Letter Health Consultation

Hexavalent Chromium Contamination in Well Water near the

SELMA TREATING COMPANY
SELMA, CALIFORNIA

AUGUST 21, 2017

U.S.DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
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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LETTER HEALTH CONSULTATION

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Western Branch

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Agency for Toxic Substances
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Atlanta GA 30333

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Superfund Division
US Environmental Protection Agency, Region 9
75 Hawthorne St.
San Francisco, CA 94105

August 21, 2017

Subject: Hexavalent Chromium Contamination in Well Water near the Selma Pressure Treating Company Superfund Site, Selma, CA

Dear Ms. Ma,

This letter health consultation is a response to your request that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate health risks related to exposure to hexavalent chromium in water from private wells near the Selma Pressure Treating Company Superfund Site in Fresno County, California [EPA 2016a]. You also requested ATSDR's assistance in reviewing information on plant uptake of hexavalent chromium.

ATSDR first evaluated the potential exposure pathways related to hexavalent chromium in private wells near the site (Appendix A, Table 1). Next, ATSDR analyzed EPA chromium sampling summary data (1997-2016 [EPA 2016b]) from these wells to determine which wells had levels above ATSDR comparison values (CVs).[1] This evaluation also included identifying data limitations. In Appendix A, Table 2 reports data from domestic wells and Table 3 reports data from irrigation wells. Finally, we provided you with literature on plant uptake of hexavalent chromium with assistance from the U.S. Department of Agriculture (Appendix B).

Conclusions

ATSDR concluded the following regarding exposures to hexavalent chromium from private wells:

1) **The hexavalent chromium in all the private domestic wells sampled posed minimal health risks because exposure doses are below ATSDR's intermediate and chronic Minimal Risk Levels (MRLs)[2]. EPA's 2016 actions mitigated potential future health risks.**

   a. A child drinking a lot of water every day for 14 - 364 days from the private domestic well with the highest hexavalent chromium level, DW-90, could have been exposed to a level close to, but below, ATSDR's intermediate MRL (calculations on pages 15-16). The

[1] Comparison values (CVs) are substance concentrations set below levels that are known or anticipated to result in adverse health effects.

[2] ATSDR MRLs are doses expected to be without appreciable risk of adverse noncancerous health effects during a specified duration of exposure. Intermediate MRLs address exposures of >14 – 364 days and chronic MRLs address exposures of a year or more.

concentration of hexavalent chromium in this well was as high as 84.7 micrograms per Liter (µg/L) and has been increasing in recent years (page 14, Figure 2). ATSDR agrees with EPA's initial action to provide bottled water to residents using this well. ATSDR also concurs with EPA's follow up (long-term) solution, completed in December 2016, to install a treatment system to reduce hexavalent chromium levels to below 10 µg/L (the former California maximum contaminant level (MCL) for hexavalent chromium).[3]

b. Eight private domestic wells deserve attention because their hexavalent chromium levels produce a dose close to ATSDR's chronic MRL for children and the levels appeared to be increasing in some cases. These wells are shaded in Table 2 (Appendix A).

c. Hexavalent chromium was recently detected in three wells above the chronic child Environmental Media Evaluation Guide (EMEG).[4] Two were above the former California MCL as well, and now have EPA-installed treatment systems (DW-90 and DW-32). Post mitigation testing found wells to have hexavalent chromium concentrations below the child chronic EMEG. Well DW-192 did not receive treatment. It had some hexavalent chromium concentrations just above ATSDR's child chronic EMEG, but below the former California MCL.

d. Five other wells had estimated average hexavalent chromium levels above the chronic EMEG, due to elevated concentrations in the past. There has been no recent sampling of these wells; thus the potential continued risk is less certain.

2) **Using conservative exposure estimates, ATSDR determined that long-term exposures (beginning in childhood and continuing into adulthood) to hexavalent chromium from private domestic wells might produce a low increased risk of cancer.** These exposure estimates assumed a 10% oral bioavailability adjustment for hexavalent chromium in water which is a upperbound bioavailability estimate. The true risk from long-term consumption of drinking water containing detected levels of hexavalent chromium is likely lower.

3) **We don't have enough information about whether people are drinking from irrigation wells to assess whether hexavalent chromium levels in those wells pose a human health risk.** ATSDR noted that four irrigation wells had hexavalent chromium levels above the ATSDR screening values (see Table 3 in Appendix A). While irrigation wells are not intended to serve as drinking water sources, ATSDR is available to assess hexavalent chromium exposure health risks for any irrigation well that EPA determines is used for drinking water purposes.

4) **Inhalation and dermal exposure to the hexavalent chromium in the groundwater is not expected to harm people's health. Ingestion of groundwater is the primary hexavalent chromium exposure pathway at the site (Table 1).** Dermal and inhalation exposure studies show little or no exposure to hexavalent chromium in water.[5]

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[3] In 2017, the California Water Resources Control Board revoked the state's 10 µg/L hexavalent chromium MCL after it was invalidated by the Superior Court of Sacramento County [California Water Resources Control Board 2017]. The Court found that the state had "failed to properly consider the economic feasibility of complying with the MCL." The state's 50 µg/L total chromium MCL remains in effect.

[4] ATSDR's EMEGs are concentrations of substances in water, soil, or air to which humans may be exposed during a specified period of time (acute, intermediate or chronic) without experiencing adverse health effects. EMEGS are derived from MRLs using additional health protective assumtions.The hexavalent chromium chronic EMEG for children is 6.3 µg/L and for adults is 23 µg/L [ATSDR 2016a].

[5] While inhalation and dermal exposures to sodium chromate can be a health hazard, low levels of hexavalent chromium in water is not.

5) Ingestion of chromium in plants is not expected to harm people's health. Plant uptake studies show most of the chromium from water will reside in a plant's roots or in soils on the plant. Therefore, we expect that raisins and other fruits that grow off the ground will take up less chromium than root vegetables.

