Health Consultation

HOMESTAKE MINING COMPANY MILL SITE

MILAN, CIBOLA COUNTY, NEW MEXICO

JUNE 26, 2009

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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HEALTH CONSULTATION

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Prepared By:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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Summary

In 1958, the Homestake Mining Company (Homestake), located in Milan, New Mexico, opened a mill to process uranium. The mill operated for approximately 30 years, closing in 1990. Today, two tailings (waste) piles remain on the Homestake site. The tailings piles overlie an alluvial groundwater aquifer, into which contaminants from the piles have migrated. The migration of contaminants in mixing zones between the alluvial aquifer and the underlying aquifers, within the Chinle formation, resulted in the cross-contamination of the aquifers, as well as contamination of some private wells that are completed in the alluvial and Chinle aquifers.

Beginning in the mid-1970s, some of the private wells in the Felice Acres, Broadview Acres, Murray Acres, Valle Verde, and Pleasant Valley Estates subdivisions were sampled for radionuclides, chemicals, and metals. Additional sampling continued in the 1980s and 1990s. Sample results indicated uranium, selenium, and molybdenum concentrations in residential wells during the mid-1970s and up until the mid-1980s were one to two orders of magnitude greater than they have been ever since. The lack of consistent monitoring over the years, the considerable concentration differences in wells within the same aquifer, the unknown usage of wells during the alternate water supply period, and anomalies with the sampling data are all factors that make past exposures an indeterminate health hazard.

In September 1983, the United States Environmental Protection Agency (USEPA) placed the Homestake site on the National Priorities List (NPL) primarily because of groundwater contamination in residential wells. In December 1983, USEPA and Homestake entered into a consent decree to provide for an alternate water supply to the owners of wells in these subdivisions. Homestake was required to provide an alternate potable water supply to nearby residences and to pay for such water usage for 10 years. Alternate water supply hookups to residences were completed in April 1985, and Homestake paid the water bills until 1995. Remediation of the contaminated aquifers has been ongoing since 1977, and over the years, contaminant levels have decreased.

Selenium and uranium levels in some of the wells have, however, remained above their respective maximum contaminant level (MCL)— enforceable drinking water standards. The MCL applies to public water systems, which provide water for human consumption through at least 15 connections, or regularly serve at least 25 individuals. The MCL is set at a level that is based upon someone drinking 2 liters of water containing the contaminant per day over a 70 year period with no resulting adverse health effects. These wells are private wells so the MCL does not apply per se, but was used as a reference or comparison in our analysis.

In 2005, USEPA and the New Mexico Environment Department (NMED) initiated work to determine if area residents had access to uncontaminated potable drinking water. As part of that work, a well survey was conducted by USEPA and NMED in September 2005, which identified 5 of 34 well owners who were using their wells as a primary drinking water source, with the remaining 28 using the alternate water supply (Village of Milan). The September 2005 sampling event identified approximately two-thirds of the wells (22 out of 34) had uranium concentrations above the MCL, three wells had selenium concentrations above the MCL, and one had nitrate above the MCL.

USEPA and NMED conducted an additional round of well sampling in May 2006. Nine of the wells sampled in September 2005 were re-sampled, and an additional 19 wells were sampled that had not been previously. The May 2006 sampling event identified 16 of the 19 wells that were being used as a primary source of drinking water. It is unknown if six other well owners, who had their well sampled during this time, were using their wells. Seven wells were sampled in May 2007. One of these wells had been sampled previously (#20) and another is located where the residence has been connected to the alternate water supply. A total of 57 residential wells were sampled over the three year period. The New Mexico Environment Department (NMED) did notify well owners of the results of their well samples and advised those with MCL exceedances not to use these wells as potable water sources.

Because of remediation efforts and aquifer recharging, concentrations of uranium, arsenic, selenium, and molybdenum have declined in most of the wells. Arsenic concentrations were above the MCL in the past, but were below the MCL during the most recent sampling. Molybdenum does not have an enforceable standard, but it did exceed ATSDR's drinking water comparison value in the past. Molybdenum concentrations from the most recent sampling were below ATSDR's comparison value. Selenium and uranium concentrations in the mid-1970s, 1980s, and in some cases the 1990s were one to two orders of magnitude greater than the last three sampling rounds.

Some of the wells still have levels of contaminants above their respective drinking water standard and/or guideline and could still have them after the remedial actions at the site are completed. It is estimated that the on-going remediation will lower the concentrations of contaminants down to background by 2015, but some of the contaminant concentrations will be above their respective drinking water standard. Homestake's groundwater remedial action is only required to achieve federally–approved background contaminant concentration standards, most of which exceed MCLs. In accordance with accepted public health practice, ATSDR recommends that well owners that are using their well as a source of potable water and have contaminant concentrations above the MCL should obtain another source of potable water. Also, individuals who have obtained a connection to the alternate source of water should continue to use this source of water. This will ensure that they are not exposed to elevated levels of uranium and selenium in the alluvial and Chinle aquifers.

ATSDR calculated exposure doses for the contaminants above health comparison values and MCLs in well sample results from 2005 through 2007 and determined that those being used as a source of potable water were not at levels that would produce known adverse health effects. However, there are a few wells (#12, #16, # 26, #27, and #41) that have uranium concentrations well above the background concentration that are not being used and should not be used. ATSDR has categorized the groundwater in the private wells not connected to the Milan water supply as a no apparent public health hazard. ATSDR defines the no apparent public health hazard category as those sites where exposure to site-related chemicals might have occurred in the past or is still occurring, but the exposures are not at levels likely to cause adverse health effects.

1. Background

The Homestake Mining Company uranium mill, which opened in 1958, is located 5.5 miles north of the Village of Milan in northwest New Mexico. For approximately 30 years, Homestake milled uranium at the site. In September 1983, USEPA placed the Homestake site on the National Priorities List (NPL), primarily because of groundwater contamination. Further investigations at the site identified groundwater contamination in on-site monitoring wells and some residential wells. Shortly thereafter, USEPA and Homestake entered into a consent decree to provide an alternate water supply to the affected residents.

In 1990, the mill closed and was decommissioned and demolished. During 1993–1995, the Nuclear Regulatory Commission (NRC) oversaw surface reclamation activities at the site. Although the mill is gone, two tailings piles remain. The tailings piles are the result of waste products generated from the milling of uranium. The larger pile covers 200 acres and is approximately 100 feet high; the smaller pile covers 40 acres and is 25 feet high.

In September 2005, the NMED and USEPA conducted a well survey in the subdivisions south of the mill site to verify that residents were not drinking contaminated well water. These two agencies collected samples from 34 private drinking water wells. The samples were analyzed for USEPA's target analyte list of compounds and radionuclides. In November 2005, USEPA Region 6 contacted the Agency for Toxic Substances and Disease Registry (ATSDR) and requested that ATSDR review the results and determine whether a public health hazard exists. Additional sampling was conducted in 2006 and 2007; this consultation includes ATSDR's review of those sampling results.

During its survey of the data ATSDR asked USEPA and NMED about any previous sampling that had been done in the area around Homestake. The NMED informed ATSDR of a database Homestake Mining Company generated some years ago containing data for private well sampling in the area. ATSDR obtained and analyzed the data; and incorporated this analysis into the health consultation.

The database included some wells that were sampled as far back as 1975, and others that were only sampled once or twice before September 2005 (USEPA 2005). Many of the wells were not sampled from 1985 through 1995, which is the timeframe of when alternate water was being supplied.

The state of New Mexico's standard for uranium in groundwater was recently changed in June 2007 from 5,000 parts per billion (ppb) to 30 ppb (Court of Appeals State of New Mexico 2006, NMED). USEPA's MCL for uranium is 30 ppb and has been since 2000 (USEPA 2001).

1.1 Demographics

Approximately 200 people live within a mile of the tailings piles. Five residential subdivisions are located south and southwest of the mill site: Felice Acres, Broadview Acres, Murray Acres, Valle Verde, and Pleasant Valley Estates, along with a few residences located near the Pleasant Valley Estates. Within the subdivisions and farther south and west, the land is used for agriculture and livestock. The subdivisions are located between 0.5 mile to 2 miles from the tailings piles, with the nearest residence and drinking water well about 3,000 feet away. The well sample results are from the above five subdivisions and several residences east of State Route 605 that are located southeast of the mill site.

