RELATIVE BIOAVAILABILITY OF ARSENIC IN SOIL AFFECTED BY CCA-TREATED WOOD

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EXECUTIVE SUMMARY

A study using juvenile swine as test animals was performed to measure the gastrointestinal absorption of arsenic from soil affected by chromated copper arsenate (CCA)-treated wood (utility poles). The relative bioavailability of arsenic was assessed by comparing the absorption of arsenic from the test material (utility pole soil) to that of a reference material (sodium arsenate). The study was performed as nearly as possible within the spirit and guidelines of Good Laboratory Practices and followed a protocol that was submitted to and reviewed by USEPA.

The arsenic concentration in the utility pole soil was 320 µg/g. Groups of five swine were given oral doses of sodium arsenate or utility pole soil twice a day for 15 days. The amount of arsenic absorbed by each animal was evaluated by measuring the amount of arsenic excreted in the urine (as measured on days 8 to 9 and 10 to 11). The urinary excretion fraction (UEF) (the ratio of the amount excreted per 48 hours divided by the dose given per 48 hours) was calculated for sodium arsenate and the utility pole soil using linear regression analysis. The relative bioavailability (RBA) of arsenic in the test material compared to that in sodium arsenate was calculated as:

$$RBA = \frac{UEF(test\ material)}{UEF(sodium\ arsenate)}$$

The results are summarized below:

Material Administered	UEF ± SEM (N)	RBA (90% CI)
Sodium Arsenate (reference material)	0.680 ± 0.048 (30)	[1.00]
Utility Pole Soil (test material)	0.331 ± 0.025 (30)	0.49 (0.41-0.58)

SEM = Standard error of the mean (standard deviation)
N = Number of data points used in curve fitting
CI = Confidence interval

Using sodium arsenate as a relative frame of reference, the RBA estimate for the test material is 49% (90th % CI = 41% - 58%). This value is significantly lower than the default value of 80%-100% that is usually employed when reliable site-specific data are lacking. This indicates that the arsenic in this utility pole soil is not as well absorbed as soluble arsenic. Use of these data is likely to improve the accuracy of risk estimates for humans who may incidentally ingest soil affected by CCA-treated wood.

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ABBREVIATIONS

ABA	Absolute bioavailability
AF_o	Oral absorption fraction
As+3	Trivalent inorganic arsenic
As+5	Pentavalent inorganic arsenic
CCA	Chromated copper arsenate
CI	Confidence interval
DMA	Dimethyl arsenic
$Dose_{adj}$	Adjusted dose based on site-specific data
g	Gram
GLP	Good Laboratory Practices
ICP-AES	Inductively coupled plasma atomic emission spectroscopy
IRIS	USEPA's Integrated Risk Information System
kg	Kilogram
K_u	Fraction of absorbed arsenic which is excreted in urine
L	Liter
mL	Milliliter
MMA	Monomethyl arsenic
N	Number of data points
NaAs	Sodium Arsenate
PDF	Probability density function
PE	Performance Evaluation
PIC	Pig Improvement Corporation
QA	Quality assurance
RBA	Relative bioavailability
RBA(test vs. NaAs)	RBA of the test material compared to sodium arsenate)
RBA(test vs. ref)	RBA of the test material compared to the reference material
RFD_{adj}	Adjusted reference dose (RfD) value for non-cancer risk based on site-specific data
RFD_{IRIS}	Default reference dose (RfD) value for non-cancer risk from IRIS
RPD	Relative percent difference
SEM	Standard error of the mean (standard deviation)
SEM	Standard error of the mean (standard deviation)
SF_{adj}	Adjusted slope factor (SF) value for cancer risk based on site-specific data
SF_{IRIS}	Default slope factor (SF) value for cancer risk from IRIS
UEF	Urinary excretion fraction
UEF(NaAs)	UEF of sodium arsenate
UEF(ref)	UEF of the reference material
UEF(test)	UEF of the test material
USEPA	United States Environmental Protection Agency
wt	Weight
µg	Microgram
µm	Micrometer

RELATIVE BIOAVAILABILITY OF ARSENIC IN SOIL AFFECTED BY CCA-TREATED WOOD

1.0 INTRODUCTION

Accurate assessment of the health risks resulting from oral exposure to arsenic requires knowledge of the amount of arsenic absorbed from the gastrointestinal tract into the body. This information on absorption may be described either in absolute or relative terms:

> Absolute Bioavailability (ABA) is the ratio of the amount of arsenic absorbed to the amount ingested:
>
> $$ABA = \frac{Absorbed\ Dose}{Ingested\ Dose}$$
>
> This ratio is also referred to as the oral absorption fraction (AF_o).
>
> Relative Bioavailability (RBA) is the ratio of the absolute bioavailability of arsenic present in some test material to the absolute bioavailability of arsenic in some appropriate reference material:
>
> $$RBA = \frac{ABA\ (test\ material)}{ABA\ (reference\ material)}$$
>
> Usually the form of arsenic used as the reference material is an arsenic compound dissolved in water or some readily soluble form (e.g., sodium arsenate) that is expected to completely dissolve when ingested.

For example, if 100 µg of arsenic dissolved in drinking water were ingested and a total of 90 µg were absorbed into the body, the ABA would be 0.90 (90%). Likewise, if 100 µg of arsenic contained in soil were ingested and 30 µg were absorbed into the body, the ABA for soil would be 0.30 (30%). If the arsenic dissolved in water was used as the frame of reference for describing the relative amount of arsenic absorbed from soil, the RBA would be 0.30/0.90, or 0.33 (33%).

Using Relative Bioavailability Data to Improve Risk Calculations for Arsenic

When reliable data are available on the relative bioavailability of arsenic in a site medium (e.g., soil), this information can be used to adjust the default toxicity values (RfD_{IRIS}, SF_{IRIS}) for arsenic to account for differences in absorption between arsenic ingested in water (RBA) and arsenic ingested in site media, as follows:

$$RfD_{adj} = \frac{RfD_{IRIS}}{RBA}$$

$$SF_{adj} = SF_{IRIS} \cdot RBA$$

Alternatively, it is also acceptable to adjust the dose (rather than the toxicity factors) as follows:

$$Dose_{adj} = Dose_{default} \cdot RBA$$

This dose adjustment is mathematically equivalent to adjusting the toxicity factors as described above.

Purpose of This Study

The objective of this study, sponsored by the American Chemistry Council, was to use juvenile swine as a test system in order to determine the oral bioavailability of arsenic in soil affected by arsenic complexes from chromated copper arsenate (CCA)-treated wood relative to the bioavailability of a soluble form of arsenic. The relative bioavailability estimates may be used to improve accuracy and decrease uncertainty in estimating exposures to arsenic in soil in human health risk assessments for media impacted by CCA-treated wood.

2.0 STUDY DESIGN

This investigation of arsenic relative bioavailability was performed according to the basic design presented in Table 2-1. As shown, the study investigated arsenic absorption from sodium arsenate (the reference material) and from utility pole soil (the test material), each administered to groups of five animals at two different dose levels for 15 days (a detailed schedule is presented in Appendix A, Table A-1). Additionally, the study included a non-treated group to serve as a control for determining background arsenic levels. All doses were administered orally.

This study was performed as nearly as possible within the spirit and guidelines of Good Laboratory Practices (GLP: 40 CFR 792). The study followed a protocol that was submitted to and reviewed by the United States Environmental Protection Agency (USEPA). USEPA provided comments on the draft protocol and the protocol was revised to reflect USEPA comments and concerns.

2.1 Test Material

2.1.1 Sample Description

Field personnel at Arch Wood Protection, Inc., (Arch) collected utility pole soil samples from a test plot located in Conley, Georgia. These poles were installed at the test plot in 1988. The utility poles, via mobilization of releasable CCA complex from the pole to adjacent soils, are the source of the arsenic in these soil samples. The utility poles in Arch's test plot were treated in accordance with American Wood Preservers' Association (AWPA) standards for commercial, ground contact use (i.e., CCA retention is 0.6 pounds per ft^3).

2.1.2 Sample Preparation

Prior to test substance analysis and characterization, the soil sample was sieved using an ASTM No. 60 sieve (60 openings per square inch of surface area). Only materials that passed through the sieve (corresponding to particles smaller than about 250 µm) were used in the bioavailability study. The study is limited to this fine-grained soil fraction because it is believed that soil particles less than about 250 µm are most likely to adhere to the hands and be ingested by hand-to-mouth contact, especially in young children. The sieved soil fraction was then thoroughly mixed by placing a bottle containing the soil on a roller operating at low speed for about 20 to 30 minutes, followed by inverting the bottle five times.

2.1.3 Arsenic Concentration

The concentration of arsenic in the sieved and mixed utility pole soil was measured in duplicate by inductively coupled plasma atomic emission spectroscopy (ICP-AES) by L. E. T., Inc., (Columbia, Missouri). The resulting value was 320 µg/g.

2.2 Experimental Animals

Juvenile swine were selected for use in this study because they are considered to be a good physiological model for gastrointestinal absorption in children (Weis and LaVelle, 1991). The swine model has been used previously by USEPA to evaluate the bioavailability of arsenic in soil.

The animals were intact males of the Pig Improvement Corporation (PIC) genetically defined Line 26, and were purchased from Chinn Farms, Clarence, Missouri. The number of animals purchased for the study was five more than required by the protocol (25 total). These animals were purchased at an age of about 4-5 weeks (weaning occurs at age 3 weeks) and housed in individual stainless steel cages. The animals were then held under quarantine for one week to observe their health before beginning exposure to study materials. Each animal was examined by a certified veterinary clinician (swine specialist); no animals appeared to be in poor health during this quarantine period. To minimize weight variations between animals and groups, the five extra animals most different in body weight (either heavier or lighter) four days prior to exposure (day -4) were excluded from the study.

The remaining animals were assigned to dose groups at random (group assignments are presented in Appendix A, Table A-2). When exposure began (day zero), the animals were about 5-6 weeks old and weighed an average of about 10.2 kg. The animals were weighed every three days during the course of the study. On average, animals gained about 0.37 kg/day and the rate of weight gain was comparable in all groups, ranging from 0.36 to 0.40 kg/day. These body weight data are summarized in Figure 2-1 and are presented in detail in Appendix A, Table A-3. The study followed an approved animal care protocol and all animals were examined daily by an attending veterinarian while on study.

