Health Consultation

Initial groundwater sampling results based on the
CH2mHill Workplan for Assessing Background Metals Concentrations in Groundwater

PACIFIC GAS & ELECTRIC BACKGROUND METAL STUDY

GOLDEN SHORES AND TOPOCK
MOHAVE COUNTY, ARIZONA

MARCH 21, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

Arizona Department of Health Services
Office of Environmental Health
Environmental Health Consultation Services
Under a cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Purpose

The Arizona Department of Environmental Quality (ADEQ) and the California Department of Toxic Substance Control (DTSC) worked together to assess background levels of naturally occurring metals in groundwater wells at Topock and Golden Shores, Arizona (i.e., PG&E Background Metal Study). This study is one of the studies associated with the Corrective Action remediation projects of Pacific Gas and Electric Company (PG&E). Groundwater samples were collected from (1) municipal water supply wells, (2) combined industrial and domestic water supply wells, (3) private domestic water supply wells, (4) irrigation wells, and (5) monitoring wells at Topock and Golden Shores. The communities of Topock and Golden Shores have expressed concerns regarding the findings. Thus, the ADEQ requested the Arizona Department of Health Services (ADHS) to evaluate whether these naturally occurring metals in groundwater wells are present at levels that may cause adverse health effects.

Background

The Pacific Gas and Electric Company (PG&E) Topock Compressor Station, located southeast of Needles, in San Bernardino County, California, is a natural gas compressor station for transmission of natural gas by pipeline. From 1951 to 1985, PG&E used hexavalent chromium (chromium VI) as an anti-corrosion agent in the cooling towers to prevent corrosion of the cooling tower equipment. From 1951 to 1964, PG&E discharged about 6 million gallons per year of untreated wastewater containing chromium VI to Bat Cave Wash (CA, USA), which is normally a dry streambed that feeds into the Colorado River. Beginning in 1964, PG&E treated the wastewater to remove chromium VI. The treated wastewater was discharged into Bat Cave Wash until 1968, and subsequently into an on-site injection well between the years of 1970 to 1973. Over time, PG&E installed a series of lined evaporation ponds for wastewater disposal. In 1985, PG&E stopped using the chromium-based additive and switched to a phosphate-based solution. In 1996, PG&E entered into a Corrective Action Consent Agreement with the California Environmental Protection Agency, Department of Toxic Substances Control to investigate and clean up the chromium VI contamination at the Station (CalEPA 2004).

The “PG&E Background Metal Study” is one of the studies associated with the Corrective Action remediation projects of PG&E. The scope of work for the study is outlined in the *Workplan for Assessing Background Metals Concentrations in Groundwater*, prepared by CH2MHill and approved by California DTSC (PG&E 2004a). This study, started in May 2005 which is expected to be completed in May 2006, is being performed under the direction of California DTSC and involves sampling wells that are located in California and Arizona to assess potential background levels of metals that may be naturally occurring in groundwater, especially in the alluvial aquifer (i.e., an aquifer formed by material laid down by physical processes in a river channel or on a floodplain). Groundwater samples were collected in the wells by PG&E’s consultant CH2MHill under the direction of California DTSC.

The selected wells will go through a screening process after 2 rounds of sampling, some wells will be eliminated from the program, and the remaining wells will be sampled four more times at approximately 2-month intervals. This health consultation focused on a review of the first round of groundwater sampling results of the selected wells at Topock (one-half mile east-northeast across the Colorado River) and Golden Shores (eight miles north of the PG&E Topock Compressor Station), Arizona.

The Arizona Department of Health Services will prepare additional health consultations when the other sets of water sampling results are available. Wells located in California were also sampled by CH2MHill as part of this Background Metal Study, but California wells were not a part of this Arizona Department of Health Services health consultation.

This is the second health consultation performed by the Arizona Department of Health Services in the Topock Area. The Arizona Department of Health Services also performed a health consultation for a one-year study by the Arizona Department of Environmental Quality (ADEQ), referred to as the *Arizona Department of Environmental Quality Topock Groundwater Study* in 2005 (ATSDR 2005).

The two studies have slightly different constituent lists that relate to the different study goals and objectives. The ADEQ Topock Groundwater Study was initiated to assess potable use wells in the area for the presence of chromium VI and to assess whether or not chromium VI concentrations detected in wells pose a threat to human health. The ADEQ Topock Groundwater Study will also assess concentrations of chromium in the lower bedrock aquifer (i.e., an aquifer located in the solid rock underlying unconsolidated surface materials, such as sediment) and evaluate the direction of groundwater flow in the vicinity of Topock, Arizona.

The PG&E Background Metal Study has a longer list of constituents compared to the ADEQ study. The goal of the PG&E Background Metal Study is to assess background concentrations of metals to determine clean up levels for remediation efforts in California. The PG&E study focuses on concentrations of metals in the alluvial aquifer, while the ADEQ study is assessing both alluvial and bedrock aquifers.

Discussion

Groundwater Sampling

The first round of samples was collected between May 2005 to June 2005. During this period, a qualified technician from CH2MHill collected groundwater samples from the selected wells in the communities of Topock and Golden Shores using the protocols outlined in the PG&E *Draft Sampling and Analysis Plan for Groundwater and Surface Water Monitoring* (Draft SAP) (PG&E 2004b). This work was performed by PG&E’s consultant under the direction of California DTSC. Figure 1 shows the locations of the wells that were considered for the PG&E Background Metal Study. Some of the wells shown in Figure 1 were dropped from consideration because they did not appear to draw water from the alluvial aquifer.

