Health Consultation

CIBOLA

CIBOLA, LA PAZ COUNTY, ARIZONA

Prepared by

Arizona Department of Health Services
Office of Environmental Health
Environmental Health Consultation Services

Summary

INTRODUCTION

In the *Cibola*, the Arizona Department of Health Services' (ADHS') top priority is to ensure that the community and residents have the best information possible to safeguard their health.

This report was written in response to a request from the Arizona Department of Environmental Quality (ADEQ) who received increasing concerns regarding elevated levels of arsenic and manganese detected in some residential yard soils since June 2007. The Arizona Department of Health Services (ADHS) was asked to provide assistance. This health consultation will evaluate the public health risks due to exposure to metals, especially arsenic and manganese, in contaminated soil.

Soil sampling results collected in June and November 2007 were used in this report to evaluate whether exposure to metals in contaminated soil could harm people's health. In an attempt to characterize the nature and degree of the contamination that would impact the health of residents, ADHS reviewed all the available data.

CONCLUSIONS

ADHS concludes that:

(1) The detected levels of arsenic in the Cibola area are not expected to harm people's health, including pica-children, children, and adults.
(2) The detected levels of manganese in the Cibola area are not expected to harm the health of adults.
(3) The detected levels of manganese in the Cibola area may harm the health of children under the age of six.
(4) ADHS does not consider that there is a health threat to adults who ingested the contaminated soil occasionally.
(5) ADHS considers that there is a health threat to children under the age of six due to elevated levels of manganese in the contaminated soil.
(6) Soil samples evaluated in this health consultation were not collected from residential yards. Therefore, additional residential soil samples can help better characterize the exposure and health risk among children.

BASIS FOR DECISION

Exposure to high levels of arsenic and manganese can be harmful. The major exposure route for the residents is through incidental ingestion. Although the detected levels of arsenic and manganese were above the Arizona Soil Remediation Levels (SRL) for residential area. After conducted site-specific exposure evaluation, the estimated daily intakes for arsenic were below the health-based guidelines for noncancerous health effects. In addition, the estimated theoretical excess lifetime cancer risk was within the range of public health guidelines (10^{-6}~10^{-4}) for protection of human health as suggested by EPA. This cancer risk is considered to be moderate based on the qualitative ranking of cancer risk estimates. For manganese, the estimated daily intake for adults was below the health-based guideline for noncancerous health effects.

	However, the estimated daily intakes for pica-children (kids who consume excess amount of soil) and children (< 6 years old) exceeded the health-based guideline and the no-observed-adverse-effect- level (NOAEL). Manganese is not considered to have the ability to cause cancer in human.
NEXT STEPS	To ensure the health and safety of residents, ADHS recommend ADEQ working with the potential responsible parties to provide warnings and advices to residents and conduct remedial activities. ADHS will work with ADEQ to develop health education materials.
FOR MORE INFORMATION	If you have concerns about your health, you should contact your health care provider. Please call ADHS at 602-364-3128 and ask for more information on the Cibola site.

Purpose

This report was written in response to a request from the Arizona Department of Environmental Quality (ADEQ) to evaluate human health risks from exposure to metal contaminated soil at Cibola, Arizona. ADEQ is aware of the increasing concerns regarding elevated levels of arsenic and manganese detected in some residential yard soils since June 2007. To address the community's concern, ADEQ collected soil samples to understand the nature and extent of the contamination. The Arizona Department of Health Services (ADHS) was asked to provide assistance to evaluate whether exposure to the arsenic and manganese contaminated soil could harm people's health.

Background and Statement of Issues

On June 13, 2007, the ADEQ Solid Waste Inspections and Compliance Unit (SWIC) received a complaint regarding the manganese tailing used on the town of Cibola's roadways and in some resident's yards. In response to the complainant, the SWICU and Hazardous Waste Inspections and Compliance Unit (HWICU) conducted an inspection, including sampling areas where manganese tailing were present. Five soil samples, including a background sample, were collected from four quadrants within the town of Cibola, and Global Positioning System (GPS) coordinates were documented (see Appendix A). On November 27, 2007, seven additional samples, including a background sample, were collected after ADEQ compliance officers met with agency representatives from the U.S. Bureau of Land Management (BLM) and La Paz County Public Works. They conducted further investigations for the source of the manganese tailings at various locations including: the Smaller Cibola Mill Site (owned by BLM), the Larger Cibola Mill Site (owned by the Arizona State Land Department and U.S. Bureau of Reclamation (BOR)), the LaPaz County Public Works Aggregate Plant, the BOR Stockpile, the Town of Cibola, and the BOR Rock Quarry.