2.3 Diet

Animals were weaned onto standard pig chow (purchased from MFA Inc., Columbia, Missouri) by the supplier. In order to minimize arsenic exposure from the diet, the animals were gradually transitioned from the MFA feed to a special feed (Zeigler Brothers, Inc., Gardners, Pennsylvania) over the time interval from day -7 to day -3, and this feed was then maintained for the duration of the study. The feed was nutritionally complete and met all requirements of the National Institutes of Health–National Research Council. The typical nutritional components and chemical analysis of the feed is presented in Table 2-2. Each day every animal was given an amount of feed equal to 4% of the mean body weight of all animals on study. Feed amounts were adjusted every three days, when pigs were weighed. Feed was administered in two equal portions of 2% of the mean body weight at 11:00 AM and 5:00 PM daily. Analysis of a single feed sample from this study indicated that the arsenic level was less than the detection limit of 0.05 ug/g (corresponding to a dose contribution from food of less than 2.5 μg/kg-day). Previous analysis of feed samples indicated that the arsenic level was consistently below 0.1 ug/g.

Drinking water was provided *ad libitum* via self-activated watering nozzles within each cage. Analysis of samples from randomly selected drinking water nozzles (N=3) indicated that the arsenic concentration was consistently less than the quantitation limit (about 1 μg/L). Assuming water intake of about 0.1 L/kg-day, this corresponds to a dose contribution from water of less than 0.1 µg/kg-day.

2.4 Dosing

Animals were exposed to sodium arsenate (abbreviated in this report as "NaAs") or the test material (utility pole soil) for 15 days, with the dose for each day being administered in two equal portions beginning at 9:00 AM and 3:00 PM (two hours before feeding), with two minute intervals allowed for individual pig dosing. Dose material was placed in the center of a small portion (about 5 grams) of moistened feed (this is referred to as a “doughball”), and this was administered to the animals by hand. If uneaten portions of doughballs were discovered, these were retrieved and offered again for consumption. All uneaten portions of doughballs were consumed before the next dosing period, so no dose adjustments were necessary.

The dose levels administered were based on the arsenic content of the test material. The mass of test material needed to provide the appropriate doses of arsenic was calculated based on a preliminary estimation of the arsenic concentration in the test material (417 µg/g). The actual administered arsenic doses were calculated after the study was completed using the 320 µg/g soil arsenic result which was independently determined after the sample had been homogenized in the manner called for in the protocol (see sections 2.1.2 and 2.1.3). Use of the lower soil arsenic result leads to a higher estimate of the RBA and is therefore conservative. These actual administered doses are presented in Appendix A Table A-3 and were used for all RBA calculations.

2.5 Collection and Preservation of Urine Samples

Samples of urine were collected from each animal for 48-hour periods on days -2 to -1, 6 to 7, 8 to 9, and 10 to 11 of the study. Collection began at 9:00 AM and ended 48 hours later. The urine was collected in a stainless steel pan placed beneath each cage, which drained into a plastic storage bottle. Due to the length of the collection period, collection containers were checked throughout the day (e.g., at feeding, dosing, and in the evening) and emptied periodically into a separate holding container to ensure that there was no loss of sample due to overflow. Collection containers typically were emptied twice a day.

At the end of each collection period, the total urine volume for each animal was measured (see Appendix A, Table A-4) and three 60-mL portions were removed and acidified with 0.6 mL concentrated nitric acid. All samples were refrigerated until analyzed for total arsenic. Urine volume measurements for days 6 to 7 were lost, so those urine samples were excluded from all analyses. For all other urine collections, two of the aliquots were archived in the refrigerator and one aliquot was sent for arsenic analysis.

2.6 Arsenic Analysis

Urine samples were assigned random chain-of-custody tag numbers and submitted to the analytical laboratory for analysis in a blind fashion. Details of urine sample preparation and analysis are provided in USEPA (1999). In brief, 25 mL samples of urine were digested by refluxing and then heating to dryness in the presence of magnesium nitrate and concentrated nitric acid. Following magnesium nitrate digestion, samples were transferred to a muffle furnace and ashed at 500°C. The digested and ashed residue was dissolved in hydrochloric acid and analyzed by the hydride generation technique using a Perkin-Elmer 3100 atomic absorption spectrometer. Preliminary tests of this method established that each of the different forms of arsenic that may occur in urine, including trivalent inorganic arsenic (As+3), pentavalent inorganic arsenic (As+5), monomethyl arsenic (MMA) and dimethyl arsenic (DMA), are all recovered with high efficiency. Urine analytical results are presented in Appendix A, Table A-5.

2.6.1 Laboratory Quality Assurance

A number of quality assurance (QA) steps were taken during this project to evaluate the accuracy of the analytical procedures. Steps performed by the analytical laboratory included:

Spike Recovery

Randomly selected urine samples were spiked with known amounts of arsenic (usually 200 µg, as sodium arsenate) and the recovery of the added arsenic was measured. Recovery for individual samples ranged from 82.7% to 120.0%, with an average across all analyses of 95.9 ± 10.8% (N=10).

Duplicate Analysis

The laboratory analyst selected random urine samples for duplicate analysis. Duplicate results had a relative percent difference (RPD) of 0% to 2.4%, with an average of 0.9% ± 1.3% (N=5).

Laboratory Control Standards

Five different types of laboratory control standards were tested periodically during the analysis. These are samples for which a certified concentration of arsenic has been established. Results for these standards are summarized below:

Laboratory Control Standards	Certified Value	Average Recovery	Standard Deviation	N
E.R.A. P081 - Metals WasteWatR	366 ng/mL (acceptable range: 305-430)	98%	2.1%	29
N.R.C.C. Dolt-2 Dogfish Liver	16.6 +/- 1.1 µg/g dry wt	84%	0.0%	2
N.R.C.C. Tort-2 Lobster	21.6 +/- 1.8 µg/g dry wt	90%	3.3%	2
N.I.S.T. Oyster 1566b	7.65 +/- 0.65 µg/g dry wt	96%	4.6%	2
N.I.S.T. 1640	0.0267 +/- 0.0004 µg/g	101%	--	1

As seen, recovery of arsenic from these standards was generally good.

Blanks

Five of the six blank samples run along with each batch of samples were below the limit of detection for arsenic (1.25 µg/L, rounded to 1). The sixth blank sample yielded 1.60 µg/L arsenic (rounded to 2), which is very near the detection limit and is not considered significant.

2.6.2 Blind Quality Assurance Samples

In addition to these laboratory-sponsored QA samples, an additional series of QA samples were submitted to the laboratory in a blind fashion. This included a number of Performance Evaluation (PE) samples (control urine spiked with a known amount of arsenic in the form of As+3, As+5, MMA, or DMA) and blind duplicates.

The results for the PE samples are shown in Figure 2-2. As seen, all sample results were close to the expected values except for a single DMA sample. That sample (indicated in Figure 2-2 as an outlier) was expected to be about 200 ng/mL, but only yielded 2 ng/mL (which is approximately equal to the background concentration in unspiked control urine). The cause of this is not certain, but it is suspected that the laboratory technician inadvertently did not add the PE spike to that sample.

The results for blind duplicates are shown in Figure 2-3. As seen, the data tend to cluster around the line of identity, indicating that the duplicate pairs are generally in good agreement.

Based on the results of all of the quality assurance samples and steps described above, it is concluded that the analytical results for urine samples are of high quality and are suitable for derivation of reliable estimates of arsenic absorption from test materials.

3.0 DATA ANALYSIS

Figure 3-1 shows a conceptual model for the toxicokinetic fate of ingested arsenic. Key points of this model are as follows:

- In most animals (including humans), absorbed arsenic is excreted mainly in the urine over the course of several days. Thus, the urinary excretion fraction (UEF), defined as the amount excreted in the urine divided by the amount given, is usually a reasonable approximation of the oral absorption fraction or ABA. However, this ratio will underestimate total absorption, because some absorbed arsenic is excreted in the feces via the bile, and some absorbed arsenic enters tissue compartments (e.g., skin, hair) from which it is cleared very slowly or not at all. Thus, the urinary excretion fraction should not be equated with the absolute absorption fraction.

- The relative bioavailability (RBA) of two orally administered materials (i.e., a test material and reference material) can be calculated from the ratio of the urinary excretion fraction of the two materials. This calculation is independent of the extent of tissue binding and of biliary excretion:

$$RBA(test\ vs\ ref) = \frac{AF_o(test)}{AF_o(ref)} = \frac{AF_o(test) \cdot K_u}{AF_o(ref) \cdot K_u} = \frac{UEF(test)}{UEF(ref)}$$

where K_u represents the fraction of absorbed arsenic that is excreted in the urine.

Based on the conceptual model above, raw data from this study were reduced and analyzed as follows:

- The amount of arsenic excreted in urine by each animal over each collection period was calculated by multiplying the urine volume by the urine concentration:

  Excreted (µg/48 hours) = Concentration (µg/L) · Volume (L/48hours)

- For each test material, the amount of arsenic excreted by each animal was plotted as a function of the amount administered (µg/48 hours), and the best fit straight line (calculated by linear regression) through the data (µg excreted per µg administered) was used as the best estimate of the UEF.

- The relative bioavailability of arsenic in a test material was calculated as:

  RBA = UEF(test) / UEF(NaAs)

  where sodium arsenate (NaAs) is used as the frame of reference.

- As noted above, each RBA value is calculated as the ratio of two slopes (UEFs), each of which is estimated by linear regression through a set of data points. Because of the variability in the data, there is uncertainty in the estimated slope (UEF) for each material. This uncertainty in the slope is described by the standard error of the mean (SEM) for the slope parameter. Given the best estimate and the SEM for each slope, the uncertainty in the ratio may be calculated using Monte Carlo simulation. The probability density function (PDF) describing the confidence around each slope term (UEF) was assumed to be characterized by a t-distribution with n-2 degrees of freedom :

$$\frac{UEF(measured) - UEF(true)}{SEM} \sim t_{n-2}$$

For convenience, this PDF is abbreviated T(slope, sem, n), where slope = best estimate of the slope derived by linear regression, sem = standard deviation in the best estimate of the slope, and n = number of data points upon which the regression analysis was performed. Thus, the confidence distribution around each ratio was simulated as:

$$PDF(RBA) = \frac{T(slope, sem, n)_{test}}{T(slope, sem, n)_{ref}}$$

Using this equation, a Monte Carlo simulation was run for the RBA calculation. The 5^{th} and 95^{th} percentile values from the simulated distribution of RBA values were then taken to be the 90% confidence interval (CI) for the RBA.