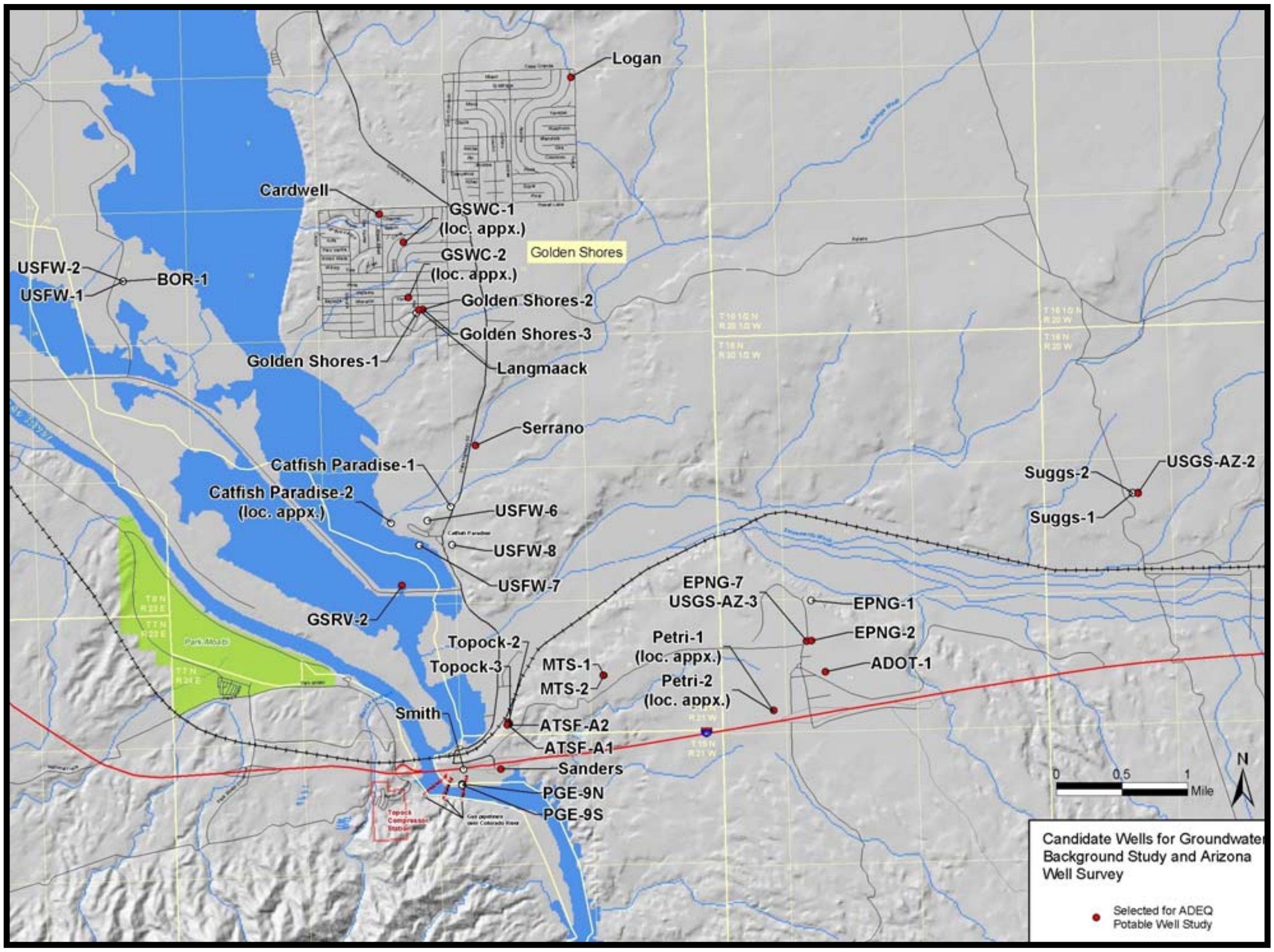

Figure 1. Pacific Gas & Electronic (PG&E) background metal study area and locations of selected wells[1].

The groundwater samples were analyzed for a variety of metals and water chemistry parameters. The parameters were analyzed in accordance with the guidance of United States Environmental Protection Agency (U.S. EPA) SW-864 (U.S. EPA 2002), U.S. EPA's *Drinking Water Methods for Chemical Parameters* (U.S. EPA 1993), and/or *Standard Methods for the Examination of Water and Wastewaters* (APHA–AWWA 1992, 1995). More detailed analytical parameters and methods are listed in the PG&E *Draft Work Plan for Assessing Background Metals Concentrations in Groundwater* (PG&E 2004a).

The Quality Assurance/Quality Control (QA/QC) during sampling and analysis were ensured by following the QA/QC procedures outlined in the Draft SAP (PG&E 2004b) and the *Draft Quality Assurance Project Plan for Groundwater and Surface Water Sampling at the Topock Compressor Station* (PG&E 2004c). Two field duplicates were randomly sampled and analyzed for quality control purposes. The measured concentrations of duplicates met quality control objectives that indicate the measured laboratory concentrations are of good quality and certainty.

[1] This figure was prepared by the Arizona Department of Environmental Quality (ADEQ)

Exposure Pathway Evaluation

The Arizona Department of Health Services identified the exposure pathways to determine if and how residents might be exposed to chemicals in groundwater wells. There are five elements are considered in the evaluation of exposure pathways:

- A source of contamination
- Transport through an environmental medium
- A point of exposure
- Route of exposure
- A receptor population

Exposure pathways are classified as completed, potential, or eliminated. Completed pathways exist when the five elements are present and indicate that exposure to a contaminant has occurred in the past and/or is occurring now. Potential pathways are those that may have occurred in the past or present, or could occur in the future. In eliminated pathways, at least one of the five elements is and was missing, and will never be present. Completed and potential pathways; however, may be eliminated when they are unlikely to be significant.

