Division of Public Health Services

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JANICE K. BREWER, GOVERNOR
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March 21, 2014

Dear Mrs. [redacted]

RE: Groundwater Well Analytical Results

The Arizona Department of Health Services (ADHS) received your request to evaluate the quality of the water collected from your kitchen sink. ADHS conducted an evaluation to determine if the water can be used for drinking, cooking, laundry, showers, and washing dishes. The following summarizes our methodology and assessment results.

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

A grab water sample was collected from the kitchen sink. The Legend Technical Services, Inc. conducted an analysis to determine the presence of microorganisms (total coliforms and E. Coli) as well as the concentrations of metals (arsenic, copper and lead), and nitrate/nitrite as nitrogen. The results indicated that the water sample contained (1) Total coliforms, (2) 0.349 milligrams per liter (mg/L) of arsenic, 0.01 mg/L of copper and < 0.001 mg/L of lead, and (3) 12.1 mg/L of nitrate as nitrogen and < 0.1 mg/L of nitrite as nitrogen.

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

5) a receptor 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.

Typical potable water exposures to contaminants include dermal exposures from bathing and showering, and ingestion exposures from drinking and using water for cooking. Metals and nitrate/nitrite tend not to be absorbed through the skin, and are not likely to be inhaled by people as aerosol while showering because they are not volatile (i.e. do not evaporate).

ADHS further evaluated the completed exposure pathways to determine whether realistic exposures are sufficient in magnitude, duration or frequency to result in acute adverse health effects.

Table 1. Exposure pathway analysis.

Exposure Pathway Elements					Time frame	Type of Exposure Pathway
Source	Media	Point of exposure	Route of exposure	Potentially exposed population		
Groundwater	Groundwater	Residences, tap	Ingestion, skin contact, inhalation	Residents	Past	Completed
					Current	Completed
					Future	Potential

Comparison to Health-based Comparison Values for Groundwater Sample

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.

The analytical results were compared to the Maximum Contaminant Levels (MCLs). MCLs are health protective drinking water standards to be met the public water systems. The results indicated that arsenic and nitrate as nitrogen exceeded their respective MCLs. Therefore, ADHS conducted further analysis to determine if the exposures were sufficient to impact public health.

Table 2. Measured chemical concentration and their respective comparison values (CVs).

Chemical	Detected Concentration (mg/L)	CV for noncancer health effects (mg/L)	Source of CV	Is it a Chemical of Interest?
Arsenic	0.349	0.01	MCL[1]	Yes
Copper	0.01	1.3	MCL	No
Lead	< 0.001	0.015	MCL	No
Nitrite as N	< 0.1	0.1	MCL	No
Nitrate as N	12.1	10	MCL	Yes

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; Radden 2005). 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 females, and 58.5 µg/day for males. Fish and seafood contain the highest concentrations of arsenic; however, most of this is the less toxic organic form of arsenic (ATSDR 2007).

Non-Cancerous Health Effects

Short-term Exposure (0-14 days):

Overview: Drinking water containing high levels of arsenic (60 mg/L) can result in death. Drinking 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 for Mizuta et al. (1956) 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 reported in Mizuta et al. (1956), and an uncertainty factor of 10 for using Low Observed Adverse Effect Level (LOAEL)[2] (ATSDR 2007).

Exposure from Water Consumption: ADHS calculated the short-term exposure dose using the detected arsenic concentration. The results were: 0.01 mg/kg/day for adults, 0.022 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 (16 kg), 0.035 mg/kg/day for 0-1 year old children (10 kg). These values exceeded the ATSDR's acute MRL. The estimation for children is approaching the reported LOAEL. Adults or children who use the water for drinking, cooking, preparing formula or beverage may experience symptoms associated with acute exposure such as edema of the face, and gastrointestinal (nausea, vomiting and diarrhea) and upper respiratory symptoms initially.

Long-term Exposure (> 365 days):

Overview: 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 was divided by an uncertainty factor of 3 for human variability. 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).

Exposure from Water Consumption: The water contains 0.349 mg/L of arsenic. ADHS estimated the daily exposure dose for long term exposure for children and adults. The exposure parameters were based on the ADHS Deterministic Risk Assessment Guidance. The estimated values were compared to health guideline values (i.e. MRL) to determine if the groundwater users 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. 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 (within an order of magnitude)[3]. The estimated daily exposure doses were: 0.0096 mg/kg/day for adults, 0.0209 for 1-6 year old children (16 kg), and 0.0335 for 0-1 year old children (10 kg). The results indicated that arsenic in the groundwater may increase the chance of non-cancerous health effects (dermal toxicity) among the exposed adults and children.

Cancerous Health Effects

Overview: 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

[3] Sample calculation to estimate long term non-cancerous exposure doses (mg/kg/day) for adult: $\frac{0.349\frac{mg}{L} \times \frac{2L}{day} \times 350\frac{day}{yr} \times 30\ yr}{70\ kg \times 10950\ day} = 0.0096$; 1-6 yr old child: $\frac{0.349\frac{mg}{L} \times \frac{1L}{day} \times 350\frac{day}{yr} \times 5\ yr}{16\ kg \times 1825\ day}$ = 0.0209; 0-1 yr old child: $\frac{0.349\frac{mg}{L} \times 1\frac{L}{day} \times 350\frac{day}{yr} \times 1\ yr}{10\ kg \times 365\ day} = 0.0335$

a cancer risk evaluation to determine if drinking the water in these wells over many years could result in an 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 1,000,000 exposed individuals indicates that there is a very low cancer risk (Appendix B).