4.0 RESULTS

4.1 Clinical Signs

The doses of arsenic administered in this study are below a level that is expected to cause toxicological responses in swine, and no clinical signs of arsenic-induced toxicity were noted in any of the animals used in the study. The animals remained healthy throughout the study, except for a few cases of transient diarrhea, which is normal in juvenile pigs. The gross findings of the autopsies were negligible.

4.2 Data Exclusions

Occasionally, the dilution of urine by spilled water was is so large that the concentration of arsenic in the urine cannot be quantified. These instances are defined by having a urine arsenic concentration at or below the quantitation limit (2 μg/L) and a total urine volume greater than 5000 mL. When both of these conditions are met, the data are deemed unreliable and excluded from further calculations. In this study, two data points from the day -2 to -1 urine collection (pig #1311, group 2, and pig #1374, group 4) were deemed unreliable for this reason and excluded. No other data were excluded.

4.3 Background Arsenic Excretion

The urinary excretion results for days –2 to –1 (prior to dosing) ranged from 2.7 to 17.6 μg/48 hours across all animals, with a mean of 8.0 μg/48 hours. These values are representative of endogenous background levels in food and water. The urinary excretion results for control animals during dosing were very similar to the pre-dosing levels, with the exception of one animal on days 10 to 11 (discussed below in section 4.5). The results for days 8 to 9 ranged from 5.4 to 12.7 μg/48 hours (mean=8.6) and the results for days 10 to 11 (excluding the outlier) ranged from 4.4 to 11.0 μg/48 hours (mean=7.3). These results support the view that the animals were not exposed to any exogenous sources of arsenic throughout the study. Detailed data are included in Appendix A.

4.4 Urinary Arsenic Excretion Over Time

Previous swine arsenic bioavailability studies have shown that urinary arsenic excretion patterns are stable after five days of dosing (USEPA, 1997). To verify that this study's RBA estimates were made during steady-state elimination conditions, the pattern of urinary arsenic excretion over time was examined. Because of the limited data (only two dosing days), an appropriate curve cannot be fit scientifically to the data points. However, as shown in Figures 4-1 (sodium arsenate) and 4-2 (utility pole soil), the data are consistent with the expected conceptual dose-response model. As seen, the data for days 8 to 9 and 10 to 11 are generally similar to each other, suggesting that a steady-state elimination stage had been reached. Therefore, the data for the two time periods were combined to obtain the RBA.

4.5 Urinary Excretion Fractions and Relative Bioavailability

Detailed results from the study are presented in Appendix A. The urinary excretion results for NaAs and utility pole soil are summarized in Figures 4-3 and 4-4, respectively. In general, the absolute variability of the data increases with dose. The reason for this is unknown; however, this increased variability with dose is not uncommon in swine arsenic bioavailability studies (data not presented). Although there is variability in the data, all of the dose-response curves are approximately linear, with the slope of the best-fit straight line being equal to the best estimate of the urinary excretion fraction (UEF).

As discussed previously, the relative bioavailability of arsenic in a specific test material is calculated as follows:

RBA(test *vs.* NaAs) = UEF(test) / UEF(NaAs)

The following table summarizes the best fit slopes (urinary excretion fractions) for sodium arsenate and the utility pole soil, as well as the estimated RBA:

Material Administered	UEF ± SEM (N)	RBA (90% CI)
Sodium Arsenate (reference material)	0.680 ± 0.048 (30)	[1.00]
Utility Pole Soil (test material)	0.331 ± 0.025 (30)	0.49 (0.41-0.58)

N = Number of data points used in curve fitting
CI = Confidence interval

As seen, using sodium arsenate as a relative frame of reference, the RBA estimate for the test material is 49%. Notice that one control urine sample from days 10-11 is noticeably higher than the other controls across the study. The reason for this is not clear. However, exclusion of this data point does not significantly influence the results (the exclusion slightly raises the RBA estimate from 48.7% to 49.1%).

The RBA estimate for this utility pole soil is significantly lower than the default value of 80%-100% that is usually employed for arsenic in soil when reliable site-specific data are lacking. This indicates that the arsenic in this soil is not as well absorbed as soluble arsenic, and it is appropriate to take this into account when evaluating potential risks to humans from incidental ingestion of soil affected by CCA-treated wood. In addition, the relatively low doses administered in this study are generally representative of the doses a human would be exposed to, and are therefore more relevant to estimating human exposure in the same low dose range.

5.0 DEVIATIONS FROM PROTOCOL

During the course of this study, there were several deviations from the protocol. These deviations and their potential implications on the study are discussed below.

Soil Arsenic Analysis

The utility pole soil sample was analyzed for arsenic in duplicate, not triplicate as called for in the protocol. Because the between-duplicate agreement was quite good (320 and 310 µg/g), the omission of a third analysis results in little additional uncertainty around the mean arsenic concentration.

Dose Calculations

Because the amount of test material to be administered was calculated based on a preliminary estimation of the arsenic concentration in the test material, the actual administered doses were lower than the nominal doses called for in the protocol (see section 2.4). This has no impact on the RBA because the actual doses administered were still sufficiently high to obtain reliable data and RBA is independent of dose. All RBA calculations were based on the actual administered doses, which were calculated after the study was completed using the most current soil arsenic result (320 µg/g).

Urine Collections

The study protocol called for the RBA calculation to be based on combined urinary arsenic excretion data from days 6 to 7, 8 to 9, and 10 to 11. Unfortunately, the urine volume data for days 6 to 7 were lost, so RBA calculations were based only on data from the two later time periods (days 8 to 9 and 10 to 11).

However, the urinary arsenic excretion data from those two later time periods are generally similar, indicating that a steady-state elimination stage had been reached (see sections 4.4 and 4.5). Therefore, the data from the two later time points can be pooled to produce a reasonably robust estimate of the RBA.

Urine Volumes

Urine volumes were measured to the nearest 10 mL rather than the nearest 5 mL as specified in the protocol. Because the urine volumes range from 760 mL to 20740 mL, the additional uncertainty from measuring only to the nearest 10 mL is negligible compared to the uncertainty among the animals' urine volumes. Thus, this deviation is a very small source of uncertainty and has no significant impact on the calculations.

Creatinine Samples

Because drinking water was often spilled by animals from the watering nozzles into the urine collection pans, many urine samples were diluted with water and, as a result, the creatinine data cannot be meaningfully evaluated. However, this study compares the total mass of arsenic excreted in urine (i.e., concentration of arsenic in the analyzed aliquot multiplied by the total volume of urine collected) to the total mass of arsenic administered in the dose. Because we are dealing only with the total mass of arsenic rather than urinary arsenic concentrations, urinary creatinine measurements are not necessary.

6.0 REFERENCES

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TABLE 2-1 STUDY DESIGN

Group	Number of Animals	Dose Material Administered	Target Elemental Arsenic Dose (ug/kg-day)
1	5	Control	0
2	5	Sodium Arsenate	30
3	5	Sodium Arsenate	60
4	5	Utility Pole Soil	60
5	5	Utility Pole Soil	120

Table 2-2 Typical Feed Composition

Nutrient Name	Amount	Nutrient Name	Amount
Protein	20.1021%	Chlorine	0.1911%
Arginine	1.2070%	Magnesium	0.0533%
Lysine	1.4690%	Sulfur	0.0339%
Methionine	0.8370%	Manganese	20.4719 µg/g
Met+Cys	0.5876%	Zinc	118.0608 µg/g
Tryptophan	0.2770%	Iron	135.3710 µg/g
Histidine	0.5580%	Copper	8.1062 µg/g
Leucine	1.8160%	Cobalt	0.0110 µg/g
Isoleucine	1.1310%	Iodine	0.2075 µg/g
Phenylalanine	1.1050%	Selenium	0.3196 µg/g
Phe+Tyr	2.0500%	Nitrogen Free Extract	60.2340%
Threonine	0.8200%	Vitamin A	5.1892 kIU/kg
Valine	1.1910%	Vitamin D3	0.6486 kIU/kg
Fat	4.4440%	Vitamin E	87.2080 IU/kg
Saturated Fat	0.5590%	Vitamin K	0.9089 µg/g
Unsaturated Fat	3.7410%	Thiamine	9.1681 µg/g
Linoleic 18:2:6	1.9350%	Riboflavin	10.2290 µg/g
Linoleic 18:3:3	0.0430%	Niacin	30.1147 µg/g
Crude Fiber	3.8035%	Pantothenic Acid	19.1250 µg/g
Ash	4.3347%	Choline	1019.8600 µg/g
Calcium	0.8675%	Pyridoxine	8.2302 µg/g
Phos Total	0.7736%	Folacin	2.0476 µg/g
Available Phosphorous	0.7005%	Biotin	0.2038 µg/g
Sodium	0.2448%	Vitamin B12	23.4416 µg/g
Potassium	0.3733%		