Completed and potential exposure pathways may result from people using the water from the contaminated wells (i.e., domestic, irrigation and municipal supply wells) either for irrigation or domestic purposes or both. Typical domestic and municipal supply well exposures to chemicals include dermal exposures from bathing and showering, and ingestion exposures from drinking and using water for cooking. Inhalation while showering is not a relevant pathway for metals and the water chemistry parameters because they are not volatile (i.e., do not evaporate). Metals tend not to be soluble and are not likely available to people as aerosols while showering.

For irrigation wells, only limited dermal and ingestion exposures could occur to anyone who comes in contact with the contaminated water. This would include exposures to adults while they are watering the lawn or gardens, children playing at grounds that are irrigated with contaminated well water, or anyone who eats vegetables or fruits that are irrigated with contaminated water and which accumulate the contaminants.

For industrial wells, the Arizona Department of Health Services determined that the exposure pathway is eliminated. The groundwater primarily is used in cooling towers. As a result, the exposure points and exposure routes cannot be identified. That is, residents are unlikely to have contact with the chemicals through inhalation, ingestion or dermal contact. Workers may contact with the chemicals through ingestion or skin contact. However, these exposure pathways are considered insignificant due to the limited amount and frequency of exposures.

For monitoring wells, the Arizona Department of Health Services determined that the exposure pathway is eliminated. The purpose of these wells is to monitor the groundwater conditions to provide geologic, hydrologic and chemical data on soil and water. Thus, residents are unlikely to have contact with chemicals through inhalation, ingestion or dermal contact. Workers may contact chemicals through ingestion or skin contact. However, these exposure pathways are considered insignificant due to the limited amount and frequency of exposures. It should be noted that workers performing routine monitoring in these wells would typically follow a health and safety plan (HASP) designed to minimize or eliminate potential contact and exposures.

Table 1 summarizes the results of the exposure pathway evaluation. The Arizona Department of Health Services further evaluated the completed and potential exposure pathways to determine whether realistic exposures are sufficient in magnitude, duration, and frequency to result in adverse health effects. Eliminated exposure pathways require no further evaluation.

Table 1. The results of the exposure pathway evaluation for wells sampled during the PG&E Background Metal Study.

Exposure Pathway Elements					Time frame	Type of Exposure Pathway	Does it need further evaluation
Type of groundwater well	**Media**	**Point of exposure**	**Route of exposure**	**Potentially exposed population**			
Domestic wells	Groundwater	Residences, tap	Ingestion Skin contact	Residents	Past	Potential	**Yes**
					Current	Completed	
					Future	Potential	
Municipal water supply wells	Groundwater	Residences, tap	Ingestion Skin contact	Residents	Past	Potential	**Yes**
					Current	Completed	
					Future	Potential	
Inactive water supply wells	Groundwater	Residents, tap	Ingestion Skin contact	Residents	Past	Eliminated	**Yes**
					Current	Eliminated	
					Future	Potential	
Irrigation wells	Groundwater	Residential yards and gardens	Ingestion Skin contact	Residents	Past	Potential	**Yes**
					Current	Completed	
					Future	Potential	
Industrial wells	Groundwater	—	—	Workers	Past	Eliminated	No
					Current	Eliminated	
					Future	Eliminated	
Monitoring wells	Groundwater	—	—	Workers	Past	Eliminated	No
					Current	Eliminated	
					Future	Eliminated	

Selection of Chemicals of Concern

Metals occur naturally in the environment and many of them are essential for life. The background concentrations of metals are mainly controlled by the geologic characteristics of a site. Some metals are naturally abundant and have high background concentrations (e.g. aluminum and iron), while others are rare and have low background concentrations (e.g. mercury and cadmium) (Elder 1988).

A large fraction of metals is bound to organic matters and particles in waters, which reduce the amount of metals for uptake by organisms (e.g., humans) and the ability of metals to affect organisms. It is known that bioavailability or toxicity of metals is directly correlated to concentrations of free metal ions, which are not bound to any matter, rather than to total metal concentrations (Cambell 1995). Bioavailability is the fraction of the amount of chemical uptake by organisms that is absorbed into the body. For example, if the bioavailability of arsenic in water is 90% and 100 µg of arsenic dissolved in drinking water were ingested, then 90 µg of arsenic will be absorbed into the body. The less the bioavailability of a toxic chemical, the less its toxic effects on an organism.

It is recognized that the dissolved metal concentration better approximates the bioavailable fraction of waterborne metals than the total concentration of metals (Elder 1988, Prothro 1993). In addition, U.S. EPA indicated that only the bioavailable fraction of a metal should be regulated (Prothro 1993, U.S. EPA 1995). The current U.S. EPA's definition of dissolved metals is that the metals components of a water sample that passes through a 0.45-micrometer (µm) filter. Thus, the Arizona Department of Health Services conducted initial screening analyses to select chemicals requiring further evaluation by using the concentrations of dissolved metals and water chemistry parameters. The selected chemicals are called chemicals of concern (COC). The screening analyses were achieved through the use of health-based comparison values (CVs).

Comparison values are concentrations of chemicals in a specific medium (i.e. water, soil or air) that can reasonably and conservatively be regarded as harmless to public health based on the available scientific data. If public exposure concentrations related to a site are below the appropriate CV, then the exposures are not of public health concern and no further analysis will be conducted. However, while concentrations below the appropriate CV are not expected to lead to any observable adverse health effect, it should not be inferred that a concentration greater than the appropriate CV will necessarily lead to adverse health effects. 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 above the appropriate CV may or may not lead to a health effect. Therefore, the CVs should not be used to predict the occurrence of adverse health effects.

The CVs used in screening analyses include (1) Environmental Media Evaluation Guides (EMEGs), (2) Reference Dose Media Evaluation Guides (RMEGs), (3) Maximum Contaminant Levels (MCLs), (4) Lifetime Health Advisory (LHA) for drinking water, (5) Drinking Water Advisory (DWA), (6) Drinking Water Equivalent Levels (DWELs), and (7) Arizona Aquifer Water Quality Standards (AAWQSs). The Agency for Toxic Substances and Disease Registry (ATSDR) develops EMEGs and RMEGs based conservative assumptions about exposure. EMEGs and RMEGs which represent concentrations of substances in water, soil, or air to which daily human exposure is unlikely to result in adverse health effects.

