MEMORANDUM

on the report titled:

RELATIVE BIOAVAILABILITY OF ARSENIC

IN MINING WASTES

PALMERTON OPERABLE UNIT (OU) 3

Prepared By:

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for:

The Palmerton Citizens For A Clean Environment

In Response to Task Schedule #24

MEMORANDUM

BACKGROUND

The following memorandum has been prepared at the request of the PCCE Board in response to Task Schedule #24. PCCE Task Schedule #24 requests a review of the report titled: Relative Bioavailability of Arsenic in Mining Wastes, which was referenced at Section 3.4.4, page 3-27 and elsewhere in the Draft Final Risk Assessment Report for Palmerton Zinc Pile Superfund Site, Operable Unit (OU) #3, Borough of Palmerton, Pennsylvania. Because he was involved in all aspects of our review of the OU#3 Risk Assessment document, and to assure the most comprehensive and competent scientific review of the subject document, Environmental Toxicologist Dr. Dale Bruns, Ph.D. was asked to briefly review and comment on the Arsenic Bioavailability report. His comments have been incorporated into this review memorandum, but I retain complete responsibility for the final content.

PCCE Task Schedule #24 specifically requested a reply to the following two (2) questions:

1. What is the relevance of the aforementioned study to the risk assessment?

2. What does this study tell us about Palmerton soil?

REVIEW

The document titled: Relative Bioavailability of Arsenic in Mining Wastes, is a report on the same research project reviewed previously, titled: Bioavailability of Lead in Soil Samples from the New Jersey Zinc NPL Site, Palmerton, Pennsylvania, except that the Lead Bioavailability report does not address arsenic bioavailability, and vice versa, the Arsenic Bioavailability report does not provide much detail about the Lead Bioavailability study. Consequently, many of the same general concerns expressed in our review of the Lead Bioavailability study, (e.g. the low sample number of n=2 for Palmerton soils, the potential for large variability among and between soil samples collected from Palmerton, and the suitability of pigs as comparison animals for humans, etc.) still apply. Similarly the same concerns expressed in our review of the Lead Bioavailability report (high data variability, and the questionable methodology for calculating Relative Bioavailability from Absolute Bioavailability) also still apply.

It seems significant that the study design was primarily oriented toward evaluating lead bioavailability, and that arsenic bioavailability was either an after thought or a secondary consideration. Consequently, urine arsenic measurements, expressed as the Urinary Excretion Fraction (UEF), were only collected on a daily basis for two samples: one, during Pilot Study 1 which involved slag collected from the AV Smelter located near Leadville Colorado, and the other, during Pilot Study 2 which involved mine tailings or "slickens" collected from the banks of the Clarks Fork River near Dear Lodge, Montana. For pigs that were fed Palmerton soil, urine arsenic measurements were only taken twice over a fifteen (15) day period, on day 7 and on day 14.

Another interesting and potentially significant feature of the study design is the variability in sample concentration, intake and dose. The two Palmerton samples will be used as an example. Location 2 soil had an arsenic concentration of 110 ppm and location 4 soil had an arsenic concentration of 134 ppm. The arsenic concentrations for both soils from Palmerton are similar, though not representative of Palmerton soils in general. However, pigs fed with location 2 soil were given an arsenic dose of 7.7 ug/kg-day, which required an intake of 131.6 ug/day on day 7 and 160.1 ug/day on day 14; while pigs fed with location 4 soils were given an arsenic dose of 14.0 ug/kg-day, requiring an intake of 248 ug/day on day 7 and 291.7 ug/day on day 14. The intake for pigs fed with location 4 soils was almost twice the mass per day as the intake for pigs fed with location 2 soils. Relative Bioavailability (RBA) values for Palmerton location 2 were calculated (or estimated) at about approximately 39%, while RBA values for location 4 are reported as approximately 52%. An important question than needs to be addressed, is: How much of the 13 % difference in Relative Bioavailability values between location 2 and location 4 samples is due to chemical and physical differences, how much is due to natural variability between pigs, and how much is due to differences in sample concentration, intake and dose? The narrative of the report states: "One of the most interesting and important objectives of this project was to obtain preliminary information on which chemical forms of arsenic tend to have high bioavailability and which tend to have low bioavailability". However, geochemical speciation data was only reported for 5 of the 8 sites included in this study, and Palmerton data was not provided.