According to the ADEQ, the aggregate material was a product placed on the roads and yards of Cibola with the intent of suppressing dust and use in landscaping. However, the elements found within the aggregate material can pose health risk if people ingest or inhale too much of them. Local residents have expressed their concerns regarding the sampling results. Some of the soil samples were found to have metal concentrations above the residential Soil Remediation Levels (rSRLs). Therefore, ADEQ requested ADHS to further investigate the potential health impacts on health of the Cibola residents and any need for remediation.

Discussion

General Assessment Methodology

ADHS generally follows a two-step methodology to assess public health issues related to environmental exposures. First, ADHS obtains representative environmental data for the site of concern and compiles a comprehensive list of site-related contaminants. Second, ADHS identifies exposure pathways, and then uses health-based comparison values to find those contaminants that do not have a realistic possibility of causing adverse health effects. For the remaining contaminants, ADHS reviews recent scientific studies to determine if the extent of environmental contamination indicates a public health hazard.

Environmental Data

On June 25, 2007, five surface soil samples, including a background sample, were collected from four quadrants with the town of Cibola. These samples were analyzed in accordance with U.S. EPA SW-846 Method 6010B/7471A for manganese and Resource Conservation and Recovery Act (RCRA) 8 metals (i.e. arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver). Toxicity Characteristic Leaching Procedure (TCLP) Test for lead and arsenic was also conducted to determine the metal leachability. Seven additional soil samples, including a background sample, were collected on November 27, 2007. Same procedure was applied to analyze total soil concentrations of manganese and RCRA 8 metals. TCLP test for barium was conducted as well. All samples were analyzed by the Transwest Geochem, Inc. in Arizona. All method blanks, laboratory spikes and/or matrix spikes met quality control objectives.

Exposure Pathway Analysis

Identifying exposure pathways is important in a health consultation because adverse health impacts can only happen if people are exposed to contaminants. The presence of a contaminant in the environment does not necessarily mean that people are actually coming into contact with that contaminant. Exposure pathways have been divided into three categories: completed, potential, and eliminated.

There are five elements considered in the evaluation of exposure pathways: (1) a <u>source</u> of contamination, (2) a <u>media</u> such as soil or ground water through which the contaminant is transported, (3) a <u>point of exposure</u> where people can contact the contaminant, (4) a <u>route of exposure</u> by which the contaminant enters or contacts the body, and (5) a <u>receptor</u> population. Completed pathways exist when all five elements are present and indicate that exposure to a contaminant has occurred in the past and/or is occurring presently. In a potential exposure pathway, one or more elements of the pathway cannot be identified, but it is possible that the element might be present or might have been present. ADHS generally evaluates completed and potential pathways to determine if there are potential public health impacts. In eliminated pathways, at least one of the five elements is or was missing, and will never be present. Completed and potential pathways, however, may be eliminated when they are unlikely to be significant.

The most likely human exposures in the area are occasional ingestion or infrequent dermal contact with contaminated surface soil. This exposure occurs when people have direct contact with soils in their environment. For instance, when children play outside, or when adults walk dogs, contaminated soil or dust particles can cling to their hands. People can then accidentally swallow the contaminants when they put their hands on or into their mouths, as children often do. Factors that affect whether or not people have contact with contaminated soil include the amount of grass cover, weather conditions, the amount of time spent outside, and personal habits. While dermal and inhalation exposure can sometimes be a concern for soil and dust, the primary pathway of concern is ingestion. Table 1 summarizes the pathways for this site. If one or more of the exposure pathways are potential or complete, ADHS then considers whether exposure to the chemicals present may be harmful to people.

Table 1. Exposure pathway evaluation

Exposure Pathway Elements					Time Frame	Type of Exposure Pathway
Source	Media	Point of Exposure	Route of Exposure	Estimated Exposed Population		
Contaminated soil	Soil	Residences, Roads	Incidental Ingestion, inhalation, dermal contact	Residents	Past	Potential
					Current	Completed
					Future	Potential

Comparison to environmental and health-based comparison values

The environmental and health-based comparison values (CVs) are screening tools used with environmental data relevant to the exposure pathways. The environmental and health-based CVs are concentrations of contaminants that the current public health literature suggest are “safe” or “harmless.” These comparison values are quite conservative, because they include ample safety factors that account for most sensitive populations. ADHS typically uses comparison values as follows: if a contaminant is never found at levels greater than its CV, ADHS concludes the levels of corresponding contamination are “safe” or “harmless.” If, however, a contaminant is found at levels at greater than its comparison value, ADHS designates the pollutant as a *contaminant of interest* and examines potential human exposures in greater detail.