Limitations

The basis for these conclusions are the 1997-2016 chromium sampling summary data provided by EPA. These data are sporadic and used various laboratory analytical methods. Further, ATSDR has very little information about the current or past use of these wells. Variability in the quality of the data available for this assessment creates additional uncertainty in evaluating groundwater migration, estimating exposures, and drawing health conclusions (explained in Appendix B). That said, ATSDR used conservative methods and assumptions to be health protective. For instance, ATSDR assumed 100% bioavailability of hexavalent chromium in our initial (EMEG) screening and then used a lower, yet protective estimate of 10% for our more detailed exposure and toxicological evaluation. The screening tables (Tables 2 and 3 of Appendix A) may help EPA prioritize exposure-reduction actions at wells posing higher recent and past risks. Because of data gaps, these tables cannot be used to determine future risks or risks prior to 1997. ATSDR provides a more detailed discussion of exposure and health risks in Appendix B.

Recommendations

ATSDR recommends that EPA take the following steps to protect the health of residents and farmworkers near the site.

- Continue groundwater sampling efforts to characterize the hexavalent chromium plume and identify all wells that might be affected by the site.
- Continue efforts to gain access to domestic wells at households that may be affected by the site, but have not been previously or recently sampled.
- Gather demographic information for households relying on private domestic well water to determine if sensitive individuals (like infants and pregnant women) are using the wells. This data helps prioritize households for monitoring and/or remedial action, as necessary.
- Continue sampling domestic and irrigation wells, at least annually. In addition, consider a well monitoring strategy that includes taking multiple samples each year from domestic wells with highly fluctuating hexavalent chromium levels, as some wells have fluctuated by more than 35 µg/L between samples.
- Continue to provide alternative water and/or an onsite water treatment system to residents whose domestic well water contains levels of hexavalent chromium that might harm their health. At homes with treatment systems, sample domestic well water both pre- and post-treatment at least yearly to ensure the system's effectiveness.

- If residents are concerned about hexavalent chromium levels in their in drinking water, share relevant information from EPA, ATSDR, and the California Water Board. For instance:
    - EPA's Chromium in Drinking Water webpage: https://www.epa.gov/dwstandardsregulations/chromium-drinking-water
    - ATSDR's 2012 ToxFAQs on Chromium: https://www.atsdr.cdc.gov/toxfaqs/tfacts7.pdf
    - The California Water Board's 2017 announcement "Maximum Contaminant Level for Hexavalent Chromium – Court's Judgement Invalidating MCL," at http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chromium6.shtml.
    - The California Water Board's 2015 fact sheet "Frequently Asked Questions about Hexavalent Chromium in Drinking Water," which is available at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/chromium6/chromium_fact_sheet_2015_final.pdf.
- Encourage well owners to follow the California State Water Resources Control Board's (WRCB's) guidance for testing and maintaining their wells. Specifically, ATSDR recommends that EPA shares WRCB's Guide for Private Domestic Well Owners, available at: http://www.waterboards.ca.gov/gama/docs/wellowner_guide.pdf. All water quality standards should be met to ensure drinking water is safe.
- Remind irrigation well owners that irrigation wells should not be used as drinking water sources and encourage them to post "do not drink" signs in English and Spanish at their irrigation wells.
- Share information with irrigation well owners (and farm operators) about the State of California's requirements for providing safe drinking water to farmworkers [State of California 2017].
- Continue efforts to learn whether people (e.g., farmworkers) are drinking water from irrigation wells near the site or whether they have done so in the past.
- Consider sampling soils in the areas irrigated with contaminated groundwater, if there are concerns about the fate and transport of hexavalent chromium from irrigation water.

Other ATSDR Actions:

- We have shared with you the studies on plant uptake of chromium and other metals that the U.S. Department of Agriculture provided to ATSDR.
- We are available to assess health risks from exposure to contaminated well water at the Selma site, as new data or information becomes available.
- We are available to assist EPA in communicating the conclusions and recommendations in this letter to affected community members.

Thank you for including ATSDR in your site work. Please do not hesitate to contact me (770-488-0778 GZarus@cdc.gov) or Ben Gerhardstein in our Region 9 office (415-947-4316; BGerhardstein@cdc.gov) if you have other questions.

Sincerely,

Gregory M. Zarus

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Technical Appendices A & B

Appendix A: Tables

Appendix B: Exposure Pathway, Toxicology Evaluations and Figures 1 & 2

Authors
References

Appendix A

Table 1: Groundwater Exposure Pathway Assessment

Pathway	Environmental Medium	Exposure Route	Location	Exposed Population	Pathway Classification
Private Domestic Wells	**Groundwater**	**Ingestion**	**Homes near site**	**Child and adult residents, adult workers**	**Completed - past, current, and future**
Private Domestic Wells	Groundwater	Inhalation (shower and evaporative coolers)	Homes near site	Child and adult residents	Completed - past, current, and future; Minimal
Private Domestic Wells	Groundwater	Dermal	Homes near site	Child and adult residents	Completed - past, current, and future; Minimal
Irrigation Wells	**Groundwater**	**Ingestion**	**Farms near site**	**Adult farmworkers**	**Potential - past, current, and future**
Irrigation Wells	Groundwater	Dermal	Farms near site	Adult farmworkers	Completed - past, current, and future; Minimal
Biota	Food (largely commercial raisins)	Ingestion	Farms near site	Children, adults	Potential – past, current, future; No data to evaluate this pathway; Expected to be minimal
Public water supply	Groundwater	Ingestion	Homes and businesses served by City of Selma	Residents, workers	Eliminated (EPA reports not affected by site)

Notes: Bolded pathways are the primary exposure pathways of concern.