1.2 History

In 1958, milling operations began at Homestake's mill site. The operations involved the use of an alkaline leach-caustic precipitation process to extract and concentrate uranium oxide from uranium ores. The byproducts (waste) were either disposed above ground in the two tailings impoundments or recycled back into the milling process. Groundwater monitoring and remediation at the site began in 1977. Since then, over 600 wells have been installed at the Homestake site for groundwater injection, collection, and monitoring purposes.

Homestake began the state-approved groundwater restoration program in 1977 (CH2MHILL 2001). The program consists of a groundwater collection/injection system for the San Mateo alluvial aquifer and the Upper and Middle Chinle aquifers. Ongoing injection and extraction activities within the Upper and Middle Chinle occurs both within and outside of the subdivisions. The objective is to reduce contaminant concentrations down to background concentrations.

Homestake and the USEPA signed a consent decree for an alternate water supply in December 1983. The decree required Homestake to provide an alternate water supply to nearby residences and to pay for water usage for 10 years. The alternate water supply hookups to residences were completed in April 1985, with Homestake paying for water usage until 1995. The soil cleanup and mill reclamation activities were completed in 1995 and approved by the NRC in 1999 (CH2MHILL 2001). Homestake is operating a groundwater restoration system to remediate those portions of the contaminant plumes, which have migrated off the mill site and are beyond the influence of the primary groundwater collection and injection system.

2. Hydrogeology

The tailings piles are located on alluvium, which is unconsolidated soil or sediment deposited by a river or other flowing water. The alluvium overlies the Chinle and San Andres aquifers, which subcrop with the alluvial aquifer at various locations near Homestake. Radioactive and nonradioactive contaminants within the tailings piles have leached and seeped downward through the soils, beneath the tailing piles into the groundwater. Mixing to some extent between the different aquifers does take place naturally via faulting and subcropping.

Site-derived contaminants within the alluvial ground water subsequently impacted the underlying Chinle aquifer through the subcrop areas. There are two faults, the East Fault and the West Fault, that exist within the Chinle and these alter the groundwater flow direction. Between the East and West Faults (underlying most of the Homestake site), flow is south to north, while west of the West Fault and east of the East Fault, Middle Chinle groundwater flow is north to south. All three Chinle aquifers subcrop with the overlying alluvial aquifer. In the areas where the Chinle subcrops with the alluvium, the area has been defined as a Chinle mixing zone (Hydro-Engineering 2001). The majority of the Upper Chinle mixing zone in the vicinity of the Homestake site occurs between the East and West Faults.

Groundwater monitoring data indicate that contamination from tailings seepage at the mill site has affected the San Mateo alluvial aquifer and the Upper, Middle, and Lower Chinle aquifers. The San Mateo alluvial aquifer is the primary aquifer of concern because it is the most contaminated, and it recharges the Chinle aquifers, which residents in the subdivisions have used as a source of drinking water. The impacted wells are completed in one of the four aquifers. The majority of residential wells that were sampled are completed in the alluvial aquifer. A few

residential wells that were sampled are completed in the San Andres aquifer, one of these wells (#46) had exceedances of the uranium MCL in 2 of the sampling events.

Uranium, molybdenum, and selenium are elements that occur naturally in the various aquifers and this is referred to as the background concentration. The background concentrations of uranium in the groundwater around Homestake are also much higher than other areas of the country due to higher levels that naturally occur within the soil. Mining activities that have occurred up gradient of the Homestake site may have also impacted the groundwater in the area.

In 1989, the NRC established groundwater protection standards (GWPSs) for the Homestake site as "background concentrations" from a single alluvial monitoring well. In December 2005, Homestake representatives proposed a request for the revision of GWPSs in the alluvial aquifer, Chinle mixing zone, and Chinle non-mixing zones to the Nuclear Regulatory Commission. Homestake Mining Company recalculated alluvial aquifer background concentrations using data from 1995 through 2004. The GWPSs were created using this data. In 2006, the NRC, EPA, and NMED established new GWPSs for 10 constituents in the various aquifers. These standards were based upon samples collected from different timeframes and vary with each aquifer. Table 1 lists the constituents for the five that are of concern in our analysis and the standards for each aquifer and mixing (or non-mixing) zone.

It is important to note that the uranium and selenium concentrations in some of the on-site monitoring wells are above their respective drinking water standards in the alluvial aquifer, Chinle mixing zone, Upper Chinle mixing zone, and Middle Chinle non-mixing zone. The mixing zones are areas in the aquifers that have fractures which allow for the inflow of alluvial water. Homestake is required to remove the concentrations of selenium and uranium that are above their respective background concentrations in each of the aquifers to their designated groundwater protection standards and not to enforceable drinking water standards, the MCLs.

Table 1. Approved Groundwater Protection Standards*

Constituent	Drinking water Standard (MCL)	Alluvial Aquifer	Chinle Mixing Zone	Upper Chinle Non-Mixing Zone	Middle Chinle Non - Mixing Zone	Lower Chinle Non-Mixing Zone
Molybdenum	NA (50)	100	100	100	100	100
Nitrate	10,000	12,000	15,000	ND	ND	ND
Selenium	50	320	140	60	70	320
Sulfate	250,000 dwa	1,500,000	1,750,000	914,000	857,000	2,000,000
Uranium	30	160	180	90	70	30

***** Concentrations in parts per billion (ppb) dwa drinking water advisory

NA Not available. 50 ppb is ATSDR's comparison value

ND None determined for the specific aquifer

2.1 Current Groundwater Contamination

During September 2005, the NMED and the USEPA sampled 34 wells in the previously mentioned subdivisions. Figure 1 depicts the locations of the wells within the five subdivisions. Several property owners have more than one well, and of the 28 well owners who consented to sampling, 22 have an alternate water supply—the Village of Milan (NMED 2008). The other five owners indicated that their residences are not connected to the Village of Milan water supply. Two of the wells (# 6, 7) are in the alluvium aquifer and the other four (#'s 9, 10, 20, and 34) are completed in the Lower Chinle aquifer. The owners of well # 6 stated they were drinking bottled water and that they have a filter on their faucet to control water hardness. The owner(s) of well # 7 told NMED officials that they have a filter on their well. The type and efficiency of the filter is unknown.

Sampling results indicated the presence of several contaminants above federal drinking water standards; known as maximum contaminant levels (MCLs), and secondary MCLs (SMCLs). MCLs are enforceable standards under the federal Safe Drinking Water Act. SMCLs are unenforceable guidelines that regulate for aesthetic effects (such as color, smell, and taste) and cosmetic effects (skin or tooth discoloration).

Uranium concentrations in the alluvial aquifer exceeding the MCL of 30 ppb extend from the tailings impoundments to the west and south as two separate, narrow, and elongated plumes. The uranium plume to the west of the impoundments extends beneath the northern portion of Pleasant Valley Estates subdivision, past Valle Verde. The southward-extending uranium plume appears

to originate beneath the east perimeter of the small tailings impoundment and extends under Highway 605, the Broadview Acres and Felice Acres subdivisions, and beyond Felice Acres to the southwest.

Other contaminants detected at levels above drinking water standards or comparison values include selenium and sulfate. One well had a high level of nitrates, but where the nitrates originate is unclear, given that no other well had such high levels.

2.1.1 Groundwater Contaminants

To screen contaminants and to determine which contaminants need further evaluation, ATSDR uses comparison values. These are doses (health guidelines) or substance concentrations (environmental guidelines) set well below levels known—or anticipated to result in—adverse health effects. In some instances the federally enforceable MCL was used as a comparison value; for other contaminants, an environmental media evaluation guideline (EMEG) was used. EMEGs are media-specific comparison values used to select chemical contaminants of potential concern at hazardous waste sites. They are not predictors of adverse health effects, nor do they set cleanup levels. The following describe what each comparison value represents.

EMEG - Environmental Media Evaluation Guides. EMEGs represent concentrations of substances in water, soil, and air to which humans may be exposed during a specified period (acute, intermediate or chronic) without experiencing adverse health effects.