Comparison values are based on extremely conservative assumptions. Depending on site-specific environmental exposure factors (e.g. duration and amount of exposure) and individual human factors (e.g. personal habits, occupation, and/or overall health), exposure to levels greater than the comparison value may or may not lead to a health effect. Therefore, the comparison values should not be used to predict the occurrence of adverse health effects.

The TCLP analysis stimulates landfill conditions. The results are used to determine how metals would leach out from a municipal landfill. Table 2 is a summary of results from the TCLP tests. All measured concentrations were below the current regulatory levels. Table 3 shows the analytical results of the RCRA 8 metal analysis. ADHS used the 95% upper confidence limit (UCL) of the arithmetic mean as the exposure point concentration as recommended by the ATSDR and EPA (ATSDR 2011; USEPA 1992). The 95% UCL is used as an estimate of the average soil concentration. It is used because it is a conservative (protective) way to estimate the average concentration of contaminants someone might be exposed to. The statistical software ProUCL was used to estimate the 95% UCL. When the data does not allow the use of ProUCL, the maximum detected value was used as an estimate of the exposure point concentration (USEPA 2010). Arsenic and manganese kept for further evaluation because the 95% UCL concentrations exceeding the Arizona Soil Remediation Levels (SRL) for residential area (see Table 3).

Table 2. Analytical results for the Toxicity Characteristic Leaching Procedure (TCLP) Test. The samples were collected from various locations at Cibola, Arizona from June to November 2007.

Chemical	Number of samples	Range of detected concentrations (mg/L)	95% UCL of the Average Concentration[1] (mg/kg)	Health-based comparison values (CVs) (mg/L)	Number of samples exceeded CV	Is it a contaminant of interest?
Arsenic	5	< 1	1	5	0	No
Barium	7	< 5	5	100	0	No
Lead	5	< 1	1	5	0	No

* EPA TCLP standard

Table 3. A summary of the measured total metal concentrations in soil samples collected from various locations at Cibola, Arizona from June to November 2007.

Chemical	Number of samples	Range of detected concentrations (mg/kg)	95% UCL of the Average Concentration[1] (mg/kg)	Health-based comparison values (CVs) (mg/kg)		Number of samples exceeded CV	Is it a contaminant of interest?
Arsenic	12	<5 – 36	27.9	10	r-SRL[2]	7	**Yes**
Barium	12	110 – 5,600	3,517	15,000	r-SRL	0	No
Cadmium	12	< 1 – 8.7	8.7	39	r-SRL	0	No
Chromium	12	< 5 – 8.7	8.7	30[3]	r-SRL	0	No
Lead	12	< 5 – 110	110	400	r-SRL	0	No
Manganese	12	110 – 20,000	12,986	3,300	r-SRL	7	**Yes**
Mercury	11	< 0.083	0.083	23	r-SRL	0	No
Selenium	12	< 5 – 5.1	5.1	390	r-SRL	0	No
Silver	12	< 5	5	390	r-SRL	0	No

1. 95% upper confidence limit (UCL) of the arithmetic mean
2. r-SRL: Arizona Residential-Soil Remediation Level
3. Based on chromium (VI) r-SRL

Public Health Implications: This section will provide general toxicological information and site-specific exposure evaluation. In this evaluation, soil concentrations in residential yards are assumed to be equal to the soil samples collected from the field because no residential soil sample is available.

Arsenic

Arsenic is widely distributed in the earth's crust, which contains about 3.4 milligrams per kilogram (mg/kg). It is mostly found in nature as minerals, and in its elemental form only to a small extent. Typical arsenic concentrations for uncontaminated soils range from 1 to 40 mg/kg (ATSDR 2005). The average arsenic concentration in Arizona soil is about 10 mg/kg.

To determine whether harmful effects might be possible, ADHS reviewed the numerous studies documenting the effects of arsenic in humans. Several factors should be considered when evaluating the potential for harm associated with arsenic in soil, include bioavailability[1], pica-like behavior in children, and carcinogenic[2] effect. For purposes of human health risk assessment, EPA evaluated numbers of studies of relative bioavailability of arsenic and recommended the use of an oral bioavailability factor of 0.25 in soil (USEPA 2001). Children and children with soil-pica behavior are a special concern for acute exposures because ingesting large amounts of soil could lead to significant arsenic exposure. Children who eat large amounts of soil exhibit soil-pica behavior. Soil-pica behavior is most likely in preschool children as part of their normal exploratory activities. General pica behavior is greatest in children aged 1–2 years and decreases with age.