The U.S. EPA develops MCLs, LHA, DWA, and DWELs. MCLs are legally enforceable standards for public drinking water supplies that are protective of human health, over a lifetime. LHA and DWA are non-regulatory concentrations of contaminants in water that are likely to be without adverse health effects. DWELs are not enforceable legal standards. DWEL defines a lifetime exposure concentration protective of adverse, non-cancer health effects, assuming that all exposure to a contaminant is from drinking water. The AAWQSs are enforceable standards developed to protect groundwater sources for drinking water use (AAC §R18-11-406) and protective of human health. In Arizona, all aquifers are identified as drinking water source aquifers unless specifically exempt (ARS §49-224).

No CVs are available for some essential nutrients (e.g. calcium, iron and magnesium) and water chemistry parameters (e.g. bromide, total Kjeldahl nitrogen and alkalinity). When no CVs are available, the chemical is generally retained for further evaluation. However, these essential nutrients and water chemistry parameters are typically not harmful to humans under most environmental exposure scenarios and are not necessarily retained for further analysis (ATSDR 2005). For example, alkalinity is a measure of the buffering capacity of water, or the capacity of bases to neutralize acids. Because alkalinity varies greatly due to differences in geology, there are no general standards for alkalinity.

Table 2 and Table 3 show the results of screening analyses for metals and water chemistry parameters, respectively. Some of the measured chemical concentrations exceeded the Secondary Maximum Contaminant Levels (SMCLs) developed by the U.S. EPA, for example, iron, chloride and total dissolved solids. These chemicals are not considered as COCs, because SMCLs are non-enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water. The identified COCs are arsenic, boron, chromium VI, sodium, vanadium (Table 2), and fluoride (Table 3). Table 4 shows the wells containing COCs and their uses.

Table 2. Measured concentrations of dissolved metals of domestic, irrigation, and municipal wells in micrograms per liter (µg/L) compared to health-based comparison values (CVs).

Chemical	Number of samples	Ranges of detected concentration (µg/L)	Health-based CV (µg/L)	Source of CV		Number of detections greater than CV	Is it a chemical of concern?
Aluminum	14	ND[a] – 73.8	20,000	EMEG-ci[b]	ATSDR	0	No
Antimony	14	ND	6	MCL[c]	U.S. EPA	0	No
Arsenic	14	3.42 – 24.4	10	MCL	U.S. EPA	3	**Yes**
Barium	14	21.8 – 83.6	2,000	MCL	U.S. EPA	0	No
Beryllium	14	ND	4	MCL	U.S. EPA	0	No
Boron[d]	14	116 – 1110	100	EMEG-ci	ATSDR	14	**Yes**
Cadmium	14	ND	5	MCL	U.S. EPA	0	No
Calcium[d]	14	21.5 – 104[e]	NA	NA		NA	No
Chromium VI	14	ND – 37.3	30	RMEG-c[f]	ATSDR	1	**Yes**
Total chromium	14	ND – 35.3	100	MCL	U.S. EPA	0	No
Cobalt	14	ND	100	EMEG-ci	ATSDR	0	No
Copper	14	ND – 6.64	100	EMEG-ci	ATSDR	0	No
Iron[d]	14	ND – 473	NA	NA		NA	No
Lead	14	ND – 1.36	15	MCL	U.S. EPA	0	No
Magnesium[d]	14	5.37 – 32.9[e]	NA	NA		NA	No
Manganese	14	ND – 456	500	RMEG-c	ATSDR	0	No
Mercury	14	ND	2	MCL	U.S. EPA	0	No
Molybdenum	14	3.56 – 31.1	50	RMEG-c	ATSDR	0	No
Nickel	14	ND – 1.37	200	RMEG-c	ATSDR	0	No
Potassium[d]	14	3.76 – 7.86[e]	NA	NA		NA	No
Selenium	14	ND – 4.34	50	MCL	U.S. EPA	0	No
Sodium[d]	14	52.6 – 374[e]	20 [e,g]	DWEL[h]	U.S. EPA	14	**Yes**
Silver	14	ND	50	RMEG-c	ATSDR	0	No
Thallium	14	ND – 1.14	2	MCL	U.S. EPA	0	No
Vanadium	14	ND – 42.8	30	EMEG-ci	ATSDR	1	**Yes**
Zinc	14	ND – 112	3,000	EMEG-cc	ATSDR	0	No

[a] ND: non-detected (i.e., dissolved metal concentrations in groundwater samples were below the laboratory reporting limit)
[b] EMEG-ci: Environmental Media Evaluation Guide for children's intermediate exposure
[c] MCL: Maximum Contaminant Level
[d] General minerals
[e] The unit for chemical concentration is expressed as milligrams per liter (mg/L); 1 mg/L is equal to 1,000 µg/L
[f] RMEG-c: Reference Dose Media Evaluation Guide for children's exposure
[g] This health-based value is for individuals on a 500 mg/day restricted sodium diet
[h] DWEL: Drinking Water Equivalent Level

Table 3. Measured concentrations of water chemistry parameters of domestic, irrigation, and municipal wells in milligrams per liter (mg/L) compared to health-based comparison values (CVs).

