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WILL HUMBLE, DIRECTOR

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Dear [redacted]

Re: Arsenic in Well Water

In order to address your concerns regarding chemicals in the well water, the Arizona Department of Health Services (ADHS) completed a letter health consultation. Funding for this letter health consultation came from a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) and the U. S. Department of Health and Human Services. This document has not been reviewed or cleared by ATSDR. In this report, ADHS reviewed water samples collected from the "New" and "Old" wells. ADHS then conducted an assessment of the results to evaluate if a person's health could be harmed if this water is used for drinking or cooking.

Background and Statement of Issue

The Arizona Department of Health Services Office of Environmental Health was contacted by phone from [redacted] on August 30, 2012, about a potential arsenic contamination of well water in [redacted], Arizona. According to the individual, the well is shared by four homes. These homes include four children: [redacted] One of his neighbors had a sample (kitchen tap inside the house) tested by Legend and received a positive result for arsenic in the water at 1200 ppb. (He called back on August 30, 2012, and stated the As (III) levels were 1250 ppb). The individual also stated that a new sample was being tested. The resident expressed concern about the health effects of arsenic (III vs. V) and wanted to know if any cleaning protocols should be followed to clean his well and items in his home. He stated as a precaution he is having the well turned off, his storage tank emptied, and fresh non-well water put in the tank. ADHS responded by stating not to use the water if arsenic levels exceeded 200 ppb. The resident also stated he used an RO system. ADHS recommended calling the manufacturer to see if the system will remove arsenic and to maintain the system on the recommended schedule. Based on this information, a request was made to use the ADHS laboratory to test additional samples for comparative analysis to confirm or rule out the contamination of the original sample. The ADHS laboratory emailed the resident and stated they would test the water for arsenic using a water drinking method. If a home contained a water filtration system, the post-filtered water would be tested. The resident replied stating he was interested, but would be out of town for the week. ADHS received lab results October 4th. ADHS decided to review the lab results and prepare a Letter Health Consultation.

Discussion

General Assessment Methodology

ADHS generally follows a three-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 exposures are sufficient to impact public health.

Available Environmental Data

We conducted the assessment based on the laboratory reports provided by you. The LEGEND Technical Services, Inc conducted analyses on groundwater collected from New well and Old well. The reports indicated that (1) the New well contains 1.13 milligrams of arsenic per liter of water (mg/L), 1.67 mg/L nitrate as nitrogen and 0.15 mg/L nitrite as nitrogen; (2) the Old well contains 0.0105 mg/L arsenic, 14.2 nitrate as nitrogen and <0.1 nitrite as nitrogen.

Exposure Pathway Analysis

Identifying exposure pathways is important in conducting 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
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. 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.

You and nearby residents can be exposed to arsenic and nitrate from using the well water for domestic purposes. Typical potable well exposures to contaminants include dermal exposures from bathing and showering, and ingestion exposures from drinking and using water for cooking. Metals tend not to be absorbed through the skin, and are not likely to be available to people as aerosol while showering because they are not volatile (i.e. do not evaporate).

Comparison to Health-based Comparison Values for Groundwater Well Samples

The health-based comparison values (CVs) are screening tools used with environmental data relevant to the exposure pathways. The health-based CVs are concentrations of contaminants that the current public health literature suggests are "harmless." These comparison values are quite conservative, because they include ample safety factors that account for the 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 that are 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.

Chemical	Well Names	Detected Concentration (mg/L)	Comparison Value (CV) (mg/L)	Source of CV	Is it a Contaminant of Interest?
Arsenic	New well	1.13	0.01	MCL	**Yes**
	Old well	0.0105			**Yes**
Nitrate as nitrogen	New well	1.67	10	MCL	No
	Old well	14.2			**Yes**
Nitrite as nitrogen	New well	0.15	1	MCL	No
	Old well	<0.1			No

MCL: EPA Maximum Contaminant Level

***Public Health Implications**: This section will provide general toxicological information and site-specific exposure evaluation.*

Arsenic:
Arsenic is a naturally occurring element widely distributed in the earth's crust and can be found in air, water and soil. In Arizona, background levels for arsenic are: 10 mg/kg for soil, and 28–40 μg/L for groundwater (AAC 2004). Arsenic exists as inorganic arsenic, organic arsenic and arsine gas. In general, organic arsenic is less toxic than inorganic arsenic. The general population is likely to be exposed to arsenic through food and water ingestion. The average dietary exposures to total arsenic are: 50.6 μg/day for female and 58.5 μg/day for male. Fish and seafood contain the highest concentrations of arsenic; however, most of this is the less toxic organic form of arsenic (ATSDR 2007).