ADHS used the maximum soil arsenic concentration of 36 mg/kg to estimate site-specific exposures. Because ProUCL was not able to provide a reliable 95% UCL estimate for arsenic due to the numbers of non-detected samples. The estimated doses are compared to acute and chronic minimum risk levels (MRLs). Appendix B shows the formula and values used to estimate the daily exposures. ATSDR developed a provisional acute and chronic oral MRL for arsenic of 0.005 milligrams of arsenic per kilogram of body weight per day (mg/kg/day) and 0.0003 mg/kg/ day, respectively. The MRL is an exposure level below which non-cancerous harmful effects are unlikely. The acute MRL is based on several transient (i.e. temporary) effects, including nausea, vomiting, and diarrhea. It should be noted that

- The acute MRL is 10 times below the levels that are known to cause harmful effects in humans,
- The acute MRL is based on people being exposed to arsenic dissolved in water instead of arsenic in soil — a fact that might influence how much arsenic can be absorbed, and
- The chronic MRL of 0.0003 mg/kg per day is about 46 times below the lowest observed adverse effect level[3] (LOAEL) of 0.014 mg/kg per day
- The MRL applies to non-cancerous effects only and is not used to determine whether people could develop cancer

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[1] Bioavailability is the amount of a contaminant that is absorbed into the body following skin contact, ingestion, or inhalation.

[2] "Carcinogen" or "carcinogenic" means the potential of a contaminant to cause cancer in humans as determined by lines of evidence in accordance with a narrative classification in "Guidelines for Carcinogen Risk Assessment", EPA/630/P-03/001F, March 2005, (and no future editions), which is incorporated by reference.

[3] The lowest tested dose of a substance that has been reported to cause adverse health effects in people or animals.

Based on the assumed exposure scenario, pica-children, children (< 6 years old) and adults are not likely to experience non-cancerous harmful health effects from acute or chronic arsenic in soil (see Table 4).

The Department of Health and Human Services, the International Agency for Research on Cancer and U.S. EPA have determined that arsenic is carcinogenic to humans (ATSDR 2005; USEPA 2011). This is based on evidence from many studies of people who were exposed to arsenic-contaminated drinking water, arsenical medications, or arsenic-contaminated air in the workplace for exposure durations ranging from a few years to an entire lifetime. For site-specific exposures, ADHS used a mathematical model to estimate a theoretical opportunity of a person developing cancer from ingestion of arsenic contaminated soil. The slop factor (1.5 per mg/kg/day) used in the cancer risk estimation is published at Integrated Risk Information System (IRIS) by EPA on 4/10/1998. The estimated theoretical cancer risk is 2.6×10^{-5}, which is within the range of public health guideline (10^{-6}~10^{-4}) for protection of human health as suggested by the EPA. This cancer risk is considered to be moderate based on the qualitative ranking of cancer risk estimates (see Appendix C). Therefore, ADHS determined it is unlikely that people would experience cancer effects from arsenic contaminated soil.

Table 4. Estimation of the chronic daily intakes from ingestion of arsenic-contaminated soil.

<table>
<tr><td colspan="5">Acute Exposure</td></tr>
<tr><td>Population</td><td>Soil Concentration (mg/kg)</td><td>Soil Intake (mg/day)</td><td>Estimated Dose (mg/kg/day)</td><td>MRL (mg/kg/day)</td></tr>
<tr><td>Pica-child</td><td>36</td><td>1,751</td><td>0.00175</td><td>0.005</td></tr>
<tr><td colspan="5">Chronic Exposure</td></tr>
<tr><td>Population</td><td>Soil Concentration (mg/kg)</td><td>Soil Intake (mg/day)</td><td>Estimated Dose (mg/kg/day)</td><td>MRL (mg/kg/day)</td></tr>
<tr><td>Adult</td><td>36</td><td>100</td><td>0.00001</td><td rowspan="3">0.0003</td></tr>
<tr><td>Child (< 6 years old)</td><td>36</td><td>200</td><td>0.00012</td></tr>
<tr><td>Pica-child</td><td>36</td><td>1,751</td><td>0.00017</td></tr>
</table>