Chemical	Number of samples	Ranges of detected concentration (mg/L)	Health -based CV (mg/L)	Source of CV		Number of detections greater than CV	Is it a contaminant of concern?
Bromide	14	ND[a]	NA[b]	NA		NA	No
Chloride	14	25.6 – 437	NA	NA		NA	No
Fluoride	14	ND – 6.17	4.0	MCL[c]	U.S. EPA	3	**Yes**
Nitrate as nitrogen	14	ND – 3.9	10	MCL	U.S. EPA	0	No
Total Kjeldahl as nitrogen	14	ND	NA	NA		NA	No
Ammonia as nitrogen	14	ND	30	LHA[d]	U.S. EPA	0	No
Alkalinity, bicarbonate as $CaCO_3$	14	75.8 – 258	NA	NA		NA	No
Alkalinity, as carbonate	14	ND	NA	NA		NA	No
Alkalinity, total as $CaCO_3$	14	75.8 – 258	NA	NA		NA	No
Perchlorate	14	ND	7	RMEG-ci[e]	ATSDR	0	No
pH	14	7.58 – 8.01	NA	NA		NA	No
Sulfate	14	17.4 – 305	500	DWA[f]	U.S. EPA	0	No
Sulfide	14	ND	NA	NA		NA	No
Total dissolved solids	14	328 – 1370	NA	NA		NA	No
Tritium[g]	14	ND	20000	AAWQS[h]	ADEQ	0	No

[a] ND: non-detected (i.e., concentrations of water chemistry parameters in groundwater samples were below the laboratory reporting limit)
[b] NA: not available
[c] MCL: Maximum Contaminant Level
[d] LHA: Lifetime Health Advisory for drinking water
[e] RMEG-ci: Reference Dose Media Evaluation Guide for children's intermediate exposure
[f] DWA: Drinking Water Advisory
[g] The unit for tritium is expressed as picocuries per liter (pCi/L).
[h] AAWQS: Arizona Aquifer Water Quality Standard

Table 4. Chemical concentrations of concern in wells[a] and the well water usages.

Contaminant of concern	Well containing contaminant of concern	Chemical concentration (µg/L)	Well use
Arsenic	Private well 1	24.4	Domestic
	Topock 2	10.6	Municipal, industrial
	Topock 3	13.6	Municipal, industrial
Boron	ADOT new well	578	Domestic[b], industrial
	EPNG 2	507	Domestic, industrial
	GSRV 2	153	Inactive water supply
	GSWC 1	244	Municipal
	GSWC 2	236	Municipal
	GSWC 3	228	Municipal
	GSWC 4	245	Municipal
	New farm well	154	Irrigation
	Private well 1	1110	Domestic
	Private well 2	180	Domestic
	TMLP 2	126	Domestic[c]
	Topock 2	735	Municipal, industrial
	Topock 3	503	Municipal, industrial
	USFW 5	116	Domestic
Chromium VI	GSRV 2	37.3	Inactive water supply
Fluoride	ADOT new well	4200	Domestic, industrial
	Private well 1	6170	Domestic
	Topock 3	4030	Municipal, industrial
Sodium[d]	ADOT new well	177	Domestic, industrial
	EPNG 2	162	Domestic, industrial
	GSRV 2	61.4	Inactive water supply
	GSWC 1	82.7	Municipal
	GSWC 2	95.9	Municipal
	GSWC 3	76.7	Municipal

	GSWC 4	84.0	Municipal
	New farm well	128	Irrigation
	Private well 1	374	Domestic
	Private well 2	58.4	Domestic
	TMLP 2	52.6	Domestic
	Topock 2	331	Municipal, industrial
	Topock 3	227	Municipal, industrial
	USFW 5	83.9	Domestic
Vanadium	Private well 1	42.8	Domestic

[a] See Figure 1 for locations of wells listed in this table
[b] Residents have been drinking bottled water, but the ADOT new well will be a source water for a public rest area.
[c] This well has uncontrolled public access
[d] The unit for sodium concentration is expressed as milligrams per liter (mg/L); 1 mg/L is equal to 1,000 µg/L

Health Effects Evaluation

To have a closer look at the selected contaminants of concerns (COCs), the Arizona Department of Health Services estimated the chronic daily intakes (CDIs) based on the site-specific conditions (e.g. duration and frequency). The CDIs were estimated based on the Arizona Department of Health Services Deterministic Risk Assessment Guidance (ADHS 2003). Appendix A shows the equations for CDI estimations. The estimated CDIs were then compared to health guideline values. The health guideline values are estimates of the daily human exposure to a chemical that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure.

Contaminants of concern having CDIs below conservatively derived health guidelines likely pose no public health hazards. However, COCs having CDIs above the health guidelines do not mean that the COCs will cause adverse health effects, but rather there is a need for further toxicological evaluation by comparing the estimated CDI for residents to CDIs known to cause harmful effects.

Uptake chemicals through skin contact

As indicated in Table 1, residents can uptake chemicals through water ingestion and skin contact. The Arizona Department of Health Services determined that uptake of metals through skin contact can be ignored because metals are not readily absorbed through the skin.

Exposure to metals through skin contact results in a much lower dose than the water ingestion pathway. For example, (1) dermal exposure to arsenic is usually not of concern because only a small amount (4.5%) will pass through skin and into the body (ATSDR 2000a). Direct skin contact with arsenic could cause some irritation or swelling, but skin contact is not likely to result in any serious internal effects; (2) very little chromium will enter the body through contact with the skin unless the skin is damaged. Nevertheless, some people are allergic to chromium and will develop rashes, redness, or swelling when in contact with chromium (ATSDR 2000b). Furthermore, studies have shown that absorption of metal ions from aqueous solutions of metal sulfate through intact skin is negligible (Fullerton et al. 1986, Tanojo et al. 2001).

Uptake chemicals through water ingestion

The CDIs from water ingestion were estimated by following the Arizona Department of Health Services Deterministic Risk Assessment Guidance (ADHS 2003). For non-cancer health effects, the estimated CDIs were compared to the ATSDR's Minimal Risk Levels (MRLs) or the U.S. EPA's Reference Dose (RfD). For cancer health effects, the estimated CDIs were used to calculate the excess lifetime cancer risk.