Explanation of ATSDR's process follows in the "Exposure pathway evaluation" section of Appendix B.

Table 2: Selma Domestic Well Data and Health Risk Screening (concentrations in μg/L)

Well ID	Range of Chromium (VI)	Exposure Concen-tration*	DQ	Comparison Values (CV)			Samples> Child cEMEG	Dates Sampled**
				Child cEMEG	CA MCL§	Child iEMEG		
DW-99	ND	4.74	J, TC	6.3	10	35	0/27	1997-2008
DW-07	ND	5.0	J, Avg, TC	6.3	10	35	0/28	1997-2008
DW-35	ND-5.4J	5.4	J	6.3	10	35	0/28	1997-2009
DW-191	ND	2.9	J, TC	6.3	10	35	0/1	2005
DW-192	6.5-7.6	7.1	Avg, ¥	6.3	10	35	2/2	2015-2016¥
DW-97	ND	5.0	U, ¥, TC	6.3	10	35	0/1	1997¥
DW-53	2.58 - 3.3	3.06	J, Avg	6.3	10	35	0/2	2015-2016
DW-578	ND-8.7 J	5.58	J, Avg	6.3	10	35	3/31	1997-2016
DW-23	ND-10	9.1	Avg	6.3	10	35	4/25	1997-2009
DW-24	**74**	**74**	**NIU**	**6.3**	**10**	**35†**	1/1	**1997**
DW-32	**ND-66**	**26.2**	**UCL**	**6.3**	**10‡**	**35†**	35/46	**1997-2016**
DW-35	ND-10	7.5	J, Avg	6.3	10	35	1/20	1997-2006
DW-778	**ND-31**	**31**	**Max**	**6.3**	**10€**	**35**	2/3	**2004¥**
DW-13	ND-6.2	5.38	Avg	6.3	10	35	0/10	2005-2016¥
DW-58	ND-13.9	7.4	J, Avg	6.3	10	35	6/26	1997-2016
DW-68	ND-8.7	5.95	Avg	6.3	10	35	0/10	2004-2016£
DW-14	ND-6 J	3.5	J, Avg	6.3	10	35	0/27	2004-2016£
DW-90	**ND-84.7**	**51.2**	**UCL**	**6.3**	**10‡**	**35†**	30/31	**2005-2016**
DW-47	ND-5.1	4.65	Avg	6.3	10	35	0/4	2015-2016
DW-50	ND-2	2	Avg	6.3	10	35	0/3	2005; 2016
DW-64	ND	3.7	J	6.3	10	35	0/1	2005
DW-36	1.2	1.2		6.3	10	35	0/1	2016

*ATSDR's methods for estimating exposure concentrations are explained in the "Exposure point concentration estimation methods" section. Exposure point concentrations involved total chromium measurements due to data quality (Appendix B).

** Some well samples were not collected due to discontinued use or due to no permitted access.

DW = Domestic (private) well; μg/L = micrograms per liter; CV = Comparison value.

cEMEG = ATSDR's chronic Environmental Media Evaluation Guide for an exposure to hexavalent chromium in drinking water for over one year [a concentration associated with the chronic Minimal Risk Level (MRL) dose; ATSDR 2016c].

§ = The State of California's former Maximum Contaminant Level (for public drinking water systems) – revoked May 31, 2017.

iEMEG = Intermediate Environmental Media Exposure Guide, ATSDR's health comparison value for 15-364 days [a concentration causing a dose above the intermediate Minimal Risk Level (MRL)].

Samples > Child cEMEG = A ratio of the number of samples greater than the child cEMEG compared with the total number of samples.

Shaded rows indicate wells with an exposure point concentration above the child cEMEG.

Bold text indicate wells with an exposure point concentration above the former California MCL and the cEMEG.

DQ = Data qualifiers that relate to how the exposure concentration was calculated

ND = Not detected; J = Estimated value; U = Detection level

TC = Total chromium value was used because hexavalent chromium detection level was high and not detected.

Avg = Arithmetic average of detected values only

UCL = 95th percent upper confidence limit of the mean

Max = Maximum value was used because of data quality issues or because measurements were increasing.

NIU = Well is not expected to be in use.

£ = Lapses in data or more than three years within the date range

¥ = One early sample was collected in 1997 that was ND and had a U of 20 μg/L.

€ = Exceedance of former California MCL was in the past; recent (2016) result was below the former California MCL.

‡= Recent (2016) sample was above the MCL.

† = Exposure concentration above the iEMEG for children

£ = Lapses in data or more than three years within the date range

Further discussion of the data in this table is provided in the "Screening to determine which wells pose a greater risk" section of Appendix B.

Table 3: Selma Irrigation Well Data and Health Risk Screening (concentrations in µg/L)

Well ID	Range of Chromium (VI)	Exposure Concen-tration*	DQ	CA MCL§	cEMEG	Samples > cEMEG	Comment	Dates Sampled
IW-7	**ND-110**	**63.6**	**UCL**	**10**	**23**	**27/33**	**Often above the cEMEG**	**2004-2016**
IW-8	**42-120**	**118.6**	**UCL**	**10**	**23**	**5/5**	**Max is close to the adult iEMEG of 130 µg/L**	**2004**
IW-9	**6.4 J-27.6**	**19.9**	**UCL**	**10**	**23**	**1/7**		**2005-2009**
IW-9B	**6.4-16.3**	**16.3**	**Max**	**10**	**23**	**0/2**		**2015-2016**
IW-12	ND	5.31	J, Avg, TC	10	23	0/14		1997-2004
IW-15	**7.02-33**	**33**	**Max**	**10**	**23**	**1/2**	**Max value in 2016**	**2015-2016£**
IW-16	**19.1-104**	**86.4**	**UCL**	**10**	**23**	**22/24**	**Frequently above the cEMEG**	**2005-2016**
IW-17	ND	4.4	J	10	23	0/1		2005
IW-17B	**7.8-11**	**11**	**Max**	**10**	**23**	**0/2**		**2016**

