ariz.	94	1.747	1.416	0.00	8.20	0.22	0.270	0.786	0.39	1.310
White Pines, Mich.	78	1.429	1.498	0.00	9.23	0.12	-0.103	0.993	0.08	0.902
San Manuel, Ariz.	14	0.990	0.709	0.01	3.14	0.39	-0.175	0.557	0.36	0.840
Miami, Ariz.	78	1.904	1.367	0.00	6.59	0.23	0.387	0.763	0.06	1.472
Morenci, Ariz.	97	1.937	1.305	0.01	6.52	0.35	0.446	0.673	0.47	1.562
Aqua Prieta, Mexico	73	1.968	1.674	0.00	8.96	0.28	0.356	0.821	0.10	1.427
Ajo, Ariz.	86	2.660	1.984	0.00	9.90	0.56	0.743	0.687	0.77	2.101
All Copper Smelters	945	1.893	1.883		36.40	0.10	0.295	0.803		1.343
All Groups	1594	2.675	3.625		66.20	0.04	0.413	0.846		1.511
Largest	105	8.063	9.500	0.15			1.785	1.051	0.82	5.960
Smallest	14	0.487	0.350	0.00			-0.952	0.557	0.00	0.386

TABLE H: Pb in Hair - Summary Statistics

	N	$\bar{X}$	S(X)	P(X)	HIGH	LOW	$\overline{\text{Log X}}$	S(log X)	P(log X)	GEO. MEAN
Perryville, Mo.	86	12.5	9.7	0.00	52.0	0.43	2.282	0.730	0.08	9.8
Nogales, Mexico	66	15.5	10.2	0.00	50.7	3.12	2.565	0.587	0.58	13.0
Safford, Ariz.	52	11.7	7.1	0.00	33.4	2.05	2.299	0.569	0.11	10.0
Albuquerque, N. Mex.	23	17.5	11.8	0.02	55.8	6.77	2.695	0.557	0.59	14.8
All Control Groups	227	13.7	9.5		55.8	0.43	2.410	0.635		11.1
Herculaneum, Mo.	76	64.0	60.1	0.00	339.0	6.87	3.380	0.820	0.29	46.1
Glover, Mo.	30	42.6	27.0	0.30	111.0	5.42	3.534	0.716	0.11	34.3
Bixby, Mo.	20	169.5	130.4	0.24	569.0	15.90	4.814	0.898	0.08	123.2
All Lead Smelters	126	75.6	70.2		569.0	5.42	3.916	0.803		50.2
Monaca, Pa.	65	19.3	17.7	0.00	102.0	0.70	2.629	0.878	0.02	13.9
Amarillo, Tex.	40	38.4	21.5	0.10	92.8	7.30	3.481	0.612	0.29	32.5
Bartlesville, Okla.	78	57.2	73.6	0.00	494.0	2.20	3.628	0.901	0.35	37.7
Corpus Christi, Tex.	38	45.4	22.9	0.24	91.0	8.13	3.681	0.580	0.15	39.7
Palmerton, Pa.	74	44.4	36.8	0.00	222.0	6.72	3.566	0.653	0.04	35.4
All Zinc Smelters	295	41.6	44.2		494.0	0.70	3.379	0.760		29.3
Copperhill, Tenn.	92	22.9	14.2	0.01	70.0	2.38	2.932	0.661	0.16	18.8
Hayden, Ariz.	105	26.4	15.5	0.00	74.4	3.33	3.104	0.611	0.29	22.3
Anaconda, Mont.	87	25.4	14.9	0.01	67.2	3.29	3.028	0.700	0.02	20.7
McGill, Nev.	47	14.4	9.2	0.03	47.3	0.77	2.451	0.744	0.06	11.6
Hurley, N. Mex.	94	20.4	17.4	0.00	106.0	3.43	2.759	0.708	0.56	15.8
Douglas, Ariz.	94	26.0	18.0	0.00	87.4	2.59	3.019	0.738	0.20	20.5
White Pines, Mich.	78	13.2	10.0	0.01	45.2	0.73	2.264	0.864	0.12	9.6
San Manuel, Ariz.	14	15.2	9.3	0.30	29.4	3.90	2.505	0.722	0.44	12.2
Miami, Ariz.	78	31.7	18.6	0.01	116.0	6.31	3.306	0.554	0.67	27.3
Morenci, Ariz.	97	17.6	11.9	0.00	80.5	3.56	2.695	0.582	0.42	14.8
Aqua Prieta, Mexico	73	23.1	16.1	0.00	92.2	5.09	2.932	0.648	0.64	18.8
Ajo, Ariz.	86	18.9	13.5	0.00	58.8	3.87	2.689	0.719	0.33	14.7
All Copper Smelters	945	22.1	14.8		116.0	0.73	2.850	0.681		17.3
All Groups	1593	28.7	29.8		569.0	0.43	2.970	0.700		19.5
Largest	105	169.5	130.4	0.30			4.812	0.901	0.67	123.2
Smallest	14	11.7	7.1	0.00			2.264	0.554	0.02	9.6