The MRLs or RfDs are derived based on the non-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) and an uncertainty factor. NOAEL is the highest exposure level of a chemical at which adverse health effects were not observed. LOAEL is the lowest exposure level of a chemical at which adverse health effects were observed.

An MRL contains uncertainty that is due to the lack of knowledge about the data on which it is based. To account for this uncertainty, "safety factors" are used to set MRLs below actual toxic effect levels (i.e. NOAEL or LOAEL). This approach provides an added measure of protection against the potential for adverse health effects to occur.

Table 5 shows the estimated CDIs for arsenic, boron, chromium VI, fluoride, sodium, and vanadium for the selected wells. These values were used to evaluate the non-cancer health effects. The maximum values of the estimated CDIs for boron, chromium VI, and vanadium did not exceed the non-cancer health guideline values, which indicates boron, chromium VI, and vanadium pose no non-cancer health hazards. In addition, boron, chromium VI, and vanadium do not pose cancer health hazards since they are not classified as human carcinogens. The estimated CDIs for arsenic and fluoride exceeded the non-cancer health guideline values, which indicate arsenic and fluoride require more careful examination (i.e., toxicological evaluation). Sodium was retained for further evaluation since no health guideline value was available.

Table 5. Estimated chronic daily intake (CDI) in milligrams per kilogram per day (mg/kg/day) compared to the non-cancer health guidelines.

Chemical	Chemical concentration (well name) (mg/L)	Chronic daily intake (mg/kg/day)		Health guideline (mg/kg/day)	Source		Does the child CDI exceed the health guideline?	Does the adult CDI exceed the health guideline?
		Child	Adult					
Arsenic	0.0106 (Topock 2)	0.0007	0.0003	0.0003	MRL[a]	ATSDR	**Yes**	No
	0.0136 (Topock 3)	0.0009	0.0004				**Yes**	**Yes**
	0.0244 (Private well 1)	0.0016	0.0007				**Yes**	**Yes**
Boron	1.11 (Private well 1)	0.07	0.03	0.2	RfD[b]	U.S. EPA	No	No
Chromium VI	0.0373 (GSRV 2)	0.002	0.001	0.003	RfD	U.S. EPA	No	No
Fluoride	4.03 (Topock 3)	0.26	0.11	0.05	MRL	ATSDR	**Yes**	**Yes**
	4.20 (ADOT new well)	0.27	0.12				**Yes**	**Yes**
	6.17 (Private well 1)	0.40	0.17				**Yes**	**Yes**
Sodium	374 (Private well 1)	23.9	10.25	NA[c]	NA		NA	NA
Vanadium	0.0428 (Private well 1)	0.0027	0.0012	0.003	MRL	ATSDR	No	No

[a] MRL: minimal risk level
[b] RfD: reference dose
[c] NA: not available

Toxicological Evaluation

(1) *Arsenic*

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds (ATSDR 2000a).

Arsenic can be released to water from the natural weathering of soil and rocks and can also leach from soil and minerals into groundwater. In some western states with mineral deposits high in arsenic, groundwater levels of up to 3400 µg/L arsenic have been found. Most arsenic in natural waters is a mixture of arsenate (trivalent arsenic or As III) and arsenite (pentavalent arsenic or As V), with arsenate (As III) usually predominating (ATSDR 2000a).

Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Ingestion of arsenic can increase the risk for skin cancer and internal cancers: liver, lung, bladder, and kidney (ATSDR 2000a).

(A) Non-cancer Health Effects

As shown in Table 5, the estimated child arsenic CDIs from water ingestion for Private well 1, Topock 2 and Topock 3 exceeded the arsenic MRL of 0.0003 mg/kg/day. The estimated adult arsenic CDIs from water ingestion for Private well 1 and Topock 3 exceeded the arsenic MRL. The results indicated that there is a need for further toxicological evaluation. Thus, the Arizona Department of Health Services further evaluated the human studies on which the arsenic MRL was based.

The arsenic MRL was derived from the long-term arsenic NOAEL of 0.0008 mg/kg/day, obtained from human epidemiologic studies, and an uncertainty factor of three (ATSDR 2000a). The long-term LOAEL associated with these epidemiologic studies is 0.014 mg/kg/day, where exposure to arsenic above this level resulted in keratosis (patches of hardened skin), hyperpigmentation of the skin, and possible vascular complication (ATSDR 2000a). In addition, studies have shown no dermal or other effects to people exposed to arsenic in drinking water at chronic doses of 0.0004 to 0.01 mg/kg/day (ATSDR 2000a).

The results in Table 5 indicate the following:

a) The estimated adult CDIs for Private well 1 (0.0007 mg/kg/day) and Topock 3 (0.0004 mg/kg/day) are below the long-term NOAEL (0.0008 mg/kg/day)

b) The estimated child CDIs for Topock 2 (0.0007 mg/kg/day) is below the long-term NOAEL (0.0008 mg/kg/day)

c) The estimated child CDI for Private well 1 (0.0016 mg/kg/day) and Topock 3 (0.0009 mg/kg/day) are higher than the long-term NOAEL (0.0008 mg/kg/day); however, they are much lower than the long-term LOAEL (0.014 mg/kg/day)

(B) Cancer Health Effect

The excess theoretical lifetime cancer risks due to arsenic from water ingestion were estimated based on the Arizona Department of Health Services Deterministic Risk Assessment Guidance (ADHS 2003) and the cancer slope factor of arsenic developed by the U.S. EPA. The estimated excess lifetime cancer risks are 0.00019, 0.00024, and 0.00043 for residents consuming water from Topock 2, Topock 3, and Private well 1, respectively, over a lifetime. It means that there is a potential increase in excess lifetime cancer of 1.9, 2.4, and 4.3 cases per 10,000 persons.