MCL – Maximum Contaminant Level. The MCL is the highest level of a contaminant that is allowed in water delivered to any user of a public water system. MCLs are enforceable standards. MCLs are deemed protective of health during a lifetime (70 years) at an exposure rate of 2 liters per day (2 L/day).

MRL - Minimal Risk Level. A MRL is an estimate of the daily human exposure to a substance that is likely to be without appreciable risk of adverse health effects during a specified duration of exposure. They are set below levels that might cause adverse health effects in most people, including sensitive populations. MRLs are based on non-cancerous health effects only and are not based on a consideration of cancer effects.

RMEG - Reference Dose Media Evaluation Guides. If no Minimal Risk Level (MRL) is available to derive an EMEG, ATSDR develops RMEGs using USEPA's reference doses (RfDs) and default exposure assumptions, which account for variations in intake rates between adults and children. RMEGs apply to chronic (greater than 1 year) exposures.

Table 2 identifies the contaminants and the concentration range found in residential wells during the September 2005 sampling event. Table 3 lists the contaminant levels in those wells not connected to the alternate water source.

A portion of the groundwater sample results ATSDR reviewed for this consultation were presented as total metal concentrations and dissolved metal concentrations. Analyzing the samples in the lab this way helps identify how much of the metal in the sample is bioavailable (dissolved) portion compared to the total (dissolved and undissolved) portion. Bioavailability is the proportion of total metals that are available for incorporation into biota (bioaccumulation). The two portions should be relatively similar regarding the concentration; the total should be slightly higher than the dissolved portion. Upon review of the groundwater monitoring data,

ATSDR recognized that a few of the well sample results had higher dissolved concentrations than total concentrations. For these results, it is likely that the sample results were entered incorrectly. None of the sample results had concentrations vastly different from one another.

ATSDR used the dissolved portion results in the following tables. Total metal concentrations do not necessarily correspond with metal bioavailability. The dissolved portion is more readily available for the body to absorb the metal.

Table 2. Contaminants found in residential wells during September 2005

Contaminants	***Concentration range in parts per billion (ppb)***	***Comparison Value in ppb***	***Type of Comparison Value***	***Number of wells exceeding the Comparison Value***
Arsenic	‹1 – 3	10	MCL	0
Molybdenum	‹1 – 81	50	RMEG	4
Nitrates	ND – 16,000	10,000	MCL	1
Selenium	‹1 – 174	50	MCL; EMEG	3
Sulfate	193,000 – 1,390,000	250,000	USEPA drinking water advisory	33
Uranium	4.3 – 837	30	MCL	23

Table 3. September 2005 contaminant levels found in residential wells not connected to the Village of Milan water supply

Well #	Selenium (50)	Uranium (30)
6	32	**40**
7	40	**47**
9	25	10
20	24	22
34	12	10

Concentrations are in ppb
Drinking water standard in parenthesis (**Bold numbers** indicate the drinking water standard was exceeded).

An open house was held in Grants, New Mexico during March 1-2, 2006 to discuss well sample results with those individuals who had their wells sampled in September 2005. Additional well owners who did not have their well sampled in September 2005 attended and requested that their wells be sampled. USEPA and NMED collected their names and addresses and notified them of when their well was to be sampled.

An additional round of sampling was conducted in May 2006 where 29 wells were sampled. Nine of the wells had been previously sampled in September 2005, but the remaining 22 had not. The well locations are also shown in Figure 1. Table 4 lists the contaminant levels in the wells sampled in May 2006 where the residence is not connected to the Village of Milan water supply.

Figure 1. Locations of wells sampled in September 2005 through May 2007

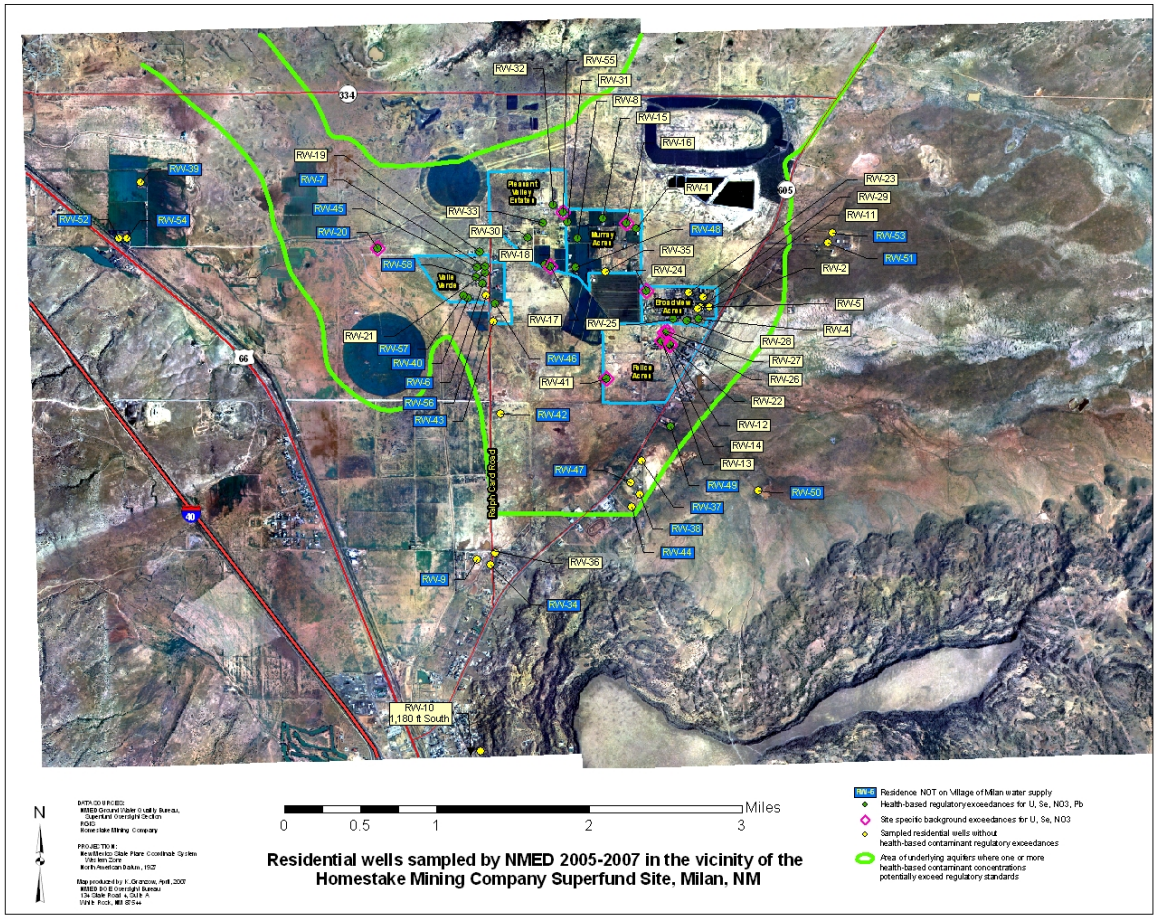


Table 4. May 2006 contaminant levels in wells not on the Village of Milan water Supply

Well #	Selenium (50)	Uranium (30)
6	27	**32**
7	38	**54**
9	26	11
20	26	23
34	13	9
37	13	16
38	8	18
39	6	7
40	24	**37**
42	18	6
43	11	5
44	9	17
45	**54**	**46**
46	18	**46**
47	11	16
49	**101**	25
50	3	9
51	2	25
52	4	4
53	ND	11
54	5	4

Concentrations are in ppb

Drinking water standard in parenthesis (**Bold numbers** indicate the drinking water standard was exceeded).

ND – Non Detection

Seven wells were sampled in May 2007. One of these wells had been sampled previously (#20) and another well sampled is located where the residence has been connected to the alternate water supply. Table 5 lists the contaminant levels in those wells sampled in May 2007 that were not connected to the alternate water supply.

Table 5. May 2007 Contaminant levels in wells not on the Village of Milan water Supply

Well #	Selenium (50)	Uranium (30)
46	21	**55**
49	**97**	**30**
56	11	9
57	26	**44**
58	29	**74**

Concentrations are in ppb

Drinking water standard in parenthesis (**Bold numbers** indicate the drinking water standard was exceeded).