Absorption: After absorption, arsenic distributed throughout the body and some may accumulate in the nails, hair, bone and skin. Most of the arsenic taken into the body excreted within one week of exposure. Although there are only a few studies on absorption through the skin, they indicate that only a small percentage is absorbed by skin.

Non-Cancer Health Effects

Short-term Exposure (0-14 days): Drink water containing high levels of arsenic (60 mg/L) can result in death. Drink lower levels of arsenic-containing water (0.3–30 mg/L) can cause irritation in stomach and intestines, with symptoms such as stomachache, nausea, vomiting, and diarrhea (ATSDR 2007). Mizuta et al. (1956) reported an arsenic poisoning incident in Japan. Two hundred and twenty poisoned individuals were exposed to arsenic contaminated soy sauce (0.1 mg/mL, probably as calcium arsenate) for approximately 2–3 weeks. The primary symptoms were edema of the face, and gastrointestinal (nausea, vomiting and diarrhea) and upper respiratory symptoms initially, followed by skin lesions and neuropathy in some patients. The estimated consumption of arsenic is about 3 mg/day (i.e. 0.05 mg/kg/day, assuming 55-kg body weight for the Asian population). ATSDR established an acute minimal risk level[1] (MRL) of 0.005 mg/kg/day based on the characteristics of the initial poisoning and an uncertainty factor of 10 for using Low Observed Adverse Effect Level (LOAEL)[2] (ATSDR 2007).

Using the detected concentration, the estimated exposure doses for New well are: 0.032 mg/kg/day for adults, 0.075 mg/kg/day for 1-6 year old children, and 0.113 mg/kg/day for 0-1 year old infants, and the estimated exposure does for old well are: 0.0003 mg/kg/day for adults, 0.0007 mg/kg/day for 1-6 year old

[1] Minimal Risk Level (MRL): it represents the daily dose of a chemical that people could be exposed to for a specific period of time without experiencing adverse health effects. There should be no risk for developing non-cancer health effects at an exposure dose less than the MRL. If the MRL is exceeded, further evaluation is needed to determine if health effects may occur.

[2] The lowest exposure level at which there are biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group

children and 0.0011 mg/kg/day well for 0-1 year old infants. The estimated exposure levels for Old well did not exceed the acute MRL. Yet, the estimated exposure levels for New well not only exceeded the acute MRL but also approaches (or exceeded) the LOAEL of 0.05 mg/kg/day. Therefore, *adults and young children can show symptoms associated with short-term exposure after drinking water from the New well for a few weeks.*

Long-term Exposure (> 365 days): In humans, skin is the most sensitive target organ after ingesting arsenic for a long period of time. Typical effects include hyperkeratosis (patches of hardened skin, especially on the palms of the hands and soles of the feet), hyperpigmentation of the skin, and changes in the blood vessels of the skin. These symptoms typically begin to manifest at exposure levels of about 0.002–0.02 mg/kg/day. Ingestion of arsenic can also result in effects on other organs such as cardiovascular and respiratory organ systems. Nausea, vomiting and diarrhea are also common symptoms in humans after repeated exposure to low doses of arsenic; their effects are due to a direct irritation of the gastrointestinal mucosa (ATSDR 2007).

ATSDR established a chronic MRL of 0.0003 mg/kg/day based on the incidence of Blackfoot Disease and dermal lesions (hyperkeratosis and hyperpigmentation) in a population exposed to high levels of arsenic well water in Taiwan. The control-, low-, medium-, and high-exposure levels correspond to doses of 0.0008, 0.014, 0.038, and 0.065 mg/kg/day, respectively. The identified NOAEL is 0.0008 mg/kg/day. Hyperpigmentation and keratosis of the skin (less serious LOAEL) were observed in the low-level exposure group, and increased incidences of dermal lesions were observed in the medium- and high-level exposure groups. The identified NOAEL is limited by the fact that the majority of the population was <20 years of age and the incidence of skin lesions increased as a function of age, and because the estimates of water intake and dietary arsenic intake are highly uncertain (ATSDR 2007). The NOAEL would be doubled (0.0016 mg/kg/day) by using the arsenic dietary intakes from rice and yams based on the food analyses conducted by Schoof et al (1998).