The estimated theoretical excess lifetime cancer risks are slightly greater than the acceptable risk range of one-in-one-million to one-in-ten-thousand persons defined by the U.S. EPA (U.S. EPA 1991). However, an April 1991 memo from Assistant Administrator Donald Clay in the Office of Solid Waste and Emergency Response (OSWER) states that in certain cases the Agency, "may consider risk estimates slightly greater than 10,000 to be protective." For example, the MCL for arsenic of 10 mg/L is associated with excess lifetime cancer risk of 0.00018 (i.e. 1.8 cases per 10,000 persons).

In a population of one million men in the United States, 333,000 (one in three) are expected to develop cancer from all causes in the lifetime (through 79 years of age) (ACS 1998). The estimated excess lifetime cancer risk of one-in-ten thousand means that if those one million men were exposed to this level of chemical for 30 years, 334,000 would be expected to develop cancer. That is, the chance for those one million men to develop cancer from all causes in their lifetime increases from 33.3 to 33.4 %.

In addition, the cancer slope factor of arsenic may be overestimated due to the uncertainty related to the model assumptions and differences in the health and nutrition between Taiwanese and American populations (ATSDR 2000a). As a result, the ability of arsenic to cause cancer is reduced. Thus, the estimated excess lifetime cancer risks (i.e., 0.00019, 0.00024, and 0.00043 for residents consuming water from Topock 2, Topock 3, and Private well 1, respectively, over lifetime) due to arsenic from water ingestion are considered to be within the acceptable range to the residents.

After a review of available exposure and health effect data, the Arizona Department of Health Services determined that detected arsenic levels in the Private well 1, Topock 2 and Topock 3 do not pose a health hazard to adults and children. However, these wells contain arsenic levels above the new MCL of 10 µg/L, which is effective as of January 2006. As mentioned earlier, MCLs are drinking water standards set by U.S. EPA in accordance with the Safe Drinking Water Act. They are applied only to public drinking water systems. MCLs are not health-based threshold levels because the MCLs include a substantial margin of safety to account for uncertainties in health studies and technology. Therefore, people ingesting chemicals slightly above MCLs will not necessarily experience any illness or other adverse health effects. However, installing a treatment system that effectively removes arsenic or using alternative water sources, such as bottled water, for drinking or cooking can provide an extra level of protection to the residents using groundwater in the Private well 1, Topock 2 and Topock 3.

(2) *Fluoride*

Fluorine is a naturally occurring, pale yellow-green gas with a sharp odor. It combines with metals to make fluorides such as sodium fluoride and calcium fluoride, both white solids. Sodium fluoride dissolves easily in water, but calcium fluoride does not. Fluorides are often added to drinking water supplies and to a variety of dental products, including toothpaste and mouth rinses, to prevent dental cavities (ATSDR 2003).

Small amounts of fluoride help prevent tooth cavities, but high levels (> 3 mg/L) can harm the health. In adults, exposure to high levels of fluoride can result in denser bones. However, if exposure is high enough, these bones may be more fragile and brittle and there may be a greater risk of breaking the bone. In animals, exposure to extremely high doses of fluoride can result in decreased fertility and sperm and testes damage.

Most of the studies of people living in areas with fluoridated water or naturally high levels of fluoride in drinking water did not find an association between fluoride and cancer risk (ATSDR 2003). However, drinking or eating excessive fluorides during the time teeth are being formed (before 8 years of age) can cause visible changes in teeth. This condition is called dental fluorosis. At very high concentrations (> 3 mg/L) of fluoride, the teeth can become more fragile and sometimes can break (ATSDR 2003).

As shown in Table 5, the estimated child and adult fluoride CDIs from water ingestion for Private well 1, ADOT new well and Topock 3 exceeded the fluoride MRL of 0.05 mg/kg/day. Thus, the Arizona Department of Health Services further evaluated the human studies on which the fluoride MRL was based.

The fluoride MRL was derived from the long-term NOAEL of 0.15 mg/kg/day, obtained from human epidemiologic studies, and an uncertainty factor of three (ATSDR 2003). The studies examined communities with higher naturally occurring fluoride in the water and found increasing incidences of hip fractures in residents (Li et al. 2001). The subjects were 50 years and older, and their mean ages ranged from 62.6 to 64.0 years. The long-term LOAEL associated with these epidemiologic studies is 0.25 mg/kg/day (ATSDR 2003).

The results in Table 5 indicate the following:

a) The estimated adult CDIs for ADOT new well (0.12 mg/kg/day) and Topock 3 (0.11 mg/kg/day) are below the long-term NOAEL (0.15 mg/kg/day)

b) The estimated adult CDI for Private well 1 (0.17 mg/kg/day) is slightly higher than the long-term NOAEL (0.15 mg/kg/day); however, it is about 1.5 times lower than the long-term LOAEL (0.25 mg/kg/day)

c) The estimated child CDIs for Private well 1 (0.4 mg/kg/day), ADOT new well (0.27 mg/kg/day) and Topock 3 (0.26 mg/kg/day) exceeded the long-term LOAEL (0.25 mg/kg/day). However, residents are not using ADOT new well as a source of drinking or cooking.

After a review of available exposure and health effect data, the Arizona Department of Health Services determined that (1) fluoride levels in the Private well 1, ADOT new well and Topock 3 wells do not pose a health hazard to adults, (2) fluoride level in the ADOT new well does not pose a health hazard to children, and (3) fluoride levels in the Private well 1 and Topock 3 may pose a health hazard to children.

(3) *Sodium*

An increase in the concentrations of sodium in the bloodstream can be toxic. The normal concentration of sodium in the blood plasma is 136 – 145 milli-molar (mM), while levels over 152 mM can result in seizures and death. Increased plasma sodium, which is called hypernatremia, causes various cells of the body, including those of the brain, to shrink. Shrinkage of the brain cells results in confusion, coma, paralysis of the lung muscles, and death (Brody 2002).