2.2 Past Groundwater Contamination

The sampling conducted in September 2005, May 2006, and May 2007 identified contaminants present at those points in time. To determine any contaminant-level trends in the private wells, ATSDR wanted a better idea of what the contamination levels were in the past. ATSDR reviewed the historical database compiled by Homestake and provided by USEPA, which contained samples dating back to 1975 for some of the wells (USEPA 2005). Table 6 contains the list of wells that were sampled in one of the last three sampling rounds (with the exception of well # 3) and their prior sampling history. Well # 3 was included to give a comprehensive history of all wells sampled over time.

Table 6. Well sampling history

Well number	Aquifer	Last sample date	Residence connected to Milan Water Supply
1	Middle Chinle	1994	Yes
2	Middle Chinle	1998	Yes
3	Upper Chinle	2004	Yes
4	Alluvium	1995	Yes
5	Alluvium	1983	Yes
6	Alluvium	NA	No
7	Alluvium	2002	No
8	Alluvium	1995	Yes
9	Lower Chinle	NA	No
10	Lower Chinle	NA	Yes
11	Alluvium	NA	Yes
12	Alluvium	2004	Yes
13	Middle Chinle	2004/2005	Yes
14	Upper Chinle	2004/2005	Yes
15	Alluvium	1994	Yes

Well number	Aquifer	Last sample date	Residence connected to Milan Water Supply
16	Alluvium	2004/2005	Yes
17	Lower Chinle	1991	Yes
18	Alluvium	1996	Yes
19	Alluvium	1996	Yes
20	Lower Chinle	2001	No
21	Alluvium	1996	Yes
22	Middle Chinle	1996	Yes
23	Alluvium	1997	Yes
24	Middle Chinle	1998	Yes
25	Alluvium	2003	Yes
26	Middle Chinle	2003	Yes
27	Alluvium	2004	Yes
28	Alluvium	2004/2005	Yes
29	Alluvium	1995	Yes
30	Alluvium	1995	Yes
31	Alluvium	1994	Yes
32	Alluvium	2002	Yes
33	Alluvium	1995	Yes
34	Lower Chinle	NA	No
35	Middle Chinle	1981	Yes
36	Unknown	NA	Yes
37	Lower Chinle	1994	No
38	Lower Chinle	NA	No
39	Lower Chinle	1996	No
40	Alluvium	1995	No
41	Middle Chinle	1998	Yes
42	Lower Chinle	1996	No
43	San Andres	1996	No
44	Lower Chinle	NA	No
45	Alluvium	1995	No
46	San Andres	1995	No
47	Lower Chinle	1994	No
48	Middle Chinle	2002	Yes
49	Lower Chinle	2003	No
50	Lower Chinle	1994	No
51	Upper Chinle	2005	No
52	Unknown	NA	No
53	Middle Chinle	1995	No
54	Unknown	NA	No
55	Lower Chinle	1983	Yes
56	Unknown	NA	No
57	Lower Chinle	1998	No
58	Alluvium	NA	No

Many of the wells sampled in September 2005 hadn't been sampled previously for ten years or more. The additional wells sampled in May 2006, that hadn't been sampled in September 2005, had no prior sampling data. Additionally, sampling between 1985 and 1995 was limited because this was the timeframe during which many residences were provided the alternate water supply by Homestake.

This sampling variability over different periods made analyzing the results difficult. Determining potential adverse health effects from exposure is dependent upon what concentrations people were exposed to, and for how long they were exposed. The different aquifers and varying concentrations of contaminants within those aquifers, as well as the depths of the individual wells, must be taken into account when determining what an individual's exposure dose may have been. Wells sampled once only tell us what was in the well at the time of sampling. Compared to past contaminant concentrations, these one-time samples could have been higher, lower, or similar.

Other than the three most recent sampling events, many of the wells (#'s 5, 7, 19, 20, 21, and 23) in the database had only been sampled a few times.

Wells #12 (1981), #13 (1984), #14 (1984), #16 (1975), and #28 (1977)[1] were sampled consistently throughout the 1980s and 1990s. The residences where these wells are located are connected to the Village of Milan water supply.

To determine any trends in contamination, ATSDR used the results from the wells that had been sampled consistently from the mid-1970s through May 2007. Using the wells that were sampled consistently gave us an indication of what the contaminant levels were over time. The following wells had enough samples to complete the evaluation of trends in the sample data:

Alluvium: well #'s 12, 16, and 28

Upper Chinle: 3, 14

Middle Chinle: 13, 26

Lower Chinle: 17

2.2.1 Trends in the data

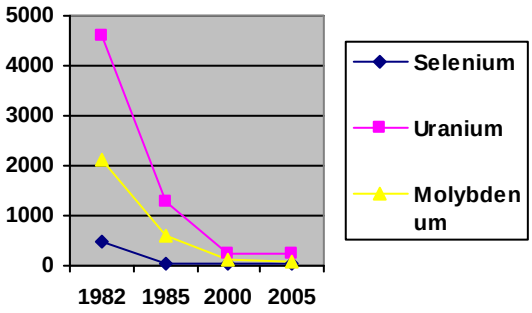
Alluvium wells:

Well #12 and Well #28 are in the Broadview subdivision and are located immediately south of the small tailings pile. Despite their proximity and their location in the alluvium, the contaminant concentrations in the two wells are considerably different:

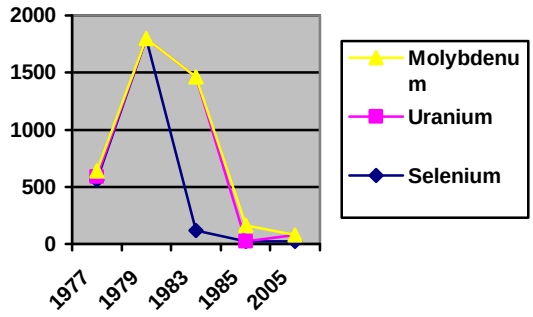
- Uranium concentrations in well #12 were four times greater than those in well #28.
- Molybdenum concentrations are still above comparison values in well #12, but are barely detectable in well #28.

[1] The year in parentheses is when the well was first sampled.

#12



#28



Well #16 is located in Murray Acres.

#16

Selenium concentrations have varied throughout this well over the past thirty years. From the mid -1970s until the mid -1980s the concentrations were well above the MCL, with the highest concentration (370 ppb) detected in 1981. Concentrations dropped in the late-1980s and then increased in the early 1990s. Since November 1999, the concentrations have been below the MCL and the most recent sampling indicated the level was the lowest since that time.

Uranium concentrations have been elevated in this well since 1992 with the highest concentrations occurring between 1996 and 2002. The maximum concentration of 1,960 ppb occurred in 2001 and the September 2005 sample contained 837 ppb.

Molybdenum concentrations do not appear to have been a problem in this well, because they never exceeded the RMEG of 50 ppb.

Upper Chinle wells

#3

Selenium concentrations were between 10 and 60 ppb during the late 1970s and throughout the 1980s. In 1996, the selenium concentration reached a maximum of 147 ppb and concentrations have decreased ever since. Since June 2004, selenium concentrations have been below the detection limit of 5 ppb.

The maximum uranium concentration (237 ppb) was detected in this well in June 1975. Uranium concentrations fluctuated between 8 and 85 ppb throughout the 1980s and 1990s. Since 2001, the concentrations dropped below the MCL and are currently around 6 ppb.

Molybdenum concentrations reached a maximum of 50 ppb in 1983. Since then, concentrations have been below the detection limit of 30 ppb.

#14

Selenium concentrations have varied over time in this well, with a maximum concentration of 70 ppb in 1986. Since 2000, concentrations have been in the 20–30 ppb range.

Since 1984, concentrations of uranium in this well have dropped consistently. In that year, uranium was detected at 916 ppb. By 1986 the concentrations were in the 500–600 ppb range. Since 1989, the concentration has varied between 200–400 ppb. In 2005, the uranium levels were in the high 100-ppb to low 200-ppb range.

The maximum molybdenum concentration (310 ppb) was detected in well 14 during 1984. From 1985 until 1995 concentrations dropped, and since 1995 they have remained below 100 ppb.

Selenium, uranium, and molybdenum concentrations have declined over the years, but uranium levels remain above the MCL of 30 ppb.