Both New and Old wells had arsenic concentrations that exceeded the MCL of 10 ppb (0.01 mg/L). ADHS estimated the daily exposure dose for long term exposure for children and adults. The estimated values were compared to health guideline values (i.e. MRL) to determine if the users of the wells were at risk for non-cancer health effects. There should be no risk for developing non-cancer health effects at an exposure dose less than the MRL of 0.0003 mg/kg/day. If the MRL is exceeded, further evaluation is needed to determine if health effects may occur. There could be concern if the estimated exposure dose approaches the LOAEL of 0.014 mg/kg/day (within an order of magnitude). The following table shows estimated daily exposure levels for adults and young children. *The results indicated that adults and young children may have increased chance to develop non-cancerous health effects (dermal toxicity) if they consume groundwater from the New well for a long time.*

Well Name	Estimated Exposure Level (mg/kg/day)		
	10-kg Child	16-kg Child	Adults
New well	0.1084	0.0722	0.0310
Old well	0.0010	0.0007	0.0003

Cancer Health Effects

Arsenic has been identified as a known human carcinogen. Ingestion of arsenic can increase the risk for developing cancers of skin, lung, bladder, and to a less extent, kidney, liver and prostate (ATSDR 2007). EPA has calculated an oral cancer slope of 1.5 $(mg/kg/day)^{-1}$ (EPA 2012). ADHS conducted a cancer risk evaluation to determine if drinking the water in these wells over many years could result in an additional increased risk for cancer. A cancer risk is estimated by using EPA cancer slope factor with the estimated exposure dose (Appendix A). These calculated values may not represent actual risk, but allows regulatory and public health officials a way to identify potential cancer risks. Cancer risks are explained in terms of the likelihood that an additional case of cancer will occur in a population. For example, one additional cancer case in 10,000 exposed individuals indicates that there is a low cancer risk (Appendix B).

ADHS conducted a cancer risk evaluation by using the measured arsenic concentrations and the EPA's standard cancer risk evaluation methodology. The estimated additional cancer risks from consuming arsenic-contaminated well water for 30 years were 2×10^{-2} for the New well, and 1.8×10^{-4} for the Old well. According to EPA, it is considered to be protective of the public health if the estimated excess lifetime cancer risk is below or within the range of 1 in 1,000,000 to 1 in 10,000 (10^{-6} to 10^{-4}). *The cancer risk due to exposure to arsenic from the New well is considered to be High, and the cancer risk due to exposure to arsenic from the Old well is considered to be Moderate based on the qualitative ranking of cancer risk estimates (Appendix B).*

Nitrate as Nitrogen:
Nitrate is a natural occurring inorganic ion, and is part of the nitrogen cycle. Nitrates (e.g. potassium nitrate and ammonium nitrate) are common ingredients of fertilizer. The most serious health concern caused by nitrate in drinking water is methemoglobinemia or "blue-baby" syndrome. It is a condition where the blood cannot carry enough oxygen to body cells or tissues.

Infants, especially those under 4 months of age, are more susceptible to the nitrate exposure due to underdeveloped digestive system favoring the growth of nitrate-reducing bacteria. These bacteria can convert ingested nitrate (NO_{3-}) to nitrites (NO_2^-). Nitrites can react with hemoglobin, the oxygen carrier in the blood found in red blood cells, to form methemoglobin (an abnormal form of hemoglobin incapable of carrying oxygen) (ATSDR 2011). Oxygen deficiency can cause the baby to look blue, slate-grey, or chocolate brown (cyanosis) because there is too much methemoglobin (10-20% of total hemoglobin) in the blood. Other adverse reactions include labored breathing, headache, dizziness, nausea, vomiting, and diarrhea at methemoglobin levels between 20-45% of total hemoglobin. If concentrations of methemoglobin increase even further (45-55% of total hemoglobin), irregular heartbeat, shock, convulsions, or coma may result. At methemoglobin levels greater than 70%, death may result (ATSDR 20011).

Most adults and older children (> 6 months) will not be affected by nitrate because their red blood cells will quickly convert back to normal. However, some people may have conditions that make them more susceptible to elevated level of nitrate in drinking water. They include: (1) individuals who do not have enough stomach acids, which promotes the conversion of nitrates to nitrites; (2) individuals with an inherited lack of methemoglobin reductase (enzyme that converts affected red blood cells back to normal) or an abnormal hemoglobin molecule as in hemoglobin M; (3) pregnant women around the 30^{th} week of pregnancy because their methemoglobin level naturally increases (ATSDR 2011, EPA 2012).