*ATSDR's methods for estimating exposure concentrations are explained in the "Exposure point concentration estimation methods" section. Exposure point concentrations involved total chromium measurements due to data quality (Appendix B).
IW = irrigation well; µg/L = micrograms per liter; CV = Comparison value.
cEMEG ATSDR's chronic Environmental Media Evaluation Guide for an adult's exposures to hexavalent chromium in drinking water for over one year [a concentration associated with the chronic Minimal Risk Level (MRL); ATSDR 2016c].
§ = The State of California's former Maximum Contaminant Level (for public drinking water systems) – revoked May 31, 2017.
iEMEG = Intermediate Environmental Media Exposure Guide for adult for 15-364 days
Samples > cEMEG= A ratio of the number of samples greater than the cEMEG compared with the total number of samples.
Shaded rows have exposure point concentrations above the cEMEG for adults.
Bold text was used to indicate exposure point concentrations above the former MCL and the cEMEG.
DQ = Data qualifiers that relate to how the exposure concentration was calculated
ND = Not detected; J = Estimated value
TC = Total chromium value was used because hexavalent chromium was undetected and detection level was high.
Avg = Arithmetic average of detected values only
UCL = 95th percent upper confidence limit of the mean
Max = Maximum value was used because of data quality issues or because measurements were increasing
£ = Lapses in data of more than three years within the date range

Further discussion of the data in this table is provided in the "Screening to determine which wells pose a greater risk" section in Appendix B.

Appendix B

Site background

The 18-acre Selma Pressure Treating Company Superfund Site is located in an agricultural area of Fresno County, California, near the City of Selma. From 1936 – 1994, a wood treatment facility operated at the site [EPA 2016a]. Historical wood treatment operations led to soil and groundwater contamination at the site. Soil remediation is complete. Groundwater is contaminated with chromium (including hexavalent chromium) and groundwater remediation is ongoing [EPA 2016a].

In 2014, in response to new information about the toxicity of hexavalent chromium, the State of California established a Maximum Contamination Level (MCL) for hexavalent chromium of 10 µg/L in public drinking water systems. On May 31, 2017, the Superior Court of Sacramento County issued a judgment invalidating the hexavalent chromium MCL because the state had "failed to properly consider the economic feasibility of complying with the MCL" [Superior Court of Sacramento County 2017]. The extent of the Selma Pressure Treating hexavalent chromium groundwater plume at the 10 µg/L level is not completely delineated or known. EPA is currently conducting an investigation to define the extent of the hexavalent chromium plume [EPA 2016a].

Private groundwater wells exist downgradient of the site and within the hexavalent chromium groundwater plume. These wells are used for drinking water, residential landscaping purposes, and irrigation. Since the extent of the hexavalent chromium groundwater plume has not been defined, there may be additional private wells with chromium contamination. EPA has sampled private wells, for which well owners have granted access, within the known extent of the chromium plume. In 2016, EPA provided bottled water to households receiving drinking water from two domestic wells with hexavalent chromium concentrations above the former California MCL. In addition, EPA has installed onsite treatment systems for those wells [EPA 2016a]. As reported by EPA, the public water supply for the nearby City of Selma appears to not be affected by the groundwater plume. Recent concentrations of total chromium in City water supplies have ranged from 1.5 to 3.5 µg/L [California Water Service 2015].

Exposure pathway evaluation

ATSDR identified exposure pathways to determine how people might be exposed to hexavalent chromium in groundwater. Five elements are considered in the evaluation of exposure pathways:

1) A source of contamination;
2) Transport through an environmental medium;
3) A point of exposure;
4) Route of exposure; and
5) An exposed 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. In a potential exposure pathway, one or more elements of the pathway cannot be identified, but it is possible that the element might be present or might have been present.

An exposure pathway can be eliminated when one or more of the five elements is and was missing, and will never be present. Completed and potential pathways can also be eliminated when they are unlikely to be significant.

Table 1 includes pathways of exposure to groundwater from private wells for irrigation and domestic uses near the Selma site. In Table 1 the most critical pathways for hexavalent chromium exposure are shaded, and the reasoning is discussed below.

Ingestion is the primary pathway of concern: Households near the site rely on private wells for drinking water and irrigation purposes. In addition, though the State of California requires that farmworkers be provided with safe drinking water, farmworkers might use irrigation wells for drinking water [State of California 2017]. ATSDR does not know whether farmworkers are consuming water from wells near the Selma site currently or if they did so in the past.

Inhalation exposure is not a significant exposure pathway for hexavalent chromium: Inhalation of hexavalent chromium from water while washing, showering, or used in evaporative coolers is not a significant pathway because chromium is not volatile (i.e., chromium does not evaporate). Studies suggest that health risks related to this pathway are minimal [Finley 1996]. Finley found hexavalent chromium air concentrations of 0.087-0.324 $\mu g/m^3$ associated with water concentrations of 890-11,500 µg/L. The maximum air level measured in that study was near ATSDR's MRL for continual exposures of up to a year for hexavalent chromium in air (0.3 $\mu g/m^3$). The concentration of hexavalent chromium in water (>890 µg/L) necessary to create the air levels observed in the study were many times higher than the levels (>100 µg/L) found in wells near the Selma site.

Dermal (i.e., skin) exposure is not a significant exposure pathway for hexavalent chromium in water at these levels. ATSDR expects exposure through the skin by washing or showering with water contaminated with hexavalent chromium to be minimal. Low dermal absorption combined with the reductive capacity of the skin results in insignificant exposure from skin contact relative to ingestion [ATSDR 2012].