Middle Chinle wells

#13

Since October 1990, selenium concentrations in this well have been above the MCL and above the chronic 50-ppb EMEG. In October 1999, the maximum selenium concentration of 261 ppb was detected. Sample results from the September 2005 sampling indicated a concentration of 171 ppb. This well was not sampled in May 2006 or May 2007.

By contrast, over the years uranium concentrations in this well have increased. Between 1984 and 1988, uranium was below the 10-ppb detection limit. Between 1989 and 2002, the concentrations fluctuated from 17 ppb to 56 ppb. From 2003 until 2005, the concentrations increased to over 100 ppb and in February 2005 a maximum of 185 ppb was detected.

Molybdenum levels in this well have remained below the comparison value of 50 ppb.

#26 Sample data was lacking from 1984 to 1994 and from 1996 to 2002.

From 1979 through 1983, selenium levels in this well ranged from as high as 800 ppb (1980) to 90 in 1983. From 1994 until 1995 they were below the comparison value.

Molybdenum levels were much greater in this well compared to well #13 even though they are in the same aquifer. They have continued to decline over the years (two orders of magnitude). A maximum 2,350 ppb was detected in 1982 and the level in the most recent sampling was 65 ppb.

Uranium levels in this well were as high as 6,530 ppb in 1980 and decreased to 180 ppb in September 2005.

In the Middle Chinle aquifer, lead is not at a level that would be considered a public health problem. Uranium levels increased in well #13, but have declined in well #26. However, both wells contain uranium at five (well # 13) to six (well #26) times the MCL.

Lower Chinle wells

The Lower Chinle has the lowest levels of contaminants of any of the aquifers. Historically, selenium and molybdenum have not exceeded comparison values. Only two wells (#17 and #20) have any prior sampling data. Well number 17 lacks sampling data from 1992 until 2005. Well number 20 was only sampled in 2001. Nitrates are elevated in this well, but no other site related contaminants were above comparison values or drinking water standards. Nitrate is also considered to be a site-related contaminant, although it is uncertain where this source is originating.

In 1976, the maximum uranium concentration in well #17 (84 ppb) was detected. Since then, concentrations have varied until the most recent sampling, when 82 ppb was detected.

In 1981, arsenic levels exceeded the comparison value, but ever since the arsenic levels have remained below the comparison value.

ATSDR reviewed over thirty years of sampling results and found that the ongoing remediation has helped in reducing the levels of contaminants. During this time, the levels of some of the contaminants have decreased by two orders of magnitude. ATSDR is concerned about increasing concentrations of uranium in well #13 in the Middle Chinle aquifer, and the elevated levels of uranium in well # 16 located in the alluvial aquifer. Although uranium concentrations are decreasing in well # 16, they are quite elevated compared to the other wells within this aquifer.

Table 7, on the following page, lists the historical concentrations found in wells screened in the various aquifers.

Table 7. Historical contaminant concentration ranges in parts per billion (ppb).

Aquifer	*Arsenic*	*Lead*	*Molybdenum*	*Selenium*	*Uranium*
Alluvial	ND-310*	ND-100	ND-2,120	ND-3,650	ND-1,510,000
Upper Chinle	ND -14	3	ND-310	ND-147	162 – 916
Middle Chinle	ND-28	ND-100	ND-4,930	ND-1,600	ND-12,300
Lower Chinle	ND-10	ND-34	ND-30	ND – 34	ND- 84.8
Comparison Value	3 Chronic EMEG (child) 10 MCL	15 USEPA Action Level	50 Child RMEG	50 Chronic EMEG(child) MCL	30 MCL

***** - Sample result may be an anomaly.

3. Contaminants of Concern

The following are contaminants of concern—that either exceeded the MCL or exceeded a comparison value.

Arsenic

Arsenic is an element that occurs naturally in soil and minerals and is widely distributed in the earth's crust. It may enter the air, land and water from windblown dust and may also enter the water from runoff and leaching. In the environment, arsenic usually bonds with other elements such as oxygen, chlorine, and sulfur. This form of arsenic is known as inorganic arsenic. Arsenic combined with carbon and hydrogen is known as organic arsenic. The organic forms of arsenic are usually less harmful than the inorganic forms. But the specific form of arsenic to which a person may be exposed is not always known—the analytical methods used by scientists to determine the levels of arsenic in the environment generally do not distinguish between organic and inorganic.

The concentration of arsenic in natural surface and groundwater is generally about 1 part in a billion parts of water (1 ppb), but it may exceed 1,000 ppb in mining areas or in areas where arsenic levels in soil are high (ATSDR 2000a). The maximum arsenic concentration was detected in well # 28 in 1977 at 310 ppb, but this reading may be an anomaly because samples

from this well that were analyzed by different labs the day before and the day after show concentrations at 31 ppb and less than 10 ppb, respectively. The sample results from this well in 1981 show arsenic levels at 20 ppb and the September 2005 sample identified a concentration of less than 1 ppb. Arsenic was detected in another well (# 8) in 1977 with the next highest concentration at 40 ppb. In 1978, the well was sampled again and the concentration was equal to 10 ppb. Arsenic concentrations have remained below 10 ppb in this well ever since 1978. The majority of the wells had a concentration of 10 ppb or less and ATSDR used 10 ppb to calculate an exposure dose.

The resulting exposure doses were compared to the MRL of 0.0003 mg/kg/day for chronic duration (365 days or more) of oral exposure to arsenic. The MRL was calculated from a study in which 17,000 people had no symptoms after exposure to an average total daily intake (i.e., from water plus food) of 0.0008 mg As/kg/day (Tseng et al. 1968). Because estimated exposure doses at Homestake are less than 0.0008 mg As/kg/day, nearby residents are not expected to experience adverse health effects due to this level of arsenic. None of the wells sampled during the past 3 sampling rounds had concentrations of arsenic above the MCL.

Lead

Like arsenic, lead is a naturally occurring element and is a known toxin. But unlike arsenic, lead is bluish-gray in color and occurs in smaller quantities in the earth's crust. The main target for lead toxicity in both adults and children is the nervous system. Children, however, are more sensitive to the effects of lead than are adults. Low levels of lead exposure can affect children's mental and physical growth.

ATSDR has not derived MRLs for lead, nor has the USEPA developed a reference concentration (RfC) for lead. USEPA also deemed as inappropriate the development of a reference dose (RfD) for inorganic lead (and lead compounds). Some health effects associated with exposure to lead occur at blood lead levels so low as to be essentially without a threshold (IRIS 1999).

The lead concentration in the areas around the Homestake site has historically been below the USEPA action level of 15 ppb. None of the wells sampled in September 2005, May 2006, and May 2007 had dissolved concentrations of lead above comparison values. Consequently, the lead levels in wells sampled around Homestake are not sufficient to cause adverse health effects.

Molybdenum

Molybdenum is another naturally occurring element found in various ores and is considered an essential trace element. The Food and Nutrition Board (FNB) of the Institute of Medicine has found little evidence that in generally healthy people any molybdenum excess was associated with adverse health outcomes. The FNB determined the tolerable upper intake level for molybdenum in children and adults (FNB 2001):

- For children 1 to 3 years of age, it is equal to 0.3 mg/kg/day;
- children 4 to 8 years of age (0.6 mg/kg/day);
- children 9 to 13 years of age (1.1 mg/kg/day);
- adolescents 14 to 18 years of age (1.7 mg/kg/day); and
- adults (2.0 mg/kg/day).

ATSDR calculated a dose based on the highest concentration (81 ppb) detected during the September 2005 sampling round and found the exposure doses to be below 0.3 mg/kg/day by two orders of magnitude (i.e., 0.0081 mg/kg/day). These doses are not sufficient to cause adverse health effects in people. None of the wells sampled in May 2006 and May 2007 had any molybdenum levels above the comparison value.

Selenium

Selenium is one more naturally occurring, solid element that is widely but unevenly distributed in the earth's crust. Selenium is an essential nutrient for humans and animals. Insufficient selenium intake can cause heart problems and muscle pain. People receive the majority of their daily intake of selenium from eating food, and to a lesser extent, from drinking water.