Death has occurred where table salt (sodium chloride) was accidentally used, instead of sugar, for feeding infants. Death due to sodium toxicity has also resulted when baking soda (sodium bicarbonate) was used during attempted therapy of excessive diarrhea or vomiting. Although a variety of processed foods contain high levels of sodium chloride, the levels used are not enough to result in sodium toxicity. Sodium in drinking water normally present no health risks, as about 99% of the daily salt intake is from food. However, elevated sodium in well water may be considered a health concern for people on salt-restricted diets. The treatment for certain heart conditions, circulatory or kidney disease, or cirrhosis of the liver may require a sodium-restricted diet (Brody 2002).

Sodium is an essential nutrient. The Food and Nutrition Board of the National Research Council recommends that most healthy adults need to consume at least 500 mg/day, and that sodium intake be limited to no more than 2,400 mg/day. Kurtzweil (1995) indicated that most American adults tend to eat between 4,000 to 6,000 mg of sodium per day and sodium therapeutic sodium restricted diet can range from below 1,000 to 3,000 mg per day.

The uptake of sodium from the groundwater wells at Golden Shores and Topock ranged from 14.6 mg to 93.5 mg per serving. Per serving is assumed to be 0.25 L of water (about an 8-once glass). These values are at the very low-sodium (< 35 mg per serving) to low-sodium (< 140 mg per serving) categories listed by the Food and Drug Administration (Kurtzweil 1995). Thus, the amount of sodium in the groundwater wells does not pose a health hazard for the general public. However, individuals on a 500 mg/day restricted sodium diet should not drink water from these wells.

ATSDR Child Health Initiative

ATSDR recognizes that the unique vulnerabilities of infants and children demand special emphasis in communities faced with contaminants in environmental media. Children's developing body systems can sustain permanent damage if toxic exposures occur during critical growth stages. Children ingest a larger amount of water relative to body weight, resulting in higher burden of pollutants. Furthermore, children often engage in vigorous outdoor activities, making them more sensitive to pollution than healthy adults. All health analyses in this report take into consideration the unique vulnerability of children. In general, children will not be adversely affected by the levels of chemicals found in groundwater wells at Topock and Golden Shores, AZ. However, the levels of fluoride detected in the Private well 1 and Topock 3 may increase the incidences of dental fluorosis among children, and they may have an increased risk of hip fractures later in their life due to their current level of exposure.

Conclusions

Based on the groundwater samples that were collected from (1) municipal water supply wells, (2) combined industrial and domestic water supply wells, (3) private domestic water supply wells, (4) irrigation wells, and (5) monitoring wells at Topock and Golden Shores, Arizona, the following conclusions were made.

Fluoride

The Arizona Department of Health Services has classified the Private well 1 and Topock 3 as “Public Health Hazard” for children only. This classification is based upon the following:

- The estimated CDIs for children exceeded the LOAEL of 0.25 mg/kg/day

The Arizona Department of Health Services has classified the wells included in this health consultation, except Private well 1 and Topock 3, as “No Apparent Public Health Hazard” for children and adults. This classification is based upon the following:

- Either the levels of fluoride did not exceed the MCL of 4 mg/L for fluoride or the ground well water is not used as a source for drinking or cooking

Other chemicals included in this health consultation

The Arizona Department of Health Services has classified the study sites (wells included in this health consultation) as “No Apparent Public Health Hazard” for children and adults. This classification is based upon the following:

- The levels of chemicals present in the groundwater wells are not at levels that may cause adverse health effects
- Exposures to these chemicals are not at levels that are likely to cause adverse health effects. However, individuals on a 500 mg/day restricted sodium diet should not drink water from these wells

If further information becomes available, the Arizona Department of Health Services will evaluate it and update conclusions as necessary.

Recommendations

- For groundwater wells (ADOT new well, Private well 1, and Topock 3) containing high fluoride levels (above 4 mg/L), a treatment system that effectively reduces fluoride in the groundwater should be installed if the wells are used as a source of drinking or cooking. Otherwise, residents with children should have an alternative water source, such as bottled water, for drinking or cooking.
- For groundwater wells (Private well 1, Topock 2 and Topock 3) containing arsenic levels above the new MCL of 10 µg/L which is effective on January 2006, installing a treatment system that effectively removes arsenic or using alternative water sources, such as bottled water, for drinking or cooking can provide extra protection to the residents.
- All residents in Golden Shores and Topock area who use private well water for drinking or cooking should have their well water tested yearly for bacteria and nitrates, and at least once for primary metals, such as arsenic, lead, etc., and fluoride.
- Individuals on restricted sodium diet should not drink water from the wells listed in Table 4.

Public Health Action Plan

The Arizona Department of Health Services staff will (1) attend community meetings to communicate the results of this consultation; (2) gather community concerns and answer any additional questions that community members have; (3) work with the ADEQ to provide the results to the affected household directly; (4) update the health consultation when addition sampling results are available.

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Certification

The Pacific Gas & Electric Topock Background Metal Study Health Consultation was prepared by the Arizona Department of Health Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner.

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The Division of Health Assessment and Consultation, Agency for Toxic Substance and Disease Registry, has reviewed this health consultation and concurs with its findings.

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Appendix A

$$CDI = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

Where,

CDI	=	Chronic Daily Intake (mg/kg/day)
CW	=	Chemical concentration in water (mg/L)
IR	=	Ingestion Rate (L/day)
EF	=	Exposure Frequency (day/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Average Time (period over which exposure is averaged, days)

Variable Values

Variable		**Child**	**Adult**
CW	mg/L	Based on site-specific measurement	
IR	L/day	1	2
EF	day/year	350	350
ED	years	6	30
BW	kg	15	70
AT (non-cancer)	days	2,190	10,950
AT (cancer)	days	—	25,550