Ingestion of plants: No site specific data is available on hexavalent chromium contamination in plants or the agricultural soils, but the literature suggests that very little chromium, including hexavalent chromium, is taken up by plants [ATSDR 2016b]. When it is taken up, it is usually limited to the leaves, roots, and lower stems [Chaney 1996 & 2008, and Tyler 2001a&b]. ATSDR requested assistance from the U.S. Department of Agriculture in evaluating plant uptake of chromium. They reported a minimal concern for chromium uptake in edible plants and provided twelve published works from their researchers supporting their position identified in the reference list [ATSDR 2016b].

Variability in data quality creates uncertainty in estimating exposures

ATSDR reviewed the hexavalent chromium and total chromium results for each private domestic and irrigation well from 1997-2016. These data have several limitations that affected ATSDR's analysis.

For certain wells there were very few samples taken over this timeframe. There was also considerable variability in the sampling and analytical methods that have been used. For instance, recent sampling rounds included both filtered and unfiltered samples (which is helpful for assessing health risks) while others did not. Dissolved hexavalent chromium is considered more mobile and biologically available and thus more useful for risk assessment. Dissolved metals analysis is performed by filtering the water before analyzing the metals. The recent results for Selma include both filtered and unfiltered results, but past sampling results do not indicate if they were filtered or not. Hexavalent chromium detection levels for recent (2015-2016) samples were reasonably low, but not so in the past (especially 1997-2009). For certain samples the detection levels were higher than ATSDR's comparison values.

ATSDR compared hexavalent and total chromium results to identify other trends and data quality issues. We noted correlations between hexavalent chromium and total chromium. The results also indicated that most of the total chromium was made up of hexavalent chromium. Further, the total chromium results were of better quality for all periods. Total chromium detection levels were often lower than hexavalent chromium. In some cases, hexavalent chromium results are reported as higher than total chromium, which indicates some uncertainty in the hexavalent chromium results. In some cases, the filtered water provided higher hexavalent chromium results than the unfiltered water, which also indicates uncertainty. To account for these uncertainties ATSDR used the following method for estimating hexavalent chromium concentrations in wells.

Exposure point concentration estimation methods

ATSDR estimated hexavalent chromium exposure concentrations by using the 95% upper confidence limit (UCL) of the mean and other statistical values calculated on data using the following data quality hierarchy:

1) Hexavalent chromium filtered: Using hexavalent chromium detected results for laboratory-filtered water (to detect soluble portion) when reliable (including "J" values);
2) Hexavalent chromium non-filtered: Using hexavalent chromium detected results for water not reported as filtered when reliable (including "J" values) and no hierarchy 1 data was available;
3) Total chromium filtered: Using total chromium detected results for filtered water when reliable (including "J" values) and no hierarchy 1 or 2 data were available;
4) Total chromium non-filtered: Using total chromium detected results for water not reported as filtered when reliable (including "J" values) and no hierarchy 1, 2, or 3 data were available; and
5) Detection level: Using the lower detection level for total or hexavalent chromium when no hierarchy 1-4 data was available.

The spreadsheet excerpt to the right, helps illustrate how a hexavalent chromium exposure history can be estimated. The yellow highlighted cells identify a time history of potential hexavalent chromium values that is conservatively high (see March 2007) yet, for this data set, more accurate than other substitution methods that only use hexavalent chromium results and detection levels. The average using the substituted data is 5.9 µg/L and the 95% UCL is 8.0 µg/L. This UCL in this case is close to the highest value measured at this well (of 8.2 µg/L; J-estimated).

Figure 1: Example sample history for one domestic well

Sampling Event	Hexavalent Chromium (ug/L)	Chromium (ug/L)
January 2005	10 U	3.0 J
February 2005	10 U	2.7 J
July 2005	10 U	4.3 J
October 2005	10 U	4.3 J
March 2006	10 U	11.7
July 2006	10 U	5 U
November 2006	10 U	7.0
March 2007	8.2 J	5.23
July 2007	10 U	4.00 J
November 2007	10 U	2.85 J
March 2008	10 U	3.98 J
August 2008	10 U	4.64 J
January 2009	10 U	17.4
July 2009	10 U	6.15
April 2016	3.2	15

We did additional checks to verify that our methods did not underestimate exposures. These checks were performed by substituting the hexavalent chromium detection levels (DL), DL/2, DL/(sqrt2). We also checked the results against the average of the measured values and the maximum value. The maximum likelihood substitution which requires a normal distribution of detected results could not be used in most cases because most wells lacked sufficient detected hexavalent chromium values. The excerpt shows this because it only contains two detected values, not a distribution.

Screening to determine which wells pose a greater risk

We estimated potential exposure-concentration histories for each well using methods described above. With that data we calculated long-term multiple year averages. We then compared these exposure concentrations to comparison values (CVs)[6], including ATSDR EMEGs[7] and the former Cal EPA MCL[8]. We used EMEGs for children to screen private domestic wells. We used adult EMEGs to screen irrigation wells, because adult workers may have used them as drinking water sources. By comparing the estimated exposure concentrations to these health-protective screening values, ATSDR is able to determine which wells require more detailed analysis.

__Private domestic well screening__

Table 2 in Appendix A identifies the private domestic well exposure concentrations along with the CVs. We have highlighted those which were higher than the chronic EMEG (the lowest CV). Some were also

[6] Comparison values (CVs) are substance concentrations set below levels that are known or anticipated to result in adverse health effects.

[7] ATSDR's EMEGs (Environmental Media Exposure Guides) are concentrations derived from doses expected to pose minimal or no risk (at the Minimal Risk Level [MRL]) for specific conditions. EMEGs are available for intermediate and chronic exposure. EMEGs to protect children from long-term (chronic) exposures are the lower screening value. The hexavalent chromium chronic EMEG for children is 6.3 µg/L and for adults is 23 µg/L [ATSDR 2016a].