In some parts of the United States, especially in the western states, some soils naturally contain high levels of selenium compounds. Still, no human populations in the United States have been identified with long-term selenium poisoning, including populations in the western part of the country where, as stated, in-soil selenium levels are naturally high. Most of the selenium that enters the body quickly leaves, usually within 24 hours. Some studies have shown that if mildly excessive amounts of selenium are eaten over long periods, brittle hair and deformed nails can develop (ATSDR 2003).

Selenium levels have been detected above the MCL (50 ppb) in the Lower Chinle, Middle Chinle, and the Upper Chinle aquifers. Results from the May 2006 sampling identified a maximum dissolved concentration equal to 101 ppb. This concentration was found in a Lower Chinle well that is used for domestic purposes and the residence is not connected to the alternate water supply. ATSDR used this concentration to calculate an exposure dose. The exposure dose based on this concentration was above the chronic MRL of 0.005 mg/kg/day, but was below (0.010 mg/kg/day) the No Observed Adverse Effect Level (NOAEL) of 0.015 mg/kg/day for nail disease. The lowest observed adverse effect level (LOAEL) in humans exposed for greater than or equal to one year of exposure was equal to 0.023 mg/kg/day, whereby nail damage was seen.

Uranium

Throughout the world uranium is a natural and common radioactive element. Rocks, soil, surface and ground water, air, plants, and animals all contain varying amounts of uranium. The area around the Homestake site has high concentrations of naturally occurring (background) uranium in the soil and is much higher than other areas of the country. For nearly three decades (1951 – 1980), the Grants uranium district in northwestern New Mexico produced more uranium than any other district in the world (McLemore and Chenoweth 1989). New Mexico ranks second behind Wyoming as the state with the most uranium reserves in the United States (EIA 2001).

Natural uranium is radioactive but poses little radioactive danger—it releases only small amounts of radiation that cannot travel far from its source. Moreover, unlike other types of radiation, alpha radiation released by natural uranium cannot pass through solid objects, such as paper or human skin. You have to eat, drink, or breathe natural uranium in order to be exposed to the alpha radiation; however, no adverse effects from natural uranium's radiation properties have been observed in humans. The National Academy of Sciences determined that bone sarcoma is the most likely cancer from oral exposure to uranium; its report noted, however, that this cancer has not been observed in exposed humans and concluded that exposure to natural uranium may have no measurable effect (BEIR IV).

Scientists have seen chemical effects in people that have ingested large amounts of uranium. Kidney disease has been reported in both humans and animals that were exposed to large amounts of uranium; however, the available data on soluble (more bioavailable) and insoluble uranium compounds are sufficient to conclude that uranium has a low order of metallotoxicity in humans (Eisenbud and Quigley 1955).

When uranium is ingested most of it leaves the body through the feces and a small portion (approximately 2% for an adult) will be absorbed into the blood stream through the gastrointestinal (GI) tract. Most of the uranium in the blood is excreted from the body through urine excretion within a few days; however, a small amount will be retained in the kidneys, bone, and soft tissue for as long as several years. The percentage of the uranium retained in the kidneys over time is different for acute and chronic ingestion of uranium (as long as the individual continues to drink the water). When an individual discontinues drinking the uranium contaminated water, the percentage of retention in the kidney decreases similar to an acute exposure. In the case of chronic ingestion of drinking water containing uranium, the kidney retention (or kidney burden) increases rapidly in the first two weeks. After approximately 100 days, the amount present in the kidney is approximately 5% of the daily intake for an infant and approximately 3% for all other ages. After 25 years of chronic ingestion, the uranium kidney burden reaches equilibrium for all age groups at approximately 6.6% of the daily intake (Chen et al 2004). If a person drank two liters (L) of water per day at the GWPS of uranium in the Alluvial Aquifer (160 µg/L) for 25 years, then the daily ingestion would be 320 µg of uranium resulting in a uranium kidney burden of 21.12 µg (320 µg × 0.066). The weight of both kidneys in adult males ranges from 250 g to 340 g and in adult females from 230 g to 310 g (Madsden et al 2007). Thus, the uranium concentration per gram of kidney tissue would be in the range 0.06 µg/g to 0.08 µg/g for adult males and 0.07 µg/g to 0.09 µg/g for adult females.

Nephrotoxicity (kidney toxicity) occurs when the body is exposed to a drug or toxin such as uranium that causes temporary or permanent damage to the kidneys. When kidney damage occurs, blood electrolytes (such as potassium and magnesium) and chemical wastes in the blood (such as creatinine) become elevated indicating either a temporary condition or the development of kidney failure. Creatinine is a chemical waste molecule that is generated from muscle metabolism. The kidneys maintain the blood creatinine in the normal range and creatinine is a fairly reliable indicator of kidney function. As the kidneys are impaired, the creatinine level in the blood will rise because of the poor clearance by the kidney. If detected early, permanent kidney problems may be avoided.

Several mechanisms for uranium-induced kidney toxicity have been proposed. In one of these, uranium accumulates in specialized (epithelial) cells that enclose the renal tubule, where it reacts chemically with ion groups on the inner surface of the tubule. This interferes with ion and chemical transport across the tubular cells, causing cell damage or cell death. Cell division and regeneration occur in response to cell damage and death, resulting in enlargement and decreased kidney function. Heavy metal ions, such as uranyl ions, may also delay or block the cell division process, thereby magnifying the effects of cell damage (Leggett 1989, 1994; ATSDR 1999b).

Animal and human studies conducted in 1940s and 1950s provide evidence that humans can tolerate certain levels of uranium, suffering only minor effects on the kidney (Leggett 1989). Most of these studies involved inhalation exposures to uranium; however, the kidney is the target organ for inhaled as well as ingested uranium. On the basis of this tolerance, the International Council on Radiologic Protection (ICRP) adopted a maximal permissible concentration of 3 µg of uranium per gram of kidney tissue for occupational exposure in 1959 (Spoor and Hursh 1973). This level has often been interpreted as a threshold for chemical toxicity.

More recent papers have been published on effects of uranium at levels below 3 µg/g, and those papers have discussed possible mechanisms of uranium toxicity (Diamond 1989; Leggett 1989, 1994; Zhao and Zhao 1990; Morris and Meinhold 1995). It is thought that the kidney may develop an acquired tolerance to uranium after repeated doses; however, this tolerance involves detectable histological (structural) and biochemical changes in the kidney that may result in chronic damage. Cells of the inner surface of the tubule that are regenerated in response to uranium damage are flattened, with fewer energy-producing organelles (mitochondria). Transport of ions and chemicals across the tubule is also altered in the tubule cells (Leggett 1989, 1994; McDonald-Taylor et al.1997). These effects may account for the decreased rate of filtration through the kidney and loss of concentrating capacity by the kidney following uranium exposure. Biochemical changes include diminished activity of important enzymes (such as alkaline phosphatase), which can persist for several months after exposure has ended. Therefore, acquired tolerance to uranium may not prevent chronic damage, because the kidney that has developed tolerance is not normal (Leggett 1989). Acting on the basis of this recent information for uranium, researchers have suggested that exposure limits be reduced to protect against these chronic effects on the kidney.

Renal damage appears to be definite at concentrations of uranium per gram of kidney tissue above 3 µg/g for a number of different animal species, but mild kidney injury can occur at uranium concentrations as low as 0.1 to 0.4 µg/g in dogs, rabbits, guinea pigs, and rats after they inhale uranium hexafluoride or uranium tetrachloride over several months (Maynard and Hodge 1949; Hodge 1953; Stokinger et al. 1953; Diamond 1989). Zhao and Zhao proposed a limit of uranium to the kidney of 0.26 µg/g based on renal effects in a man who was exposed to high concentrations of uranyl tetrafluoride dust for 5 minutes in a closed room (Zhao and Zhao 1990). The man showed signs of kidney toxicity, including increased protein content in the urine (proteinuria) and non-protein nitrogen. These signs persisted for 4.6 years, gradually returning to normal values. The kidney content 1 day after the accident was estimated to be 2.6 µg/g.