Exposure from water consumption: ADHS conducted a cancer risk evaluation by using the measured arsenic concentrations and the EPA's standard cancer risk evaluation methodology. The exposure parameter values listed in the ADHS Deterministic Risk Assessment Guidance were used in the calculations. The estimated additional cancer from consuming arsenic-contaminated water for 30 years was: 6.2×10^{-3}. 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 estimated long term cancer risk was more than 6 in 1,000, which is considered to be unacceptable based on EPA's guidance. The cancer risks due to arsenic in the water samples are considered to be "High" based on the qualitative ranking of estimated cancer risk (Appendix B).

Nitrate as Nitrogen

Overview: Nitrate is a naturally 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 systems 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 2007).

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 30th week of pregnancy because their methemoglobin level naturally increases (ATSDR 2007, EPA 2012).

Exposure from Water Consumption: The groundwater containing 12.1 mg/L of nitrate as N which exceeded the drinking water MCL of 10 mg/L. The EPA determined a Reference Dose[4] (RfD) of 1.6 mg/kg/day for infants (the most sensitive population) based on various studies of infant methemoglobinemia. The RfD 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). The calculated exposure doses were: 0.3 mg/kg/day for adults, 0.7 mg/kg/day for 1-6 year old children (16 kg), and 1.1

[4] Reference Dose is defined as an amount of chemical below which adverse health effects are not expected.

mg/kg/day for 0-1 year old children (10 kg). Therefore, ADHS does not expect to see symptoms associated with the exposure from water consumption. However, the water should not be used for drinking, cooking, preparing formula or a beverage for a child less than 7 kg.

Microorganisms (Total Coliforms Present/*E. Coli* Absent)

Overview: Total coliform bacteria test is the most basic test for bacterial contamination of the water supply. Total coliform is a collection of different kinds of bacteria. It may contain fecal coliform (types of total coliform that exist in feces) and *E. coli* (a subgroup of fecal coliform). Total coliform bacteria are common in the environment (soil or vegetation) and are generally harmless. However, if the environmental contamination can enter the system, pathogen could get in too. It is important to find and resolve the source of the contamination. Fecal coliform bacteria exist in the intestines and feces of people and animals. The presence of fecal coliform in a drinking water sample often indicates recent fecal contamination. *E. Coli* is the major group of the fecal coliform group. It is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.

Exposure from Water Consumption: The testing results showed that the water is absent of *E. Coli* and present of total coliform. The bacteria count for total coliform is not available. The presence of total coliform indicated an increased risk of getting a water-borne illness. It should be considered as an indicator of pollution in the water. The absence of *E. Coli* indicated that the contamination may not be due to fecal wastes.

Conclusion/Recommendation

Only one sample was collected from the kitchen sink, ADHS conducted this evaluation by assuming the concentration detected would remain at these levels (i.e. chemical/microorganism concentrations do not change over time). Based on the available information, ADHS made the following recommendations:

1. *Exposure to the water could harm the health of adults and children.* This conclusion was reached because the estimated acute- and chronic- noncancerous health hazards of arsenic as well as the estimated additional cancer risks are associated with increased chances of developing noncancerous (both acute and chronic), and cancerous health effects.
    a. Obtain your drinking water from another source immediately that is known to have no detectable arsenic. The water should not be used for drinking, cooking, mixing with beverages, or preparing formula.
    b. The water can be used for bathing, laundry, and brushing adults' teeth. Children should not use this water for brushing their teeth.
    c. Install and maintain a home treatment device to reduce the arsenic level in the water.
2. *Exposure to the water could increase the chance of getting a water-borne illness.* This conclusion was reached because of the presence of total coliform, which is an indicator of pollution in the water. The absent of *E. Coli* indicated that the contamination may not be due to fecal wastes.
    a. The water should not be used for drinking, cooking or mixing a beverage.
    b. The water should not be used for showering, washing dishes or brushing teeth.
    c. The water can be used for laundry.
    d. Conduct an investigation to find out how the contamination got into the water. After identifying the source of the contamination, the problem can usually be resolved by repairing, flushing, or adding chlorine for a short period.

Based on the above, with the current water condition, ADHS recommends NOT using the water for: (1) Drinking, cooking, mixing a beverage, or preparing formula; (2) Showering, washing dishes, or brushing teeth. The water is OK for doing laundry.

People who use private well water for drinking or cooking are advised to have their well water tested yearly for 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 needs to be collected before making any decisions regarding water treatment

If you have any questions, please contact me at (602) 803-3740 or linh@azdhs.gov.

Sincerely,

Hsini Lin, ScD, MSPH
Environmental Toxicologist

References:

1. Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic. Atlanta, GA: US Department of Health Services, Public Health Service
2. Agency for Toxic Substances and Disease Registry (ATSDR) (2011). ToxFAQs for Nitrate and Nitrites. Available at: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=1186&tid=258 Last accessed: 3/21/14.
3. Arizona Department of Health Services (ADHS). 2003. ADHS Deterministic Risk Assessment Guidance.

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 $\leq 10^{-4}$)	Less Low
Greater than one per ten thousand to less than one per thousand (10^{-4} < Cancer Risk $\leq 10^{-3}$)	Moderate
Greater than one per thousand to less than one per ten (10^{-3} < 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}.