[8] California EPA Maximum Contaminant Levels (MCLs) are health protective legal drinking water standards to be met by public water systems. MCLs take into account not only health risks from exposure to a chemical, but also factors such as detectability and treatability, as well as costs of treatment to reduce a chemical's presence in drinking water [California Water Boards 2015]. In 2016, the Cal EPA hexavalent chromium MCL was 10 µg/L.

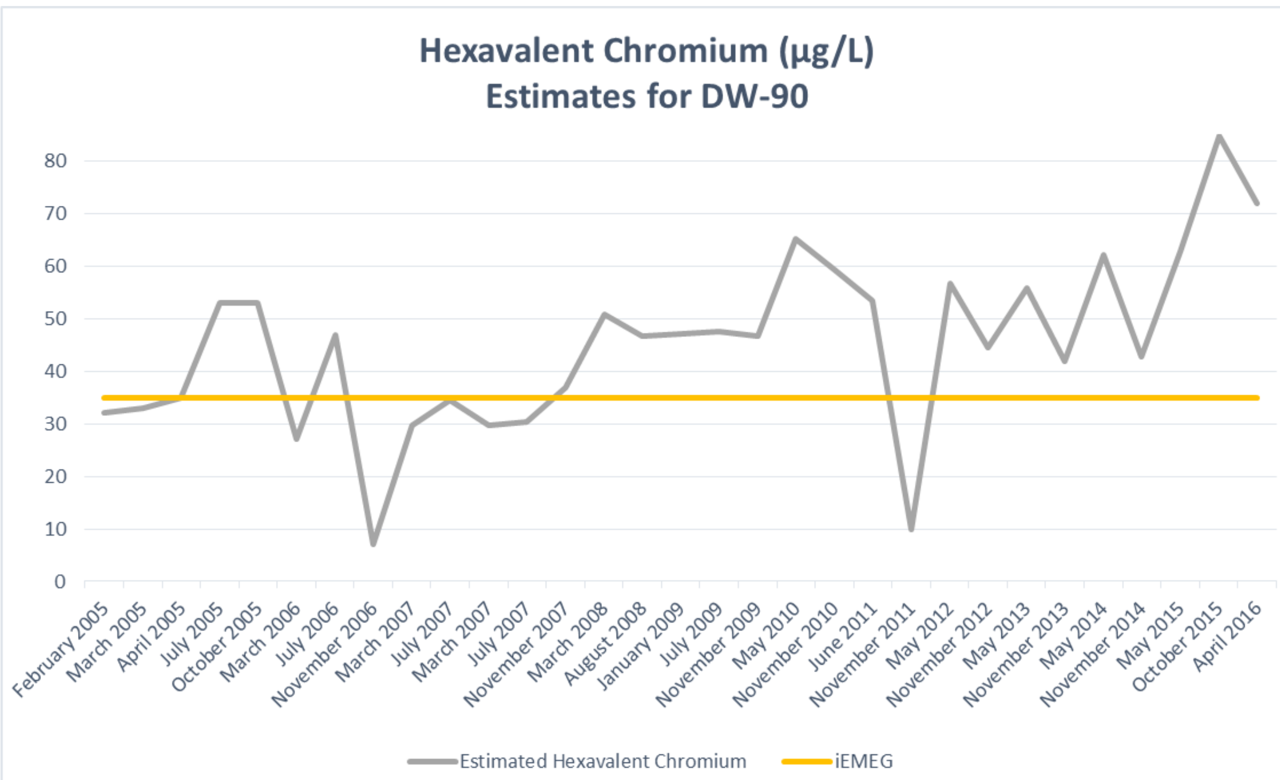
above the former California MCL. The Well identification numbers have been coded to protect privacy. ATSDR will provide EPA with the code separate from this letter.

Eight residential wells were higher than the childhood chronic EMEG. We then examined these wells to determine at what time the highest levels occurred. Three of the wells were recently above the chronic EMEG; and five were above the chronic EMEG many years ago.

Intermediate duration exposure case explanation

Two wells had concentrations above the former Cal MCL and four were above the former MCL at some time. Only one well, DW-90, was measured above the childhood intermediate EMEG of 35 µg/L within the past several years. The concentration of chromium has been increasing at that well (Figure 2). The (yellow) horizontal line represents our childhood intermediate EMEG of 35 µg/L (iEMEG in Figure 2). Two other wells were above the childhood intermediate EMEG in the past, as shown in Table 2.

Figure 2: *Hexavalent chromium estimates for domestic well DW-90 (compared with ATSDR intermediate duration comparison value for children)*



In December 2016, EPA installed a reverse osmosis treatment system for this household (after supplying bottled water as a short-term step). Well DW-32 exceeded the childhood intermediate EMEG (of 35 µg/L) in the past, but it has been below that level since 2001. Well DW-24 is not expected to be in use, but was above the childhood iEMEG in 1997. Since the adult iEMEG is 130 µg/L, there is currently no concern for adults for intermediate term effects at any of the wells. Thus additional screening analysis for intermediate exposure is focused on children.

Irrigation well screening

Table 3 identifies the irrigation well hexavalent chromium concentrations along with the CVs. We have highlighted irrigation wells that had levels higher than the EMEGs. Some were also above the former MCL (in bold).

Four wells have had hexavalent chromium above the CV (adult chronic EMEG); seven have had levels above the former California MCL. Irrigation wells should not be used for drinking water purposes. That said, EPA indicated that irrigation wells might be used for drinking water by farmworkers. If EPA confirms that this exposure pathway has been completed, ATSDR is available to evaluate hexavalent chromium-related health risks for the four wells that are above the adult screening value. None of the wells were above the intermediate EMEG for adults.