Feed obtained from and nutritional values provided by Zeigler Bros., Inc

FIGURE 2-1 BODY WEIGHT GAIN

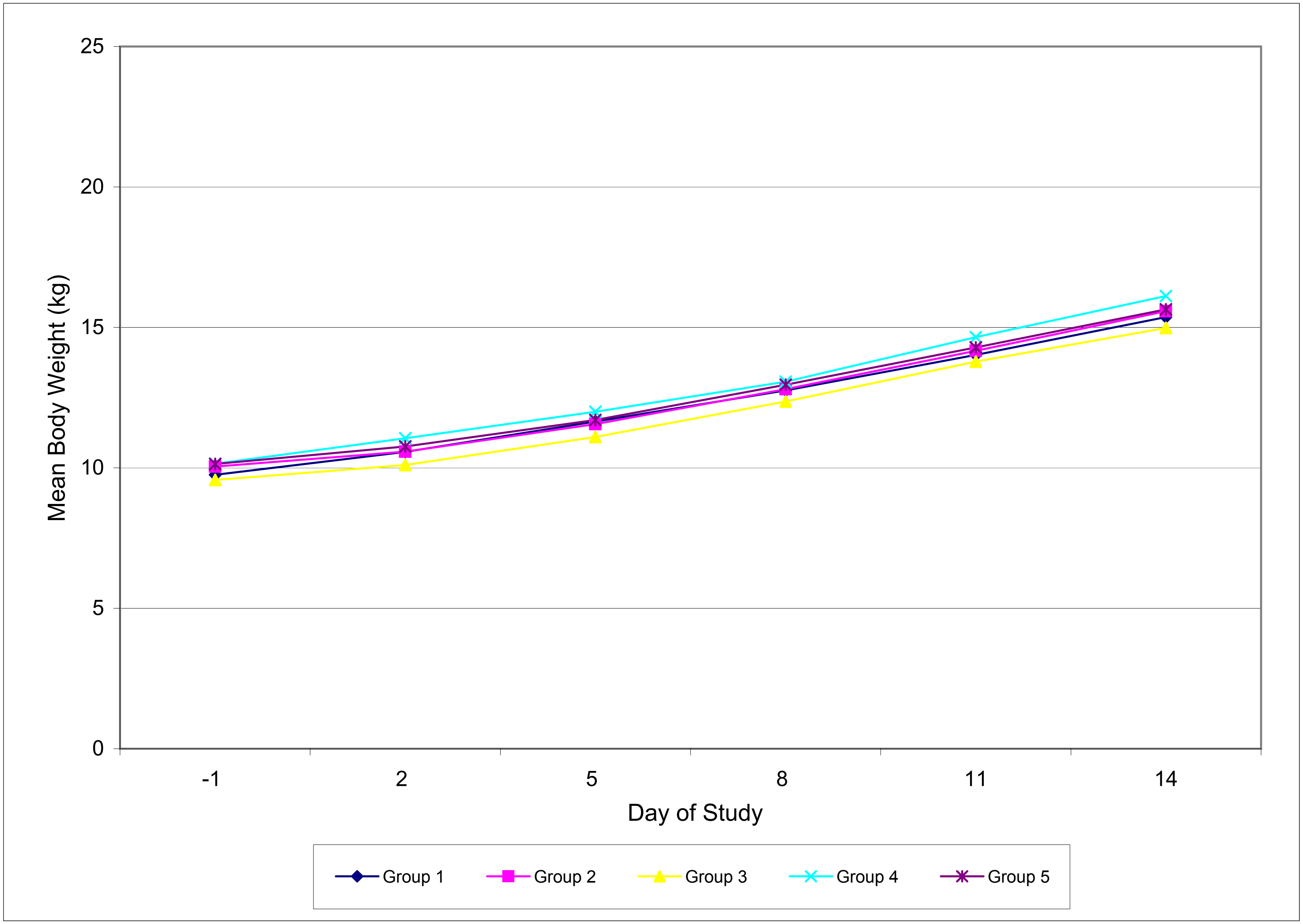


FIGURE 2-2 PERFORMANCE EVALUATION SAMPLES

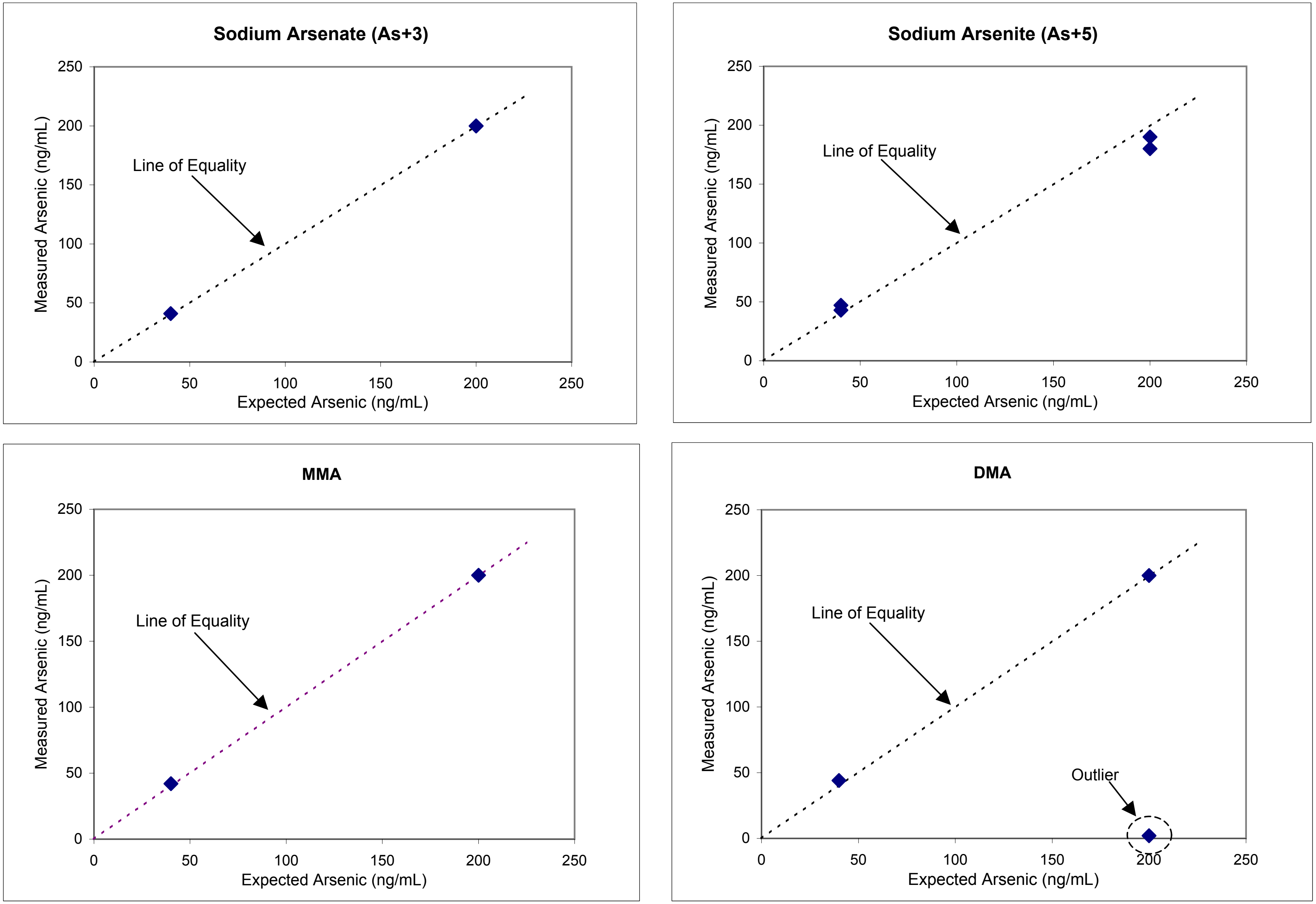


FIGURE 2-3 BLIND DUPLICATE SAMPLES

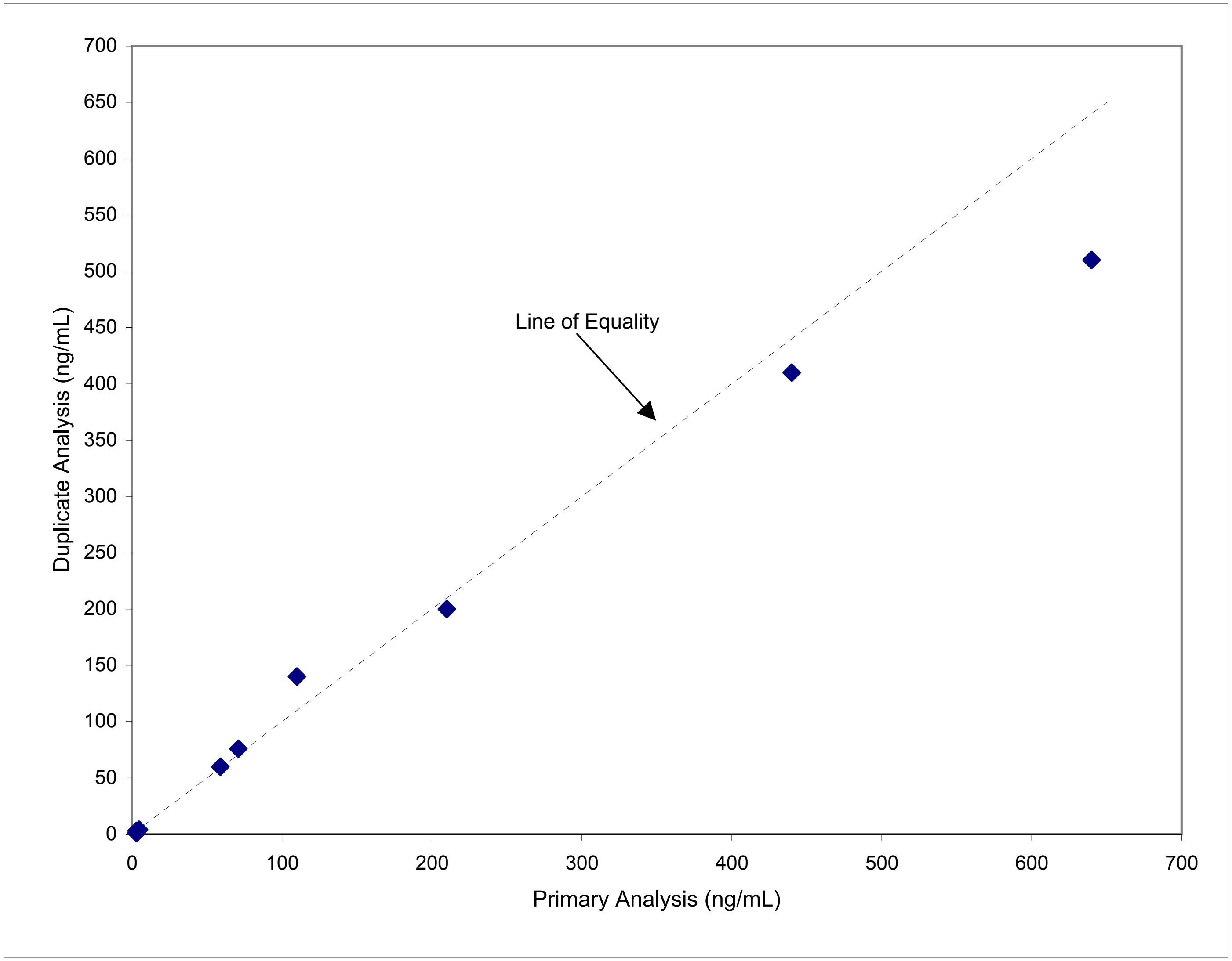
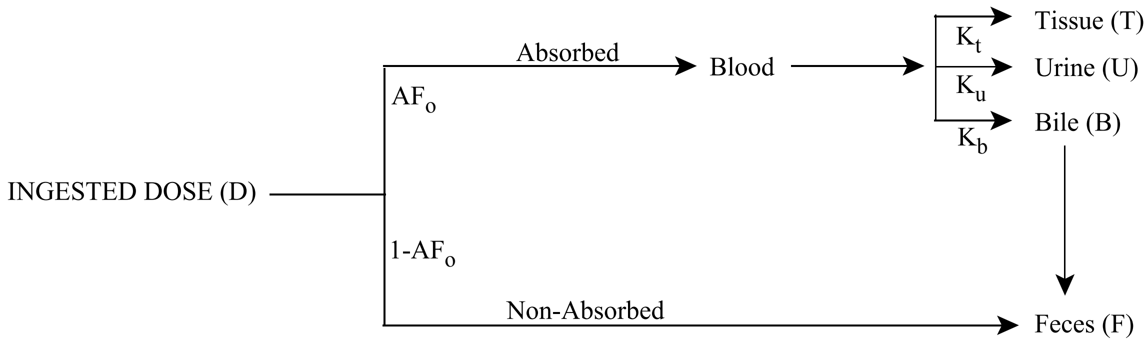