Manganese

Manganese is a naturally occurring element can be found in rock, soil, water and food. In humans and animals, it is an essential nutrient, and eating a small amount of it is important to stay healthy. It helps the body to form connective tissue, bones, and blood-clotting factor. It also plays a role in fat and carbohydrate metabolism, calcium absorption and is necessary for normal brain and nerve function (FBN 2002; ATSDR 2008). Although manganese is essential for normal physiological functions, excess intakes through ingestion or inhalation may cause some adverse effects. EPA has classified manganese as group D: not classifiable as to human carcinogenicity (ability to cause cancer) because the information regarding the carcinogenicity in human or animal is no available or inadequate (IRIS 2011).

Manganese shows low acute oral toxicity in animal studies when provide in feed. Nervous system is the primary organ for mid- to long-term exposure through ingestion, and is a sensitive organ with respect to young children. Neurotoxicity from ingested manganese has been reported. In an aged population (> 67 years), ingestion of drinking water with high concentrations of manganese (1.8–2.3 mg/L) was linked to the onset of unspecified neurological symptoms (Kondakis et al. 1989b). Kawamura et al. (1941) also reported that a small Japanese community (25 individuals) ingested high levels of manganese (29 mg/L) in contaminated well water over a three-month period. Observed symptoms in the community included lethargy, increased muscle tonus, tremor, mental disturbances, and even death. Children seemed to be less affected than adults. In contrast, two other studies indicated that oral exposure to excess inorganic manganese resulted in measurable signs of preclinical neurotoxicity in children. These studies show that children, who drank water or ate food with increased manganese content, performed less well in school and on the WHO neurobehavioral core test battery (Zhang et al. 1995; He et al. 1994).

EPA derived oral references dose (RfD) for manganese: 0.14 mg/kg/day from food only and 0.047 mg/kg/day from contaminated water or soil (IRIS 2011). These values were derived based on the following studies. First, the Food and Nutrition Board (FNB) of the National Research Council determined an "estimated safe and adequate daily dietary intake" (ESADDI) of manganese to be 2-5 mg/day for adults (FNB 1989). FNB also considered that an occasional intake of 10 mg/day to be safe. Second, the World Health Organization (WHO 1973) reported that average consumption of manganese ranged from 2.2-8 mg/day. The high manganese intakes are associated with diets high in whole-grain cereals, nuts, green leafy vegetables, and tea. The WHO indicated that 2-3 mg/day is adequate for adults and 8-9 mg/day is "perfectly safe." Third, Freeland-Graves et al. (1987) determined that standard American diets provide an average manganese intake of 2.3-8.8 mg/day. From these studies, EPA concludes that an appropriate no observed adverse effect level[4] (NOAEL) for manganese is 10 mg/day (0.14 mg/kg/day based on 70 kg body weight). EPA applies an uncertainty factor of 1 to calculate the RfD for exposure food because the supporting studies involved large populations consuming normal diets over an extended period of time with no adverse health effects. However, EPA recommends a modifying factor of 3 in computing the RfD for exposure from water or soil. The recommendation is mainly based on: (1) a concern about possible adverse health effects associated with a lifetime consumption of drinking water containing about 2 mg/L of manganese raised in the Kondakis et al. study (1999); and (2) evidence that neonates absorb more manganese from the gastrointestinal tract, are less able to excrete absorbed manganese, and absorbed manganese more easily passes their blood-brain barrier.

Based on the assumed exposure scenarios, the estimated chronic daily intake for adults did not exceed the soil and water RfD for manganese recommended by EPA (see Table 5). Therefore, they are not likely to experience adverse health effects. The estimated chronic daily intakes for pica-children, children (< 6 years old) exceeded the EPA's RfD. Although there is no firm conclusions were considered possible regarding a critical effect level of chronic intake versus essential dietary levels of manganese (ATSDR 2008), the estimated levels of chronic daily intake exceeded the NOAEL recommended by the EPA and FNB. Therefore, ADHS determined that

[4] The highest tested dose of a substance that has been reported to cause no adverse health effects in people or animals

the detected level of manganese in contaminated soil may cause harmful effects in pica-children and children under the assumed exposure scenarios.

Table 5. Estimation of the chronic daily intakes from ingestion of manganese-contaminated soil.