Chromium exposure and toxicological evaluation

Chromium is present in the environment in several different forms. The most common forms are metal chromium, trivalent chromium, and hexavalent chromium. Chromium III occurs naturally in the environment and is an essential nutrient. Hexavalent chromium and metal chromium are generally produced by industrial processes [ATSDR 2012]. EPA sampling results indicate that most of the chromium contamination in the groundwater is hexavalent chromium. Hexavalent chromium, quickly reacts with organic materials –reducing it to other forms.

The effects of chromium exposure on the human body vary according to the exposure route (i.e., inhalation, ingestion, or skin contact) and the chemical form of chromium. Breathing in high levels of hexavalent chromium aerosols can damage the respiratory tract. However, breathing in trivalent chromium will not. Similarly, breathing water droplets or steam with low concentrations of hexavalent chromium does not present a health risk [ATSDR 2012]. Studies of water containing 0.89 to 11.5 mg/L hexavalent chromium, resulted in shower air concentrations of 0.087-0.324 µg/m^3 [Finely 1996] The U.S. EPA has classified hexavalent chromium as a known human carcinogen through inhalation [EPA 2005]. No cancer effects have been identified from dermal exposures to hexavalent chromium [ATSDR 2012].

After ingestion, hexavalent chromium is absorbed more readily than trivalent chromium. Studies reporting estimates of the oral bioavailability of hexavalent chromium in humans varies widely in the scientific literature. The ATSDR toxicological profile reports a range around 2 – 7% [ATSDR 2012]. EPA incorporated a value of 2.5% for oral bioavailability in calculating regional screening levels for chromium [EPA 2017]. Due to the variation in reported oral bioavailability and the influence of chemical and nutritional factors on hexavalent chromium uptake from the gastrointestinal system, ATSDR used 10% bioavailability for this assessment as a protective upper-bound estimate.

Noncancer health risks from oral exposure to hexavalent chromium for several weeks or more:

Mice and rats exposed to high levels of hexavalent chromium showed some effects on their blood – or hematological effects. The effects included small and paler red blood cells (microcytic, hypochromic anemia). These hematological effects were observed at high doses, with minimal effects at lower doses. However, these were observed with relatively short exposures (3 weeks). The effects in male rats and female mice were observed after exposure for 22 days in a 2-year study. They were identified as the most sensitive effects of intermediate-duration. The effect observed in female mice, occurred at levels as low as 0.38 milligrams per kilogram per day (mg/kg/day) after 22 days and at 1.4 mg/kg/day for 3-months, and 3.1 mg/kg/day for 6 months. These effects were less severe than those observed in rats which were exposed to higher doses. Several study results were used to calculate a theoretical lowest effect level (i.e., benchmark dose) of 0.52 mg/kg/day. ATSDR calculated an intermediate MRL by reducing this value by a factor of 100 to 0.005 mg/kg/day, or 5 µg/kg/day.

Noncancer health risks from consuming water from* Selma *domestic wells for several weeks or more

Three domestic wells had measurements above the intermediate EMEG for children, one had levels above the EMEG for recent years (DW-90) and the others were in the past (DW-24 and DW-32) (marked with † in Table 2). The recent concentrations at well DW-90 were about twice the intermediate EMEG (35 µg/L); well DW-32 was recently lower than the EMEG; and no data is available at DW-24 which is reported not to be used [EPA 2016b].

ATSDR calculated doses for each of these wells and present the highest here.

Dose = (hexavalent chromium concentration x consumption rate x absorption) ÷ (body weight)

The highest exposure dose calculation was for a child less than one year of age (weight 7.8 kg and water ingestion rate of 1.113 L/day) drinking water from DW-90, the private domestic well with the highest recent well concentration of 84.7 µg/L.

Dose (µg/kg/day) = 84.7 µg/L x 1.113 L/day x 10% ÷ (7.8 kg) = 1.2 µg/kg/day

This calculation suggests that a 7.8 kg (17 lbs) child would receive a dose just below ATSDR's intermediate MRL of 5 µg/kg/day under an assumption of 10% absorption of chromium from drinking water. Additionaly, it is not possible for children consuming water from this well to reach the benchmark dose of 0.52 mg/kg/day (or 520 µg/kg/day). Since the well with the highest concentration presented a dose below the intermediate MRL, the others will as well. While ATSDR does not expect people consuming water from this well to experience intermediate duration health effects, we support the steps EPA has taken to reduce residents' exposures and minimize risk.

Noncancer health risks from oral exposure to hexavalent chromium for years

Studies have found that ingestion of high levels of hexavalent chromium effects the intestines of mice and rats. The most sensitive study found an increase of lesions in the lining of the small intestine that resulted in additional tissue growth (called hyperplasia) in female mice. Rats showed lesions, but not the same growth of tissues. Modeling software calculated the lowest theoretical level to cause this effect (i.e., benchmark dose) to be 0.9 mg/kg/day, or 90 µg/kg/day (90 µg of hexavalent chromium per day multiplied by the weight of the mouse in kilograms). ATSDR calculated a chronic MRL by reducing this value by a factor of 100 to 0.9 µg/kg/day [ATSDR 2012].

Noncancer health risks from consuming water from Selma domestic wells for a year or more

Eight residential wells had exposure point concentrations above the chronic childhood EMEG. The highest was eight times the EMEG. While this is within the uncertainty margin between the chronic EMEG and the effect level measured in animal studies, it is an indicator that there is a need for further assessment of childhood risk. None of the residential wells were above the adult EMEG, indicating some safety for adults.

The highest exposure dose calculation was for a child less than one year of age (weight 7.8 kg and water ingestion rate of 1.113 L/day) drinking water from domestic well DW-90 with a 95% UCL of 51.2 µg/L. ATSDR used the 51.2 µg/L UCL for a chronic dose calculation at well DW-90 because it more closely represents the highest likely long-term dose than the maximum of 84.7 µg/L used for the intermediate exposure calculation.