Figure 3-1. Conceptual Model for Arsenic Toxicokinetics



where:

- D = Ingested dose (ug)
- AF_o = Oral Absorption Fraction
- K_t = Fraction of absorbed arsenic which is retained in tissues
- K_u = Fraction of absorbed arsenic which is excreted in urine
- K_b = Fraction of absorbed arsenic which is excreted in the bile

BASIC EQUATIONS:

Amount Absorbed (ug) $= D \cdot AF_o$

Amount Excreted (ug) $=$ Amount absorbed $\cdot K_u$

$= D \cdot AF_o \cdot K_u$

Urinary Excretion Fraction (UEF) $=$ Amount excreted / Amount Ingested

$= (D \cdot AF_o \cdot K_u) / D$

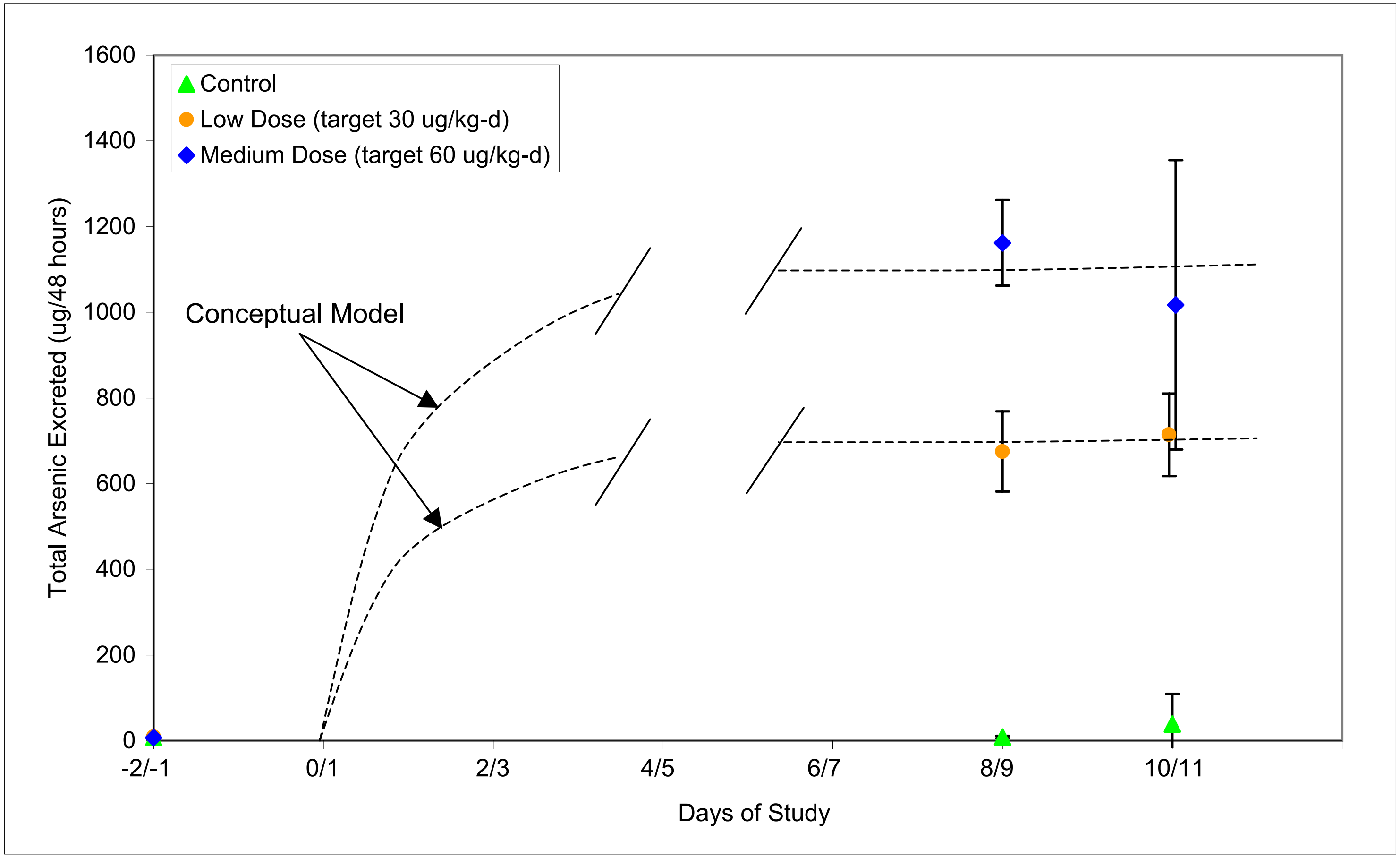
$= AF_o \cdot K_u$

Relative Bioavailability (x vs. y) $= UEF(x) / UEF(y)$

$= (AF_o(x) \cdot K_u) / (AF_o(y) \cdot K_u)$

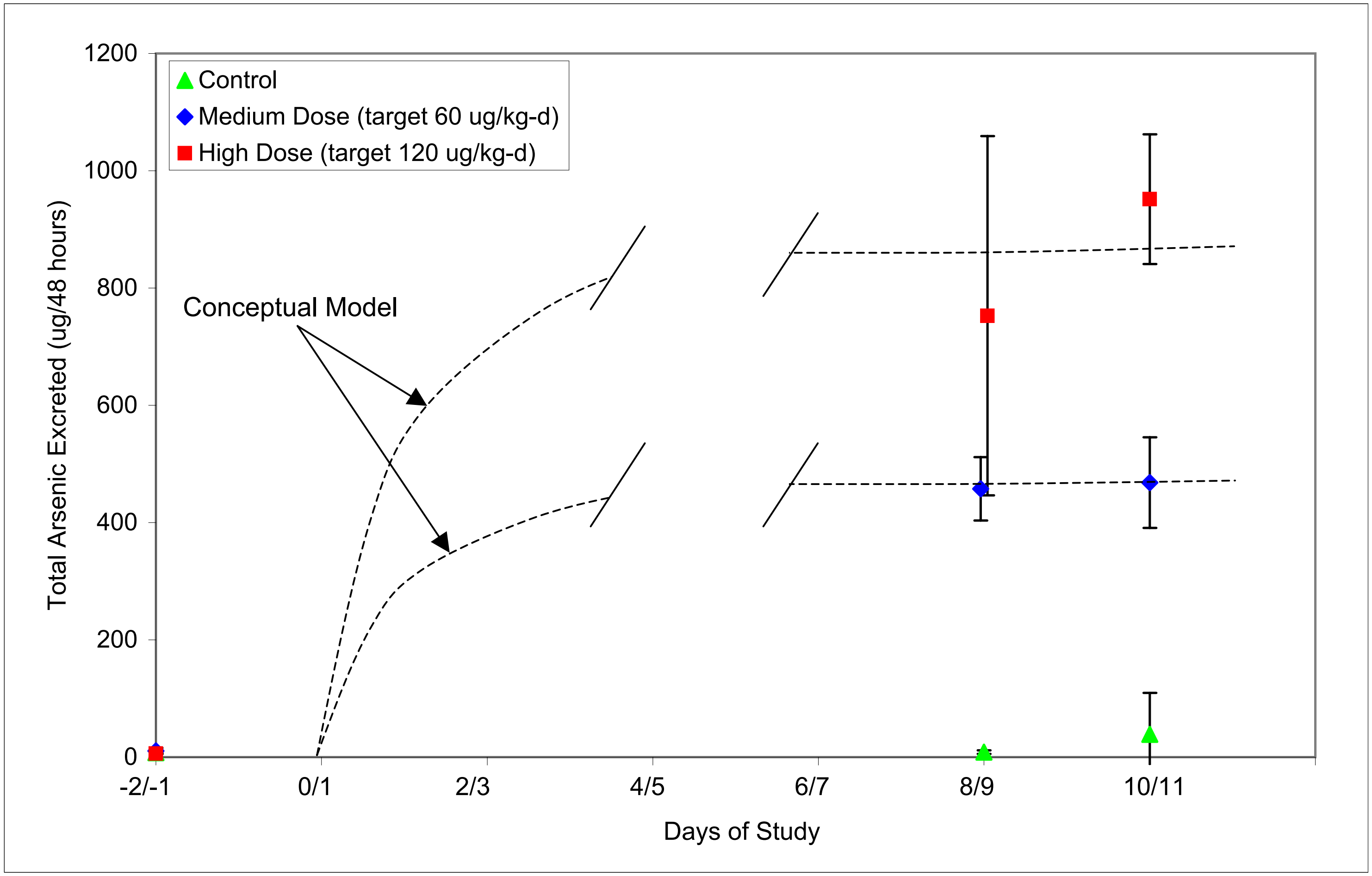
$= AF_o(x) / AF_o(y)$

FIGURE 4-1 URINARY ARSENIC EXCRETION OVER TIME - SODIUM ARSENATE



The conceptual models shown in the figure are illustrative of the relationship that is expected to apply; they are not based on any statistical analysis of the study data.

FIGURE 4-2 URINARY ARSENIC EXCRETION OVER TIME - UTILITY POLE SOIL



The conceptual models shown in the figure are illustrative of the relationship that is expected to apply; they are not based on any statistical analysis of the study data.