Among and between sites, the arsenic dose ranged from a low of 1.0 ug/kg-day (residential soils in Aspen) to 65.4 ug/kg-day (soil from the Murray Smelter); and soil concentrations ranged from a low of 17 ppm (again Aspen residential soil) to a high of 1290 ppm (Oregon Gulch in Leadville Colorado). Since dose was found to correspond with absolute and thus relative bioavailability in the lead bioavailability study, dose and/or soil concentration could also be an potentially important factors for arsenic bioavailability. These issues should be addressed before the arsenic bioavailability study is applied to the Palmerton OU-3 risk assessment.

In spite of the low number of samples from individual sites (Palmerton n=2), and an apparently large number of factors which can contribute to data variability (and possibly Relative Bioavailability), the study authors chose to control variability (rather than account for it) through the use of regression analysis and by excluding outliers. Arsenic Relative Bioavailability (RBA) calculated for all 14 samples collected from all 8 sites ranged from a high of 98% to a low of -0.08%! Predictably, the two highest RBA values calculated (from Aspen, Colorado) were determined to be highly uncertain because of the low doses involved (67 ppm and 17 ppm yielding RBA's of 62% and 98% respectively), but the negative RBA value (-0.08) calculated for residential soil in Leadville, Colorado (203 ppm dose) was not even questioned (refer to Table 3-1 in Appendix A). The negative RBA value is a statistical artifact (due to the negative slope of the regression line), but in the context of the UEF equation (refer to Figure 1-1 in Appendix A), a negative value makes no sense. In fact the adjusted R^2 values ("the coefficient of determination" which is a measure of the proportion of the variance that is accounted for) for both the excluded Aspen data as well as the negative RBA value (-0.08) calculated for residential soil in Leadville, Colorado, are all zero (0). The justification for excluding only the higher Aspen RBA values, and not the lower RBA value from Leadville, is not addressed.

The exclusion of outliers, while possibly justified on statistical grounds, appears to have biased the data toward lower urine arsenic excretion values. For example, the one outlier excluded from the Palmerton sample 2 data set (day 14 measurement) resulted from a urine volume of 4340 mL, with a corresponding Arsenic excretion value of 39.1 ug/day. Non-excluded day 14 values from location 2 pigs were 1480, 1260, 1280, and 2800 ug/day for urine volume, with corresponding arsenic excretion values of 17.8, 11.2, 24.3, and 22.4 ug/day. The urine volume and arsenic excretion values for the excluded data set were both inordinately high (2.5 times more urine volume than the mean of the other values, and more than 2 times the arsenic excretion value than the mean of the other values). Intuitively it would seem that an inordinately high urine volume corresponding to a similarly high arsenic excretion value does not indicate a problem with the reliability of that data set. In fact, after reviewing the urine volume from each pig for day 7 and day 14 measurements, it becomes apparent that the same pig was responsible for strikingly high urine volumes both times measurements were taken. However, because the smaller day 7 pigs received a smaller dose and excreted less urine, and because of a statistical bias toward a lower predicted 95% confidence interval, data from the pig considered an outlier on day 14, was found to be acceptable on day 7.

A similar pattern can be observed when data sets from the Palmerton location 4 pigs are reviewed, except that location 4 data includes both inordinately high and inordinately low values. The excluded outlier value from location 4 was for a urine volume of 13560 mL measured on day 14. This pig provided approximately 3 times more urine than the mean of all location 4 values measured on day 14. The same pig also provided the highest volume of urine on day 7, 3840 mL, which is approximately 2.5 times more than the mean of all location 4 values on that day. Again, only data from the day 14 measurement were excluded. Predictably, the same pig that produced the lowest volume of urine on day 7 (480 mL) also produced the lowest volume of urine on day 14 (400 mL). In both instances the location 2 and location 4 outliers were produced by pigs that consistently (for both day 7 and day 14 measurements) produced higher volumes of urine, and so also excreted a greater mass of arsenic per day. The urine concentrations for Palmerton location 1 and location 2 outliers are within the range observed for useable data values indicating that the data is probably reliable. The Urinary Excretion Factor is calculated using the mass of arsenic excreted per day, which correlates well with the volume of urine excreted. Again the justification for excluding these data sets as outliers is not addressed. It is not a commonly accepted practice to exclude outliers from non-normal distributions. If the data were log transformed to generate a normal distribution, it is likely that the inordinately high data values would fall within the predicted 95% confidence interval, and not be considered outliers. This would result in a higher Urinary Excretion Factor, and higher bioavailability factors.