A study conducted in Finland and published in 2002 observed 325 people that had used their drilled wells for drinking water over a period of 13 years on average (range 1 – 34 years) (Kurttio, Auvinen, Salonen, Saha, et. al 2002). The median uranium concentration in the water was 28 ppb (range 0.001 – 1,920 ppb). The study showed an association between increased uranium exposure through drinking water and tubular function, but not between uranium exposure and indicators of glomerular injury. The primary target is the proximal convoluted tubule of the kidney which is where most of the sodium, water, glucose, and other filtered substances are reabsorbed and returned to the blood. The authors of the study indicated that tubular dysfunction may merely represent a manifestation of subclinical toxicity, and it is unclear if it carries a risk of development into kidney failure or overt illness. This study concluded that "The public health implications of these findings remain uncertain, but suggest that the safe

concentration of uranium in drinking water may be close to the guideline values proposed by the WHO and the U.S.EPA." However, this study found that altered tubular function was statistically significant at water uranium concentrations exceeding 300 µg/L (Kurttio, Auvinen, Salonen, Saha, et. al 2002), which is an order of magnitude higher than EPA's guideline and the median concentration in this study. At 300 µg/L and assuming ingestion of two liters of water per day, the kidney burden after 25 years of chronic ingestion would be 39.6 µg of uranium with the uranium concentration per gram of kidney tissue ranging 0.12 µg/g to 0.17 µg/g.

A review of studies of uranium effects on the kidney (Morris and Meinhold 1995) suggests a probability distribution of threshold values for kidney toxicity ranging from 0.1 to 1 µg/g, with a peak at about 0.7 µg/g. The researchers proposed that the severity of effects increases with increasing dose to the kidney with probably no effects below 0.1 to 0.2 µg/g, possible effects on the kidney at 0.5 µg/g, more probable effects at 1 µg/g, and more severe effects at 3 µg/g and above (Morris and Meinhold 1995; Killough et al. 1998b).

ATSDR's health-based guidelines for ingested (and inhaled) uranium are lower than the lower limit threshold for kidney toxicity proposed by Morris and Meinhold (1995). ATSDR's guidelines are derived by use of levels of toxicity observed in animal studies, and those guidelines incorporate safety factors to account for uncertainty in extrapolating from animals to humans and to protect the most sensitive human individuals (ATSDR 1992).

Note that urinalysis has limitations as a test for kidney toxicity. First, the presence of substances in urine may indicate that kidney damage has occurred, but it cannot be used to determine whether the damage was caused by uranium. Second, most uranium leaves the body within a few days of exposure, so that urine tests can be used only to determine whether exposure has occurred in the past week or two. Finally, the tests may be used to detect mild effects on the kidney, but such effects are generally transient in nature and may not result in permanent damage. More severe effects involve greater damage to the kidney that is likely to be clinically manifest and longer lasting. The kidney has incredible reserve capacity and can recover even after showing pronounced clinical symptoms of damage; however, biochemical and functional changes can persist in a kidney that appears to have recovered structurally (Leggett 1989, 1994; CDC 1998).

The maximum dissolved uranium concentration detected from the September 2005 sampling was 837 ppb. The residence where this concentration was detected is connected to the village of Milan water supply. This well was not sampled in May 2006. ATSDR recommends that this well not be used. The highest concentration detected in wells at residences not connected to the Milan water supply during September 2005 was 46.7 ppb. If people were exposed to this concentration on a daily basis, children and infants expected exposure dose would exceed the MRL of 0.002 mg/kg/day for an intermediate-duration oral exposure. The MRL is based on a LOAEL of 0.05 mg U/kg/day for renal effects in rabbits. The MRL level for intermediate-duration oral exposure is also protective for chronic-duration oral exposure.

In May 2006, the maximum uranium concentration detected was 287 ppb. The residence where this was detected is connected to the Milan water supply. In May 2007, the maximum concentration found in private wells not connected to the Milan water supply was 74 ppb. People

exposed at this concentration would exceed the MRL, but the estimated dose would be below the LOAEL of 0.05 mg U/kg/day. For systemic effects the LOAEL in humans was equal to 131 mg/kg/day (ATSDR 1999).

Other Contaminants

The USEPA has established National Secondary Drinking Water Regulations which set non-mandatory water quality standards for 15 contaminants. These non-enforceable standards are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. These standards are also used as guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration). These contaminants are not considered to present a risk to human health at the secondary maximum contaminant level (SMCL) (USEPA 1992).

Many of the wells sampled contained elevated levels of total dissolved solids (TDS), sulfates, iron, and chloride which exceeded USEPA's SMCLs. A few wells exceeded the SMCL for manganese. The following contaminants were found to exceed the SMCL in the well samples:

Manganese

Three wells contained manganese levels above USEPA's SMCL of 50 ppb. The residences where these three wells are located are connected to the Village of Milan water supply. Manganese is an essential nutrient, and eating a small amount of it each day is important to stay healthy. Too much manganese may also cause serious illness. Manganese miners or steel workers exposed to high levels of manganese dust in air may have mental and emotional disturbances, and their movements may become slow and clumsy. This combination of symptoms is a disease called "manganism".

It is not certain whether eating or drinking too much manganese can cause symptoms of manganism. In one report, people who drank water with above-average levels of manganese seemed to have a slightly higher frequency of symptoms such as weakness, stiff muscles, and trembling hands. However, these symptoms are not specific for manganism and might have been caused by other factors. Another study in adults over 40 years old who drank water with high manganese levels for at least 10 years reported no changes in behavior and no symptoms which commonly occur in people exposed to excess levels of manganese. Two studies reported that children who drank water and who ate food with higher-than-usual levels of manganese did more poorly in school and on specific tests that measure coordination than children who had not eaten above-average amounts of manganese. However, these studies included several limitations; it is not clear whether the adverse effects in the children were caused only by eating too much manganese (ATSDR 2000b).

Sulfates

Many of the wells sampled had elevated sulfate concentrations. The maximum sulfate concentration detected in May 2006 was 2,340 ppm. USEPA's SMCL is equal to 250 ppm and the state of New Mexico's water quality criteria is 600 ppm. Consumption of drinking water with sulfate levels above 600 ppm can cause laxative effects, including diarrhea. Dehydration can result from persistent diarrhea. Infants and children are more susceptible to diarrhea induced dehydration than healthy adults because of their smaller size and more frequent turnover of water

and electrolytes. The elderly and people who are already ill are also at a higher risk of dehydration resulting from persistent diarrhea.

4. Exposure Scenario for Those Persons Still Using Their Well(s)

The three most recent sampling events identified several homeowners who are using their well(s) as a source of drinking water. In addition, there are homeowners who had their well(s) tested, but it is uncertain if they are using their well(s) as a source of drinking water. No institutional controls have been put in place to restrict the use of well water.

The September 2005 sampling identified five well owners whose residences were not connected to the Village of Milan water supply. In September 2005 and May 2006, uranium concentrations in well #6 and well # 7, both located within the alluvium, were above the MCL.

The additional round of sampling conducted in May 2006 identified sixteen additional well owners who are using their wells for drinking water. It is uncertain if six other wells that were sampled are being used as a source of drinking water. A total of 23 current well owners either do not have or it is uncertain if they have any other alternative water supply.

Sampling in May 2007 identified one well with a selenium concentration above the MCL, a uranium concentration equal to the MCL, and sulfates above the MCL. The one well that has had nitrate in excess of the MCL in the past still has them. Three additional wells have uranium and sulfate concentrations above the MCL and the SMCL, respectively.

Remedial actions are expected to continue until 2015. Even when the remedial actions are complete, uranium and selenium levels will still be above their respective drinking water standard. In order to be protective of the public's health, ATSDR recommends that well owners refrain from using their well(s) if any of these contaminants are above their respective MCL. Also, any residential wells with contaminants above their respective SMCL should not be used as a potable water source for the very young, very old, or very ill.

5. Community Concerns

During the meetings held on March 1–2, 2006, ATSDR noted several concerns from the community regarding the use of well water. Included among those concerns, many residents have horses and grow alfalfa for feed and are concerned that the contaminants in the water could contaminate the alfalfa and the horses.

Other residents were concerned about growing vegetables in their gardens and then consuming them. Both selenium and uranium occur naturally in the soil in New Mexico. Hence, any vegetables grown in the yards around Milan would be exposed to both in the soil. Additional exposure could occur if well water containing selenium and uranium are used to water the vegetables. Unfortunately, no vegetable or soil samples were collected and analyzed during the well monitoring event. Therefore, ATSDR does not know what levels of selenium and uranium were in the vegetables.