FIGURE 4-3 URINARY EXCRETION OF ARSENIC FROM SODIUM ARSENATE

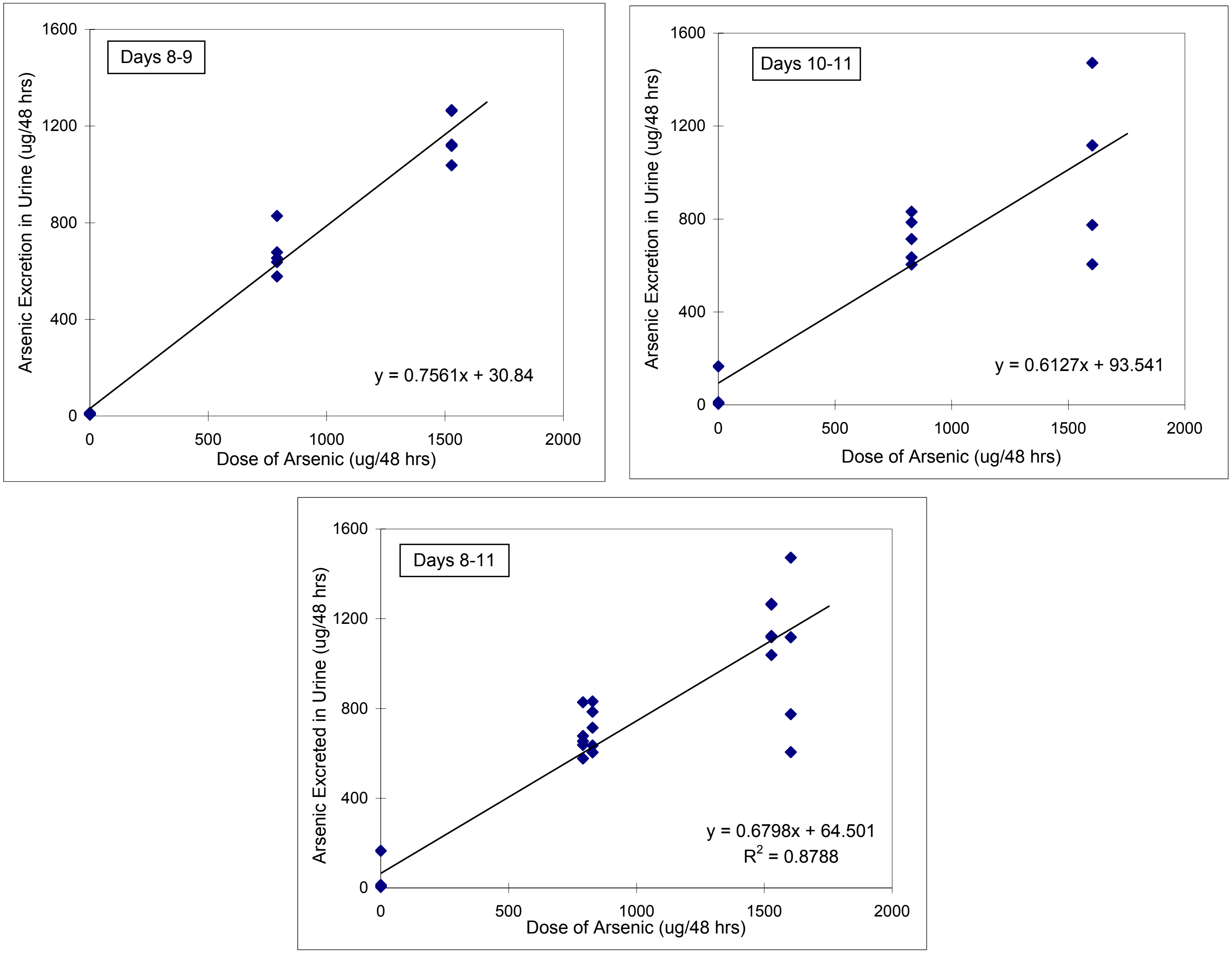
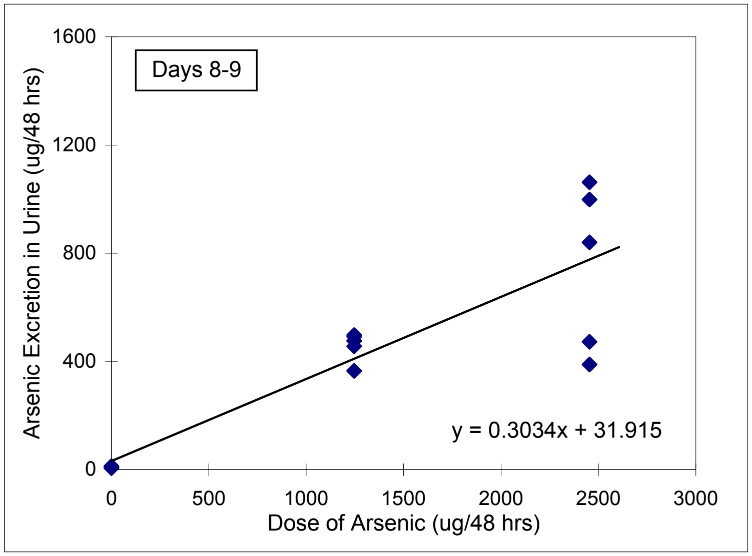
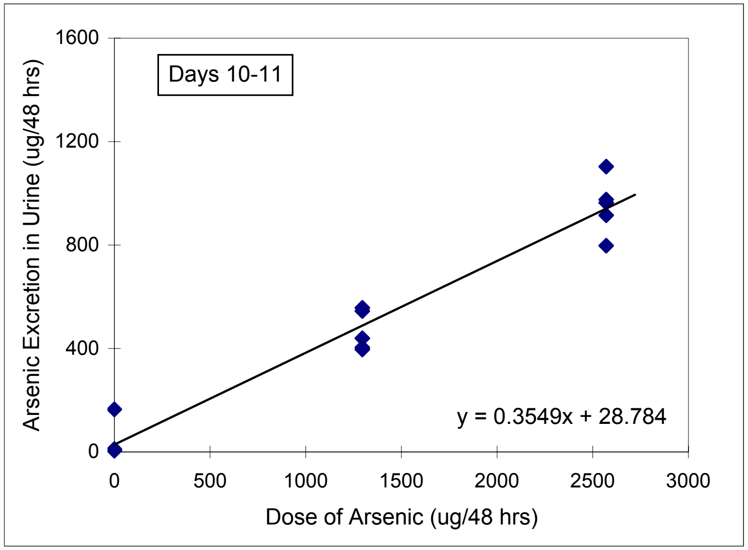
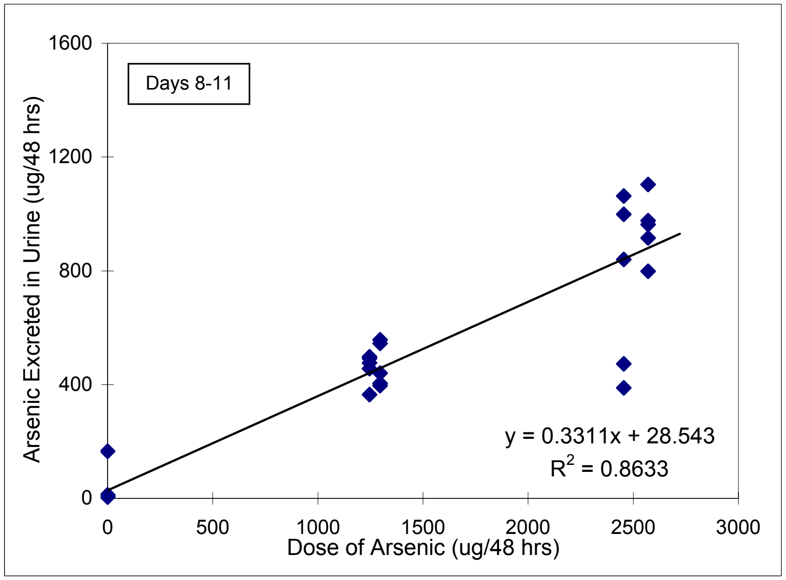


FIGURE 4-4 URINARY EXCRETION OF ARSENIC FROM UTILITY POLE SOIL







APPENDIX A

DETAILED RESULTS

TABLE A-1 SCHEDULE

Study Day	Day	Date	Dose Administration	Feed Special Diet	Weigh	Dose Prep	Cull Pigs/ Assign Dose Group	48-hour Urine Collection	Sacrifice/ Necropsy
-7	Monday	10/28/02		X	X				
-6	Tuesday	10/29/02		X					
-5	Wednesday	10/30/02		X					
-4	Thursday	10/31/02		X	X		X		
-3	Friday	11/01/02		X					
-2	Saturday	11/02/02		X					
-1	Sunday	11/03/02		X	X	X			
0	Monday	11/04/02	X	X					
1	Tuesday	11/05/02	X	X					
2	Wednesday	11/06/02	X	X	X	X			
3	Thursday	11/07/02	X	X					
4	Friday	11/08/02	X	X					
5	Saturday	11/09/02	X	X	X	X			
6	Sunday	11/10/02	X	X					
7	Monday	11/11/02	X	X					
8	Tuesday	11/12/02	X	X	X	X			
9	Wednesday	11/13/02	X	X					
10	Thursday	11/14/02	X	X					
11	Friday	11/15/02	X	X	X	X			
12	Saturday	11/16/02	X	X					
13	Sunday	11/17/02	X	X					
14	Monday	11/18/02	X	X	X				
15	Tuesday	11/19/02							X

TABLE A-2 GROUP ASSIGNMENTS

Pig Number	Dose Group	Material Administered	Target Dose of Arsenic (ug/kg-day)
1313 1322 1324 1354 1366	1	Control	0
1311 1317 1325 1353 1372	2	NaAs	30
1312 1318 1319 1323 1355	3	NaAs	60
1321 1351 1369 1374 1375	4	Utility Pole Soil	60
1315 1356 1361 1363 1365	5	Utility Pole Soil	120

TABLE A-3 BODY WEIGHTS AND ACTUAL ADMINISTERED DOSES, BY DAY

Body weights were measured on days -1, 2, 5, 8, 11, and 14. Weights for other days are estimated, based on linear interpolation between measured values.
Doses calculated based on final arsenic concentration of 320 ug/g. All doses were fully consumed, so no dose adjustments were necessary.