The results section reports that RBA estimates for all sites ranged from a high of nearly 100% to a low of near 0%. Excluding data from the two Aspen samples, arsenic RBA estimates range from a high of about 50% to a low near 0% (actually Table 3-1 indicates that two "reliable" samples resulted in RBA values slightly greater than 50%, one of these samples is from Palmerton). Consequently it can be concluded that the results of this study express a high degree of variability. Because of the low sample number, and the apparent inability of the study to account for variability in a large number of potentially confounding factors, it can also be concluded that there is a high degree of uncertainty associated with these results. As stated previously, an attempt was made to try to correlate arsenic geochemical speciation with RBA values, but because of the low number of observations, none of the resulting coefficients were statistically significant. Of greater relevance is the fact that no arsenic geochemical speciation was reported for Palmerton samples, making any correlation with RBA values impossible. Consequently, it would be appropriately conservative to maintain use of the standard (non-adjusted) default values of 80% to 100% for the Palmerton OU-3 risk assessment.

DISCUSSION AND COMMENT

As stated earlier, PCCE Task Schedule #24 specifically requested a reply to the following two (2) questions:

1. What is the relevance of the aforementioned study to the risk assessment?

The bioavailability of arsenic is still a concern as indicated in our earlier reviews of the OU-3 Risk Assessment report. Recall that about 28 percent of homes (30 out of 167), suggest hazard indices of 1 or greater (5-8 Palmerton OU-3 Risk Assessment). Also, the risk assessment report stated that a possible remediation goal for arsenic in soil might lie in the range of 40 to 50 mg/kg (the range where hazard quotients begin to exceed the target hazard index of 1). The Location 2 and Location 4 samples collected and used in the Palmerton lead and arsenic bioavailability studies had arsenic concentrations of 110 ppm and 134 ppm respectively (recall that for general discussion purposes mg/kg and ppm are equivalent). As stated in the subject Arsenic Bioavailability report, the standard default relative bioavailability (RBA) values may range from 80% to 100% in the absence of reliable site specific data. The Palmerton OU-3 risk assessment assumed an RBA value of 70% based on results of the Arsenic Bioavailability document which is the subject of this memorandum. Because of a number of issues discussed on the previous pages, and below, the use of a 70% RBA value in the Palmerton OU-3 Risk Assessment may actually underestimate risk. It is recommended that the standard default RBA value (80% to 100%) be used as a basis of comparison and analysis to those arsenic risk estimates reported in Figure 5-3 of the OU-3 risk assessment document.

The subject Arsenic Bioavailability document should not reduce the perception of risk from exposure to arsenic in Palmerton since the Palmerton OU-3 Risk Assessment report, reviewed recently, used an RBA value of 70% instead of the more appropriately conservative standard default values which range from 80% to 100%. However, the subject Arsenic Bioavailability report seems to emphasize low arsenic RBA values by excluding the two highest values as being too uncertain. Overall, Appendix B indicates that regression data for many of the soil samples had a very low (poor) statistical fit to the data, even after the exclusion of outlier data points in a number of cases. Furthermore, as with the Lead Bioavailability study, it appears the method used to calculate arsenic RBA's (based on "average" regression values across a wide range of exposures) results in lower RBA values than if RBA's were calculated from the raw data.

Also, there is a very serious "overall" flaw to the study design since the investigators had very low recovery rates of arsenic from urine, fecal excretion and body tissues (less than 25%). The impact of this problem on the estimated RBAs is only briefly mentioned at the end of the Discussion section. At the bottom of page 31, it is stated that RBA values calculated in this study are "expected to be correct" if the "error" leading to the low recovery "is systemic and applies equally in all cases." It is also stated on page 31 that "Because the basis for the low recovery is not clear, interpreting the significance is also not clear." In short, there is no evidence, one way or the other, in this study as to whether the RBA values presented are correct or incorrect.

On the basis of the preceding comments, it is recommended that a default RBA value (80% - 100% RBA) be used for arsenic in the Palmerton OU-3 risk assessment.

2. What does this study tell us about Palmerton soil?

The Arsenic Bioavailability study report does not tell us anything about Palmerton soil that wasn't already addressed in the recently reviewed risk assessment. As stated previously, no geochemical speciation data was provided for Palmerton in the subject "arsenic bioavailability" document. Consequently it is not possible to estimate arsenic RBA values in Palmerton because of it's geochemical characteristics. Furthermore, no additional information was provided relative to arsenic risks from exposure to Palmerton soil, except that possibly the adjusted RBA value applied (70%) is lower than the more appropriate standard default RBA range of 80% to 100%.

APPENDIX A