Population	Soil Concentration (mg/kg)	Soil Intake (mg/day)	Estimated Dose (mg/kg/day)	Reference Dose (mg/kg/day)
Adult	12,986	100	0.018	0.047
Child (< 6 years old)	12,986	200	0.166	
Pica-child	12,986	1,751	0.249	

ATSDR Child Health Considerations

ADHS considers children in its evaluations of all exposures, and we use health guidelines that are protective of children. In general, ADHS assumes that children are more susceptible to chemical exposures than are adults. Children six years old or younger may be more sensitive to the effects of pollutants than adults. Children generally have lower body weights, breathe more air by body weight and air that is closer to the ground, and are more often in contact with the ground than adults. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. The CVs used in this health consultation were developed to be protective of susceptible populations such as children.

Studies showed that children, who exposed to elevated levels of manganese in drinking water and/or foods, performed less well in school and on the WHO neurobehavioral core test battery (Zhang et al. 1995; He et al. 1994). Evidence showed that neonates absorb more manganese from the gastrointestinal tract, are less able to excrete absorbed manganese, and absorbed manganese more easily passes their blood-brain barrier (IRIS 2011).

Conclusions

Arsenic: the detected levels of arsenic in contaminated soil are not expected to harm the health of people, including pica-children, children (< 6 years old) and adults. Based on the assumed exposure scenarios, the estimated chronic daily intakes were below the health-based guidelines for acute or chronic noncancerous adverse health effects. In addition, the estimated theoretical excess lifetime cancer risks was within the range of public health guidelines (10^{-6}~10^{-4}) for protection of human health as suggested by EPA. The cancer risk is considered to be moderate based on the qualitative ranking of cancer risk estimates. Therefore, ADHS does not consider that there is a health threat to people who expose to arsenic in the contaminated soil.

Manganese: the detected levels of manganese in contaminated soil are not expected to harm the health of adults. However, at these levels, the estimated chronic daily intakes for pica-children and children were above the health-based guidelines, and the NOAEL. Therefore, based on the assumed exposure scenarios, it may harm the health of small children (< 6 years old), especially

pica-children who consume excess amount of soil. Therefore, ADHS determined that the detected level of manganese in contaminated soil is a public health hazard to the pica-children, and children under 6 years old.
Soil samples evaluated in this health consultation were not collected from residential yards. ADHS recommends that ADEQ to collect additional residential soil samples to better characterize the exposure and health risk among young children.

Recommendations

- ADEQ works with potential responsible parties to collect additional soil samples from residential area to better characterize the exposure and health risk among young children
- If no additional residential soil samples were collected, ADEQ should work with potential responsible parties to conduct remedial activities.
- ADEQ works with potential responsible parties to provide warnings or advices to local residents before the additional soil sampling or remediation activities are completed.

Public Health Action Plan

- ADHS will continue to review and evaluate soil results from the site when data are acquired by ADEQ or other agencies overseeing the site.
- ADHS will attend public meetings, make presentations, and develop educational information on the public health implications of soil contaminants when requested by the community, and ADEQ.