Group	Pig #	Day -1		Day 0		Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12		Day 13	
		BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)	BW (kg)	As Dose (ug/kg-d)
1	1313	9.5	0.00	9.8	0.00	10.2	0.00	10.5	0.00	10.9	0.00	11.2	0.00	11.6	0.00	12.0	0.00	12.5	0.00	12.9	0.00	13.2	0.00	13.5	0.00	13.8	0.00	14.4	0.00	14.9	0.00
1	1322	10.0	0.00	10.3	0.00	10.7	0.00	11.1	0.00	11.4	0.00	11.7	0.00	12.0	0.00	12.3	0.00	12.7	0.00	13.1	0.00	13.6	0.00	14.1	0.00	14.6	0.00	15.0	0.00	15.3	0.00
1	1324	10.5	0.00	10.6	0.00	10.7	0.00	10.9	0.00	11.3	0.00	11.8	0.00	12.2	0.00	12.5	0.00	12.8	0.00	13.2	0.00	13.7	0.00	14.2	0.00	14.7	0.00	15.2	0.00	15.6	0.00
1	1354	8.9	0.00	9.2	0.00	9.6	0.00	10.0	0.00	10.3	0.00	10.5	0.00	10.8	0.00	11.1	0.00	11.5	0.00	11.9	0.00	12.3	0.00	12.7	0.00	13.1	0.00	13.5	0.00	13.8	0.00
1	1366	10.1	0.00	10.2	0.00	10.3	0.00	10.5	0.00	10.9	0.00	11.3	0.00	11.8	0.00	12.1	0.00	12.5	0.00	12.8	0.00	13.2	0.00	13.5	0.00	13.9	0.00	14.4	0.00	14.9	0.00
2	1311	9.4	0.00	9.6	34.59	9.8	33.77	10.1	32.99	10.3	33.62	10.6	32.72	10.9	31.87	11.3	33.25	11.8	32.02	12.2	30.89	12.6	32.86	13.0	31.85	13.4	30.90	13.9	32.82	14.3	31.75
2	1317	10.5	0.00	10.6	31.22	10.7	30.89	10.9	30.55	11.1	31.44	11.3	30.88	11.5	30.34	11.9	31.80	12.3	30.76	12.7	29.79	13.1	31.52	13.6	30.40	14.1	29.36	14.5	31.31	15.0	30.41
2	1325	10.0	0.00	10.1	32.71	10.3	32.13	10.5	31.57	11.0	31.73	11.4	30.47	11.9	29.32	12.2	30.80	12.6	29.87	13.0	28.98	13.5	30.74	13.9	29.71	14.4	28.75	14.8	30.78	15.2	30.01
2	1353	10.0	0.00	10.1	32.82	10.2	32.50	10.3	32.18	10.8	32.32	11.2	31.02	11.7	29.82	12.0	31.31	12.4	30.35	12.8	29.44	13.3	31.13	13.8	30.00	14.3	28.95	14.8	30.68	15.4	29.62
2	1372	10.5	0.00	10.7	30.98	11.0	30.27	11.2	29.60	11.5	30.34	11.7	29.69	12.0	29.07	12.4	30.35	12.9	29.25	13.4	28.22	13.8	30.04	14.2	29.12	14.7	28.26	15.2	29.97	15.7	28.96
3	1312	8.0	0.00	8.2	77.34	8.4	75.50	8.6	73.74	9.2	72.79	9.7	68.66	10.3	64.98	10.6	68.60	10.9	66.50	11.3	64.53	11.7	68.42	12.2	65.79	12.7	63.37	13.0	68.22	13.4	66.43
3	1318	9.7	0.00	9.7	65.61	9.6	65.83	9.6	66.06	9.8	68.31	9.9	67.27	10.1	66.27	10.5	69.25	10.9	66.50	11.4	63.96	11.8	68.03	12.2	65.62	12.7	63.37	13.0	68.13	13.4	66.26
3	1319	11.1	0.00	11.4	55.79	11.7	54.28	12.0	52.85	12.3	54.15	12.6	52.86	12.9	51.63	13.3	54.45	13.8	52.74	14.2	51.13	14.6	54.84	15.0	53.32	15.5	51.88	15.9	55.83	16.3	54.35
3	1323	9.1	0.00	9.2	68.93	9.4	67.83	9.5	66.76	9.8	68.19	10.0	66.38	10.3	64.66	10.8	67.02	11.4	63.87	11.9	61.01	12.4	64.65	12.9	62.14	13.4	59.82	13.8	64.18	14.2	62.30
3	1355	10.1	0.00	10.3	61.57	10.6	60.11	10.8	58.72	11.2	59.46	11.6	57.41	12.0	55.50	12.4	58.71	12.7	57.02	13.1	55.42	13.7	58.73	14.2	56.45	14.8	54.35	15.2	58.41	15.6	56.79
4	1321	10.6	0.00	10.9	47.10	11.3	45.63	11.6	44.26	11.8	46.89	12.1	45.98	12.3	45.11	12.8	46.95	13.2	45.35	13.7	43.85	14.1	46.11	14.5	44.83	14.9	43.62	15.4	46.94	15.9	45.46
4	1351	11.2	0.00	11.5	44.84	11.8	43.69	12.1	42.60	12.4	44.68	12.8	43.40	13.2	42.19	13.6	44.12	14.0	42.81	14.4	41.57	15.0	43.24	15.6	41.62	16.2	40.11	16.7	43.23	17.2	41.93
4	1369	8.9	0.00	9.0	57.25	9.1	56.52	9.2	55.80	9.6	58.10	9.9	56.04	10.3	54.13	10.5	57.28	10.7	56.20	10.9	55.17	11.4	56.74	12.0	54.06	12.6	51.62	13.1	55.15	13.6	53.05
4	1374	9.0	0.00	9.4	54.71	9.8	52.56	10.2	50.58	10.4	53.26	10.7	51.93	11.0	50.67	11.3	52.97	11.7	51.38	12.0	49.88	12.5	52.03	12.9	50.22	13.4	48.53	13.9	51.96	14.4	50.10
4	1375	11.2	0.00	11.6	44.45	11.9	43.14	12.3	41.91	12.6	43.98	13.0	42.73	13.4	41.56	13.7	43.64	14.1	42.50	14.5	41.42	15.1	42.95	15.7	41.22	16.4	39.62	16.8	43.02	17.2	42.02
5	1315	11.1	0.00	11.4	90.25	11.6	88.18	11.9	86.21	12.1	89.25	12.4	87.57	12.6	85.95	13.0	89.96	13.4	87.28	13.8	84.75	14.4	89.48	14.9	86.08	15.5	82.94	16.0	88.09	16.5	85.51
5	1356	10.2	0.00	10.2	100.41	10.3	99.76	10.4	99.12	10.8	100.58	11.2	96.83	11.6	93.36	12.1	96.92	12.5	93.31	13.0	89.96	13.5	95.58	13.9	92.48	14.4	89.58	14.8	95.03	15.3	92.13
5	1361	9.6	0.00	9.9	103.97	10.2	100.74	10.5	97.70	10.7	101.53	10.8	99.96	11.0	98.45	11.3	103.50	11.6	100.82	11.9	98.28	12.4	103.95	12.8	100.17	13.3	96.66	13.8	102.03	14.3	98.46
5	1363	10.3	0.00	10.6	97.24	10.8	94.99	11.1	92.84	11.4	94.99	11.8	92.16	12.1	89.50	12.6	92.82	13.1	89.27	13.6	85.99	14.0	91.93	14.4	89.48	14.8	87.15	15.2	92.63	15.7	89.97
5	1365	9.6	0.00	9.7	105.39	9.9	103.97	10.0	102.58	10.4	104.13	10.8	100.27	11.2	96.69	11.6	100.53	12.1	96.92	12.5	93.56	12.9	100.04	13.2	97.39	13.6	94.87	13.9	101.29	14.3	98.81

TABLE A-4 URINE VOLUMES - 48 HOUR COLLECTIONS

Units of Volume: mL

Group	Pig ID	Urine Collection		
		Days -2/-1 (11/2-11/3)	Days 8-9 (11/12-11/13)	Days 10-11 (11/14-11/15)
1	1313	2540	5500	8840
	1322	1460	2680	3140
	1324	1220	3560	3260
	1354	2380	4220	5160
	1366	2320	1250	1410
2	1311	13430	10430	14000
	1317	1990	1520	1550
	1325	2800	9960	10070
	1353	2920	2510	4620
	1372	3210	4840	5540
3	1312	1340	1490	1210
	1318	1640	860	1140
	1319	4940	14620	20740
	1323	1080	3210	3020
	1355	10000	13160	11420
4	1321	920	3320	2020
	1351	8820	8610	20180
	1369	2620	13520	11280
	1374	11290	8340	12950
	1375	1700	2800	3600
5	1315	915	1100	2080
	1356	2680	4000	7510
	1361	760	1050	1120
	1363	3900	4250	4200
	1365	840	3330	3680