Dose (µg/kg/day) = 51.2 µg/L x 1.113 L/day x 10% (realistic estimate) ÷ (7.8 kg) = 0.73 µg/kg/day

Using 10% absorption of chromium, the exposure dose is less than the chronic MRL of 0.9 µg/kg/day, indicating a minimal risk. Furthermore, an average child's consumption rate is expected to be much lower than 1.113 L/day; 0.504 L/day is more likely, resulting in

Dose = 51.2 µg/L x 0.504 L/day x 10% ÷ (7.8 kg) = 0.33 µg/kg/day.

The exposure dose calculations do not suggest that health effects are likely for children as their estimated doses fall below the minimal risk level.

A high estimate for a dose for adult exposures from this well (DW-90) is

Dose (µg/kg/day) = 51.2 µg/L x 3.092 L/day[9] x 10% ÷ (80 kg) = 0.20 µg/kg/day.

And a more typical dose over a lifetime is

Dose (µg/kg/day) = 51.2 µg/L x 1.227 L/day [10] x 10% ÷ (80 kg) = 0.0785 µg/kg/day

EPA's chronic dose estimates (0.15 µg/kg/day) using 2.4 L/day[11] as a default consumption rate and 10% bioavailability would fall between the two estimates provided above. All three calculated drinking water doses for adults are below the ATSDR chronic oral MRL.

Evaluation of cancer risks:

Adverse effects observed in the small intestine of mice indicate that long-term ingestion of hexavalent chromium may increase cancer risk. Repeated injury of the lining of the intestine caused extra tissue growth, or hyperplasia, which is hypothesized to increase the probability of mutations leading to tumor formation. Some studies have indicated DNA damage in cell cultures exposed to hexavalent chromium

[9] ATSDR's default reasonably maximally exposed estimate for an adult's short term consumption rate per day applied for other times for screening purposes.
[10] ATSDR's default estimate for an adult's long-term consumption rate per day, a central tendency estimate.
[11] EPA's [2011] default value based on a per capita estimate from 2003-2006.

[Raffeto 1977; Fradkin 1975]. While mutations as a result of that damage have not been fully documented, the possibility suggests that hexavalent chromium has a mutagenic mode of action via ingestion (i.e. the carcinogen reacts and binds to the DNA in exposed cells, increasing the potential for mutations leading to cancer cell formation) [ATSDR 2012]. Children are assumed to be at increased risk for cancer and tumor development following exposure to mutagenic compounds because their bodies are growing – their cells are rapidly replicating during this time. It is hypothesized that a child's DNA repair mechanisms may not be able to keep up with rapid cell replication, which may increase risk of later cancer formation due to DNA damage [NMCPHC 2008]. To account for increased susceptibility, we use age dependent adjustment factors to assess the upper end risk from exposure to chemicals that might have a mutagenic mode of action.

EPA applied mathematical models to the data from animal studies to estimate a cancer slope factor (CSF) for ingestion of hexavalent chromium. Slope factors are used to estimate the risk of cancer associated with exposure to a carcinogenic substance. The extrapolation resulted in an oral slope factor of 0.5 $(mg/kg\text{-}day)^{-1}$. This value is multiplied by the exposure dose to estimate the lifetime cancer risk.

Cancer Risk = (Age specific dose (mg/kg/day) x CSF $(mg/kg\text{-}day)^{-1}$ x age-specific number of years)/78 year lifetime

Using the adult dose derived above (7.85 mg/kg/day) and a 78 year exposure period generates a cancer risk of 4×10^{-5}, equivalent to a probability of four extra cancer cases in a population of 100,000. For an adult with a 12 year exposure duration (the central tendency residential duration), the theoretical increased lifetime cancer risk is 6×10^{-6}, or six additional cancer cases per million people.

Because of the possibility of exposure to a mutagen during childhood, we apply age-dependent adjustment factors (ADAF) to account for the contribution to lifetime cancer risk from exposure as a child. Child doses are estimated using age-specific exposure assumptions. As an example, for a one-year old, dose calculations use a water consumption rate of about 0.504 L/day and a body weight of 7.8 kg

Dose = 51.2 µg/L x 0.504 L/day x 10% ÷ (7.8 kg) = 0.33 µg/kg/day or 0.00033 mg/kg/day (from above)
Risk = 0.00033 mg/kg/day x 0.5 $(mg/kg/day)^{-1}$ x (10 ADAF) x (1/78) =2×10^{-5}

Cancer risks are estimated for individual age groups, and then added up for a 12 year exposure duration (central tendency residential duration), for a combined cancer risk of 5×10^{-5}. The adult cancer risk estimate for an adult over the same duration is 6×10^{-6}. The contribution to lifetime cancer risk from exposure as a child is combined with the adult cancer risk estimate for a total cancer risk of 5.4×10^{-5} for 24 years of exposure.

These risk estimates are probabilities and not measured risks. True cancer risks associated with hexavalent chromium exposure from drinking well water are expected to be lower.

Additional information on plant uptake from EPA and USDA

EPA shared a draft review of literature on plant uptake of hexavalent chromium [CB&I 2016]. The review included several recent documents that had not been included in ATSDR's chromium toxicological profile [ATSDR 2012]. The new plant uptake studies are beyond the scope of this drinking water assessment. However, this information was forwarded to ATSDR's Division of Toxicology and Human Health Sciences for review and consideration in the next ATSDR's Chromium Toxicological Profile update.

The U.S. Department of Agriculture reported a minimal concern for chromium uptake in edible plants and provided twelve published works from their researchers supporting their position identified below [ATSDR 2016b]. They also recommended that any new reports on plant uptake be evaluated to determine if the researchers thoroughly cleaned the soil from the plants. The USDA publications are listed following the reference section of Appendix B in this letter.

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