The EPA determined a reference dose of 1.6 mg/kg/day for infants (the most sensitive population) based on various studies of infant methemoglobinemia. It was based on the NOAEL of 10 mg/L (1.6 mg/kg/day) with an uncertainty factor of 1. EPA also determined the LOAEL to be 11-20 mg/L (1.8-3.2 mg/kg/day). For people consume water from the Old well, the estimated daily intakes are 0.39 mg/kg/day for adults, 0.89 mg/kg/day for 1-6 year old children and 1.42 for 0-1 year old children. These values did not exceed the reference dose set by the EPA. *The results indicated that both young children and adults are not likely to experience adverse effects from consuming water from the Old well.*

Conclusion

Based on the available information, ADHS concludes that:

(1) Arsenic:

Old Well: People consume water from the Old well are not likely to develop symptoms associated with short-term exposure or non-cancerous adverse health effect. The estimated lifetime cancer risk due to exposure to arsenic from the Old well (1.8×10^{-4}) is within the range of public health guidelines (10^{-6}~10^{-4}) for protection of human health as suggested by the EPA. It is considered to be Moderate based on the qualitative ranking of cancer risk estimates (Appendix B).

New Well: People consume water from the New well can have increased chance to develop adverse (both non-cancerous and cancerous) health effects. Adults and children can also show symptoms associated with short-term exposure after drinking water from the New well for a few weeks.

The estimated lifetime cancer risk due to exposure to arsenic from the New well (2×10^{-2}) exceeded the range of public health guidelines (10^{-6}~10^{-4}) for protection of human health as suggested by the EPA. It is considered to be High based on the qualitative ranking of cancer risk estimates (Appendix B).

(2) Nitrate as Nitrogen

Adults and you children are not likely to experience adverse health effects from consuming water from both New well and Old well. Although the detected concentration of nitrate as nitrogen exceeded the MCL but the estimated daily exposure levels for adults and young children were within the reference dose set by the EPA.

Recommendation

Water testing
ADHS recommends testing wells at least annually for potential acute contaminants such as bacteria and nitrates, and every 3 years for chronic contaminants including arsenic, radon, uranium, lead and copper. If any parameter is found to be above the recommended levels, a confirmation sample should be collected before making any decisions regarding water treatment.

Arsenic III vs. V
Arsenic in natural waters is present predominantly as two types: Arsenic-III and Arsenic-V. The presence of these types can be important for the selection of treatment. At ambient water pH 6 to 9, the predominant forms are:

- As-III (Arsenite) present as Arsenious Acid H_3AsO_3 (no charge)
- As-V (Arsenate) present as anions $H_2AsO_4^-$ and $HAsO_4^{2-}$

Although some technologies can reduce both forms of arsenic, their efficiency for removal of Arsenic-III is drastically lower. For this reason, DES recommends testing for Arsenic-III before selecting a treatment system.

References

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Sincerely,

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Appendix A

Chronic Daily Intake from Water

$$ED_{water} = \frac{Conc. \times IR \times EF \times ED}{BW \times AT}$$

ED_{water}: chronic daily exposure via water ingestion (mg/kg/day)
Conc.: chemical concentration in water (mg/L)
IR: water ingestion rate (L/day)
EF: exposure frequency (day/year)
ED: exposure duration (year)
BW: body weight (kg)
AT: averaging time (day)

Excess Lifetime Cancer Risk Calculation

$$CR = ED_{water} \times SF$$

CR: cancer risk
ED_{water}: chronic daily exposure from water ingestion (mg/kg/day)
SF: slop factor $(mg/kg/day)^{-1}$

Appendix B

Qualitative Descriptors for Excess Lifetime Cancer Risk

ADHS estimated increased excess lifetime cancer risks by using site-specific information on exposure levels, and cancer potency derived by authoritative agencies, such as USEPA, Cal EPA and others. ADHS then ranked the excess lifetime cancer risk from very low to very high based on the qualitative ranking of cancer risk estimates developed by the New York State Department of Health (http://www.health.ny.gov/environmental/investigations/hopewell/appendc.htm). For example, if the qualitative descriptor was "low", then the excess lifetime cancer risk from that exposure is in the range of greater than one per million to less than one per ten thousand. Other qualitative descriptors are listed below:

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}.