TABLE A-5 URINE ANALYTICAL RESULTS

Tag Number	Pig Number	Group	Day	Material Administered	Target Dose (ug/kg-d)	48-hr BWAdj Dose (ug/kg-48hr)*	Urine Volume (mls/48hrs)	Q	Arsenic Conc in Urine	DL	Units
ACC-1-0102	1313	1	-2/-1	Control	0	0	2540		3	1	ng/mL
ACC-1-0120	1322	1	-2/-1	Control	0	0	1460		4.8	1	ng/mL
ACC-1-0131	1324	1	-2/-1	Control	0	0	1220		7.8	1	ng/mL
ACC-1-0129	1354	1	-2/-1	Control	0	0	2380		2	1	ng/mL
ACC-1-0112	1366	1	-2/-1	Control	0	0	2320		3.4	1	ng/mL
ACC-1-0111	1311	2	-2/-1	NaAs	30	0	13430		2	1	ng/mL
ACC-1-0128	1317	2	-2/-1	NaAs	30	0	1990		4.4	1	ng/mL
ACC-1-0114	1325	2	-2/-1	NaAs	30	0	2800		3	1	ng/mL
ACC-1-0132	1353	2	-2/-1	NaAs	30	0	2920		2	1	ng/mL
ACC-1-0117	1372	2	-2/-1	NaAs	30	0	3210		4.6	1	ng/mL
ACC-1-0106	1312	3	-2/-1	NaAs	60	0	1340		2	1	ng/mL
ACC-1-0130	1318	3	-2/-1	NaAs	60	0	1640		4.3	1	ng/mL
ACC-1-0110	1319	3	-2/-1	NaAs	60	0	4940		2	1	ng/mL
ACC-1-0126	1323	3	-2/-1	NaAs	60	0	1080		4.7	1	ng/mL
ACC-1-0107	1355	3	-2/-1	NaAs	60	0	10000		1	1	ng/mL
ACC-1-0103	1321	4	-2/-1	Utility Pole Soil	60	0	920		7.8	1	ng/mL
ACC-1-0104	1351	4	-2/-1	Utility Pole Soil	60	0	8820		2	1	ng/mL
ACC-1-0118	1369	4	-2/-1	Utility Pole Soil	60	0	2620		3	1	ng/mL
ACC-1-0113	1374	4	-2/-1	Utility Pole Soil	60	0	11290		2	1	ng/mL
ACC-1-0125	1375	4	-2/-1	Utility Pole Soil	60	0	1700		6.2	1	ng/mL
ACC-1-0109	1315	5	-2/-1	Utility Pole Soil	120	0	915		6.4	1	ng/mL
ACC-1-0122	1356	5	-2/-1	Utility Pole Soil	120	0	2680		2	1	ng/mL
ACC-1-0115	1361	5	-2/-1	Utility Pole Soil	120	0	760		9.2	1	ng/mL
ACC-1-0121	1363	5	-2/-1	Utility Pole Soil	120	0	3900		2	1	ng/mL
ACC-1-0123	1365	5	-2/-1	Utility Pole Soil	120	0	840		5.5	1	ng/mL
ACC-1-0189	1313	1	8/9	Control	0	0	5500		2	1	ng/mL
ACC-1-0194	1322	1	8/9	Control	0	0	2680		2	1	ng/mL
ACC-1-0166	1324	1	8/9	Control	0	0	3560		2	1	ng/mL
ACC-1-0193	1354	1	8/9	Control	0	0	4220		3	1	ng/mL
ACC-1-0178	1366	1	8/9	Control	0	0	1250		5.3	1	ng/mL
ACC-1-0181	1311	2	8/9	NaAs	30	63.74	10430		65	1	ng/mL
ACC-1-0196	1317	2	8/9	NaAs	30	61.31	1520		380	10	ng/mL
ACC-1-0195	1325	2	8/9	NaAs	30	59.73	9960		64	1	ng/mL
ACC-1-0177	1353	2	8/9	NaAs	30	60.57	2510		330	10	ng/mL
ACC-1-0175	1372	2	8/9	NaAs	30	58.26	4840		135	1	ng/mL
ACC-1-0186	1312	3	8/9	NaAs	60	132.95	1490		850	10	ng/mL
ACC-1-0182	1318	3	8/9	NaAs	60	131.99	860		1300	20	ng/mL
ACC-1-0197	1319	3	8/9	NaAs	60	105.97	14620		71	1	ng/mL
ACC-1-0168	1323	3	8/9	NaAs	60	125.65	3210		350	10	ng/mL
ACC-1-0174	1355	3	8/9	NaAs	60	114.15	13160		96	5	ng/mL
ACC-1-0173	1321	4	8/9	Utility Pole Soil	60	89.96	3320		150	5	ng/mL
ACC-1-0179	1351	4	8/9	Utility Pole Soil	60	84.8	8610		53	1	ng/mL
ACC-1-0184	1369	4	8/9	Utility Pole Soil	60	111.91	13520		27	1	ng/mL
ACC-1-0170	1374	4	8/9	Utility Pole Soil	60	101.91	8340		59	1	ng/mL
ACC-1-0192	1375	4	8/9	Utility Pole Soil	60	84.37	2800		170	5	ng/mL
ACC-1-0187	1315	5	8/9	Utility Pole Soil	120	174.23	1100		430	10	ng/mL
ACC-1-0171	1356	5	8/9	Utility Pole Soil	120	185.54	4000		210	5	ng/mL
ACC-1-0167	1361	5	8/9	Utility Pole Soil	120	202.23	1050		370	5	ng/mL
ACC-1-0190	1363	5	8/9	Utility Pole Soil	120	177.93	4250		250	5	ng/mL
ACC-1-0176	1365	5	8/9	Utility Pole Soil	120	193.6	3330		300	4	ng/mL
ACC-1-0204	1313	1	10/11	Control	0	0	8840	<	1	1	ng/mL
ACC-1-0223	1322	1	10/11	Control	0	0	3140		3.5	1	ng/mL
ACC-1-0224	1324	1	10/11	Control	0	0	3260		2	1	ng/mL
ACC-1-0217	1354	1	10/11	Control	0	0	5160		32	1	ng/mL
ACC-1-0199	1366	1	10/11	Control	0	0	1410		5	1	ng/mL
ACC-1-0207	1311	2	10/11	NaAs	30	62.74	14000		51	1	ng/mL
ACC-1-0208	1317	2	10/11	NaAs	30	59.77	1550		410	10	ng/mL
ACC-1-0214	1325	2	10/11	NaAs	30	58.46	10070		60	1	ng/mL
ACC-1-0211	1353	2	10/11	NaAs	30	58.95	4620		170	5	ng/mL
ACC-1-0202	1372	2	10/11	NaAs	30	57.38	5540		150	5	ng/mL
ACC-1-0210	1312	3	10/11	NaAs	60	129.16	1210		640	10	ng/mL
ACC-1-0209	1318	3	10/11	NaAs	60	128.98	1140		980	10	ng/mL
ACC-1-0228	1319	3	10/11	NaAs	60	105.21	20740		71	1	ng/mL
ACC-1-0216	1323	3	10/11	NaAs	60	121.96	3020		370	10	ng/mL
ACC-1-0198	1355	3	10/11	NaAs	60	110.8	11420		53	5	ng/mL
ACC-1-0220	1321	4	10/11	Utility Pole Soil	60	88.46	2020		200	5	ng/mL

Tag Number	Pig Number	Group	Day	Material Administered	Target Dose (ug/kg-d)	48-hr BWAdj Dose (ug/kg-48hr)*	Urine Volume (mls/48hrs)	Q	Arsenic Conc in Urine	DL	Units
ACC-1-0226	1351	4	10/11	Utility Pole Soil	60	81.73	20180		27	1	ng/mL
ACC-1-0203	1369	4	10/11	Utility Pole Soil	60	105.68	11280		39	1	ng/mL
ACC-1-0221	1374	4	10/11	Utility Pole Soil	60	98.75	12950		43	1	ng/mL
ACC-1-0222	1375	4	10/11	Utility Pole Soil	60	80.84	3600		110	5	ng/mL
ACC-1-0219	1315	5	10/11	Utility Pole Soil	120	169.02	2080		440	10	ng/mL
ACC-1-0227	1356	5	10/11	Utility Pole Soil	120	182.07	7510		130	5	ng/mL
ACC-1-0206	1361	5	10/11	Utility Pole Soil	120	196.83	1120		860	10	ng/mL
ACC-1-0215	1363	5	10/11	Utility Pole Soil	120	176.63	4200		190	5	ng/mL
ACC-1-0201	1365	5	10/11	Utility Pole Soil	120	192.26	3680		300	5	ng/mL

* For animals dosed with the test material, the 48-hour body weight adjusted (actual administered) doses shown here were calculated using the final estimate of arsenic concentration in the utility pole soil (320 µg/g).

Tag Number	QC Type	QC Identifier	Orginal Pig #	Material Administered	Group	Target Dose (ug/kg-d)	DL	Q	As Conc	AdjConc (ng/mL)	OrigAdj Conc (ng/mL)
ACC-1-0127	Blind Duplicate	21323	1323	NaAs	3	60	1		4	4	4.7
ACC-1-0119	Blind Duplicate	21325	1325	NaAs	2	30	1		1	1	3
ACC-1-0108	Blind Duplicate	21369	1369	Utility Pole Soil	4	60	1		3	3	3
ACC-1-0185	Blind Duplicate	21319	1319	NaAs	3	60	1		76	76	71
ACC-1-0172	Blind Duplicate	21363	1356	Utility Pole Soil	5	120	5		200	200	210
ACC-1-0180	Blind Duplicate	21374	1374	Utility Pole Soil	4	60	1		60	60	59
ACC-1-0213	Blind Duplicate	21312	1312	NaAs	3	60	10		510	510	640
ACC-1-0212	Blind Duplicate	21315	1315	Utility Pole Soil	5	120	10		410	410	440
ACC-1-0225	Blind Duplicate	21375	1375	Utility Pole Soil	4	60	5		140	140	110

Tag Number	QC Type	QC Identifier	Material Administered	PE Conc (ug/L)	DL	Q	As Conc	AdjConc	Units
ACC-1-0105	PE Sample	AsCtrl-b	Control Urine	0	1		3.2	3.2	ng/mL
ACC-1-0124	PE Sample	AsOB200-a	Dimethyl arsenic acid	200	1		2	2	ng/mL
ACC-1-0101	PE Sample	AsOA40-b	Disodium methylarsenate	40	1		42	42	ng/mL
ACC-1-0116	PE Sample	AsIB200-a	Sodium arsenite	200	5		180	180	ng/mL
ACC-1-0188	PE Sample	AsIB40-b	Sodium arsenite	40	1		47	47	ng/mL
ACC-1-0169	PE Sample	AsOB40-b	Dimethyl arsenic acid	40	1		44	44	ng/mL
ACC-1-0183	PE Sample	AsIA200-b	Sodium arsenate	200	5		200	200	ng/mL
ACC-1-0191	PE Sample	AsOB200-b	Dimethyl arsenic acid	200	5		200	200	ng/mL
ACC-1-0218	PE Sample	AsIA200-a	Sodium arsenate	200	5		200	200	ng/mL
ACC-1-0229	PE Sample	AsIB40-a	Sodium arsenite	40	1		43	43	ng/mL
ACC-1-0230	PE Sample	AsIA40-a	Sodium arsenate	40	1		41	41	ng/mL
ACC-1-0200	PE Sample	AsIB200-b	Sodium arsenite	200	5		190	190	ng/mL
ACC-1-0205	PE Sample	AsOA200-a	Disodium methylarsenate	200	5		200	200	ng/mL