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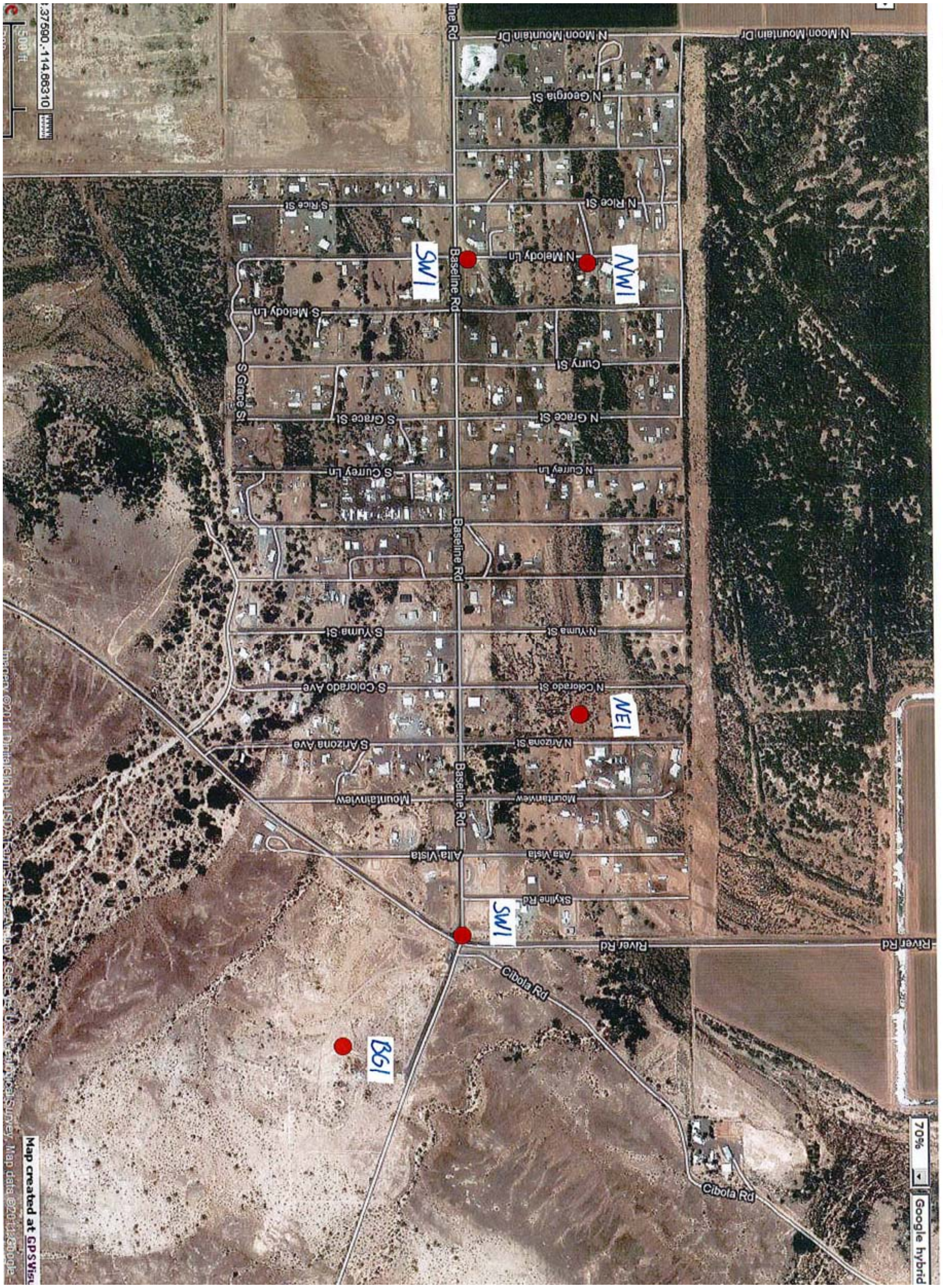
Appendix A



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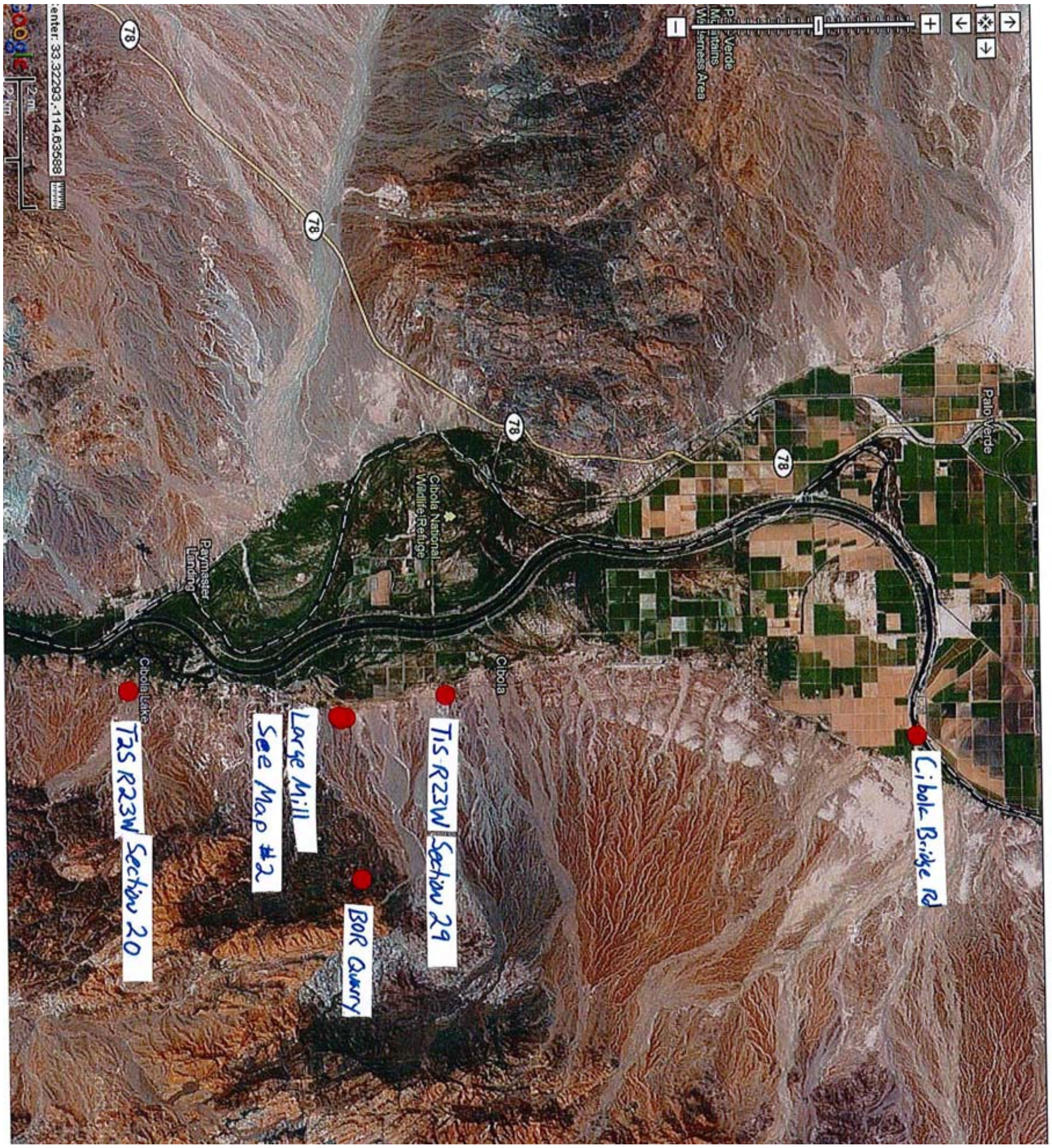