However, scientific research has shown that uranium transports poorly from soils to plants (Dreesen et al. 1982; Moffett and Tellier 1977). In fact, uranium uptake by plants may be limited to the outer membrane of the root system and may not occur at all within the interior of the root (Van Netten and Morley 1983; Sheppard et al. 1983). That said, because of the higher root

sorption of uranium, the consumption of radishes and other root vegetables grown in soils containing uranium may be a source of human exposure, but a thorough cleaning of the plant exterior—especially if performed in conjunction with removal of the outer membrane—may remove most or all of the uranium (Van Netten and Morley 1983).

Some plants can build up selenium to levels that harm livestock feeding on them. A condition referred to as "blind staggers" has been repeatedly observed in cattle feeding on vegetation in areas with high selenium content in the soil. Blind staggers is a symptom of several unrelated animal diseases, in which the affected animal walks with an unsteady, staggering gait and seems to be blind. These neurological effects however, have not been replicated in experimentally exposed cattle receiving doses of selenium sufficient to induce hoof lesions. Thus, the neurological signs associated with "blind staggers" may be due to other compounds found within the vegetation (ATSDR 2003). At Homestake, ATSDR spoke with several residents who raised cattle in areas near the site; none had observed any "blind stagger" behavior in cattle.

The Agricultural Research Service, within the United States Department of Agriculture (USDA), conducted studies on the bio-transfer possibilities of selenium from plants used in phytoremediation (USDA 2002). Phytoremediation is the use of plants to remediate soils and water that are contaminated with organic or inorganic pollutants. One of the studies involved the feeding of selenium enriched canola or alfalfa to sheep, rabbits, and dairy cows to determine the bio-transfer capability. Results from the study indicated that the levels of selenium did increase in the animal tissues. The effects of the transfer did not appear to be hazardous, and may even have been beneficial for increasing selenium content in different biological systems (USDA 2002). The transfer of selenium to the milk of the cow was too low to pose a potential health hazard to human health or to be detected. A limitation of the study is the fact that the cows were only fed the selenium enriched feed (canola and alfalfa) for 14 days.

Several other residents stated they had moved into the area after the alternate-water consent decree had been issued and consequently did not know about contamination in the residential wells. USEPA and NMED collected the name of every resident who came to the public meeting and their well number. Those who did not have their wells sampled in September 2005 provided their names and addresses to USEPA and NMED. Those individuals had their well sampled in May 2006 and some in May 2007.

One homeowner's well, which is one of the wells farthest from the site, contained nitrates at 25.3 ppm in May 2006. This level is above the drinking water standard of 10 ppm. All other wells were below the standard. Sampling of the well in May 2007 identified a concentration of 16 ppm. The source of the nitrates is unknown. Potential sources of nitrate contamination include runoff due to fertilizer use, leaching from septic tanks or sewage, and its use during the milling of uranium. NMED is currently working with this well owner to determine the source of the nitrates.

6. Conclusions

1. During the 1970s, 1980s, and 1990s, uranium, selenium, and molybdenum concentrations in several private wells near the Homestake site were at levels much greater than those found during September 2005, May 2006, and May 2007. Uranium, selenium, and molybdenum concentrations were sometimes as much as 100 times greater than those found in the past three years. The lack of consistent monitoring over the years, the considerable concentration differences in wells within the same aquifer, the unknown usage of wells during the alternate water supply period, and anomalies with the sampling data are all factors that make past exposures an indeterminate health hazard.
2. From 1985 to 1995, residents near the Homestake site were offered and provided an alternate water supply (City of Milan). Those who accepted the offer for the alternate water source and used this as their sole source of water eliminated their exposure to the contaminated well water. These residents are still using this source of water. If residents continued to use their well water for drinking, showering, watering gardens and lawns, they were potentially exposed to the contaminants.
3. ATSDR did not have any vegetable or soil sample results to determine what the contaminant levels were in the vegetables, and therefore doesn't know what levels people may have been exposed to via this route. The amount of uranium, selenium, and molybdenum ingested would depend upon what type of vegetable it is and the likelihood of the vegetable bioaccumulating any of the contaminants, how often they consumed vegetables, if they used contaminated well water to irrigate the vegetables, and if the vegetables were thoroughly cleaned prior to eating them.
4. Because no institutional controls have been established, residents have had the option of using the contaminated groundwater for irrigation purposes and to provide water for their livestock (e.g., cattle, horses, pigs, and sheep). At a public meeting in March 2005, residents did not indicate to ATSDR any adverse health effects occurring in the livestock.
5. The three rounds of private well sampling conducted between September 2005 and May 2007 identified some owners that are using the village of Milan water supply as their potable water source; others that are using their well(s); and it is unknown if several other owners are using their well(s). Sample results indicated several wells with uranium and/or selenium concentrations above the MCL, but below levels that are known to cause adverse health effects. In order to ensure the health and safety of residential well owners, ATSDR believes the prudent health action for the owners of residential wells that have selenium or uranium concentrations above the MCL would be to refrain from using the wells for potable purposes. Many of the wells also exceed USEPA's drinking water advisory for sulfates and total dissolved solids. These constituents are more of an aesthetic (color, smell, or taste) problem than a health problem, but could pose a problem to the very young, very old, and those that are already ill. ATSDR calculated exposure doses for individuals that are not connected to the Milan water supply and determined that the concentrations are not sufficient to cause adverse health effects. ATSDR has categorized the water in the wells not connected to the Milan water supply as a no apparent public health hazard.

7. Public Health Action Plan

Homestake continues to operate the groundwater extraction/injection system to flush the large tailings impoundment and to clean up groundwater contaminated by the tailings seepage. In an area between the tailings impoundments and the northern edge of the subdivisions, the natural southwest groundwater flow direction has been reversed. This created a capture zone for recovering contaminated groundwater and for preventing further migration of contaminants away from the Homestake site (Hydro-Engineering 2001). Groundwater restoration is expected to continue until 2015. Although ongoing remediation efforts have helped decrease the level of contaminants in the various aquifers, even upon completion of the remediation, the levels of uranium and selenium will be above drinking water standards.

The large tailings pile is currently capped, with a radon barrier and erosion-protection cover on its sides and an interim soil cover on its top. A final radon barrier will be constructed after the tailings are flushed. The small tailings pile is also capped by an interim soil cover. Once the groundwater restoration is complete, a final radon barrier will be constructed.

In January 2009, the NMED and Homestake entered into a Memorandum of Agreement in which the company voluntarily agreed to connect residents within a designated area near the Homestake Mill site to the village of Milan's water supply (NMED 2009). The agreement provides water connection services to 16 designated residences around the mill site. Other property owners can contact Homestake for information on whether their property is eligible.

NMED is studying the area upgradient of the Homestake site and sampling more wells to determine if other mining activity in the area is affecting the various aquifers. USEPA recently initiated a remedy system evaluation (RSE) conducted independently by Environmental Quality Management, an EPA contractor. The purpose of the RSE was to evaluate and look for opportunities to optimize the current remedy at the site. At the time this report was finalized the USEPA had received numerous comments regarding the RSE and was continuing to resolve some additional issues through technical assistance from the US Army Corps of Engineers. ATSDR will continue to work in collaboration with the USEPA and the NMED to evaluate any future sampling results and determine if a public health hazard exists.

8. Recommendations

1. Advise residents who have moved to the area since 1995 of the contamination in the wells and advise those who are using well water to have their water supply tested before using that water for household purposes.
2. Advise residents who are not using the alternate source of drinking water to have their wells sampled, to use bottled water if concentrations are greater than the MCL, or arrange for connection to the Village of Milan water supply. Residents in the 16 designated residences that are eligible for connection to the Village of Milan water supply should accept the offer from Homestake and use this source of water for potable uses.
3. Refrain from using any wells that have concentrations of uranium, selenium, or nitrates above the MCL and any wells that have manganese or sulfates above the SMCL.
4. Advise residents who have vegetable gardens to wash the vegetables thoroughly and remove the skin before cooking or eating them. This is especially true for root vegetables, given their high root sorption of uranium.
5. Conduct sampling of garden vegetables and pasture grasses to determine the concentrations of contaminants in these media.

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