Sampling location. Map are provided by Arizona Department of Environmental Quality (ADEQ).

Appendix B

Formula and assumptions used to calculate chronic daily intakes and cancer risk from soil ingestion:

$$\text{Chronic Daily Intake (mg/kg/day)} = \frac{C_s \times \text{BA} \times \text{IR} \times \text{CF} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

$$\text{Cancer Risk} = \text{Chronic Daily Intake} \times \text{SF}$$

Variable			Arsenic			Manganese		
			A	C	PC	A	C	PC
C_s	Soil chemical concentration	mg/kg	36			12,986		
BA	bioavailability	—	0.25			1		
IR	Ingestion rate	mg/day	200	100	1,751	200	100	1,751
CF	Conversion factor	kg/mg	0.000001			0.000001		
EF	Exposure frequency	days/year	350	350	36	350	350	36
ED	Exposure duration	years	30	5	1	30	5	1
BW	Body weight	kg	70	15	9	70	15	9
AT	Averaging time	days	10,950	2,190	365	1,0950	2,190	365
SF	Slope Factor	$(\text{mg/kg/day})^{-1}$	1.5			—		

A: Adult; C: Child (< 6 years old); PA: pica-child

Appendix C

Qualitative Descriptors for Excess Lifetime Cancer Risk

Cancer Risk	Qualitative Descriptor
Equal to or less than one per million (Cancer Risk $\leq 10^{-6}$)	Very Low
Greater than one per million to less than one per ten thousand ($10^{-6} <$ Cancer Risk $\leq 10^{-5}$)	Low
Greater than one per ten thousand to less than one per thousand ($10^{-5} <$ Cancer Risk $\leq 10^{-4}$)	Moderate
Greater than one per thousand to less than one per ten ($10^{-4} <$ Cancer Risk $< 10^{-1}$)	High
Equal to or greater than one per ten (Cancer Risk $\geq 10^{-1}$)	Very High

An estimated increased excess lifetime cancer risk is not a specific estimate of expected cancers. Rather, it is a plausible upper-bound estimate of the probability that a person may develop cancer sometime in his or her lifetime following exposure to that contaminant.

There is insufficient knowledge of cancer mechanisms to decide if there exists a level of exposure to a cancer-causing agent below which there is no risk of getting cancer, namely, a threshold level. Therefore, every exposure, no matter how low, to a cancer-causing compound is assumed to be associated with some increased risk. As the dose of a carcinogen decreases, the chance of developing cancer decreases, but each exposure is accompanied by some increased risk.

There is general consensus among the scientific and regulatory communities on what level of estimated excess cancer risk is acceptable. The EPA considers an acceptable cancer risk range from 10^{-6} to10^{-4}.