Health Consultation

Molybdenum in Oak Creek and Caledonia Private Wells

Oak Creek, Milwaukee County and Caledonia, Racine County, Wisconsin

Prepared by
Wisconsin Department of Health Services

SEPTEMBER 8, 2015

Prepared under a Cooperative Agreement with the
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

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners 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 or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Summary and Statement of Issues

INTRODUCTION The top priority of the Agency for Toxic Substances and Disease Registry (ATSDR) and the Wisconsin Department of Health Services (DHS) at this site is to ensure that the communities of Oak Creek and Caledonia have the best information possible to safeguard their health.

In 2009, the Wisconsin Department of Natural Resources (DNR) learned of 18 private wells in Oak Creek and Caledonia, Wisconsin, that had exceeded the Wisconsin Groundwater Enforcement Standard (ES) for molybdenum during routine water sampling at least once since 1993. DNR requested technical assistance from DHS for testing and evaluation of molybdenum exposures. In 2010, DHS collaborated with the DNR to test over 120 additional homes' private wells in the area.

The purpose of this *Health Consultation* is to evaluate area residents' molybdenum and other metal exposures by comparing contaminant levels in wells against health-based comparison values (CV) from ATSDR and U.S. Environmental Protection Agency (EPA); review the current literature of health effects associated with these contaminants in drinking water; and address health questions and concerns raised by the public.

Molybdenum in Area Groundwater

CONCLUSION **DHS concludes that drinking well water with elevated levels of molybdenum for a year or longer from Oak Creek and Caledonia private wells is not expected to harm people's health.**

BASIS FOR DECISION Groundwater in Oak Creek and Caledonia, Wisconsin, has levels of molybdenum that intermittently exceeds the CV for molybdenum. The highest level found in drinking water, although above the CV for molybdenum, is unlikely to cause adverse health effects.

NEXT STEPS

1. The DNR and DHS are working together to characterize the source of molybdenum in area groundwater as well as the extent of the groundwater contamination problem (how many homes might be affected).

2. In the interim and as a precautionary measure, residents living in homes with private wells known to contain molybdenum above the Wisconsin Groundwater Enforcement Standard (ES) have been advised by DNR to not use their well for drinking or food preparation.

3. Residents in the area who rely on private wells for potable water should consider testing their wells annually for molybdenum.

4. Residents with drinking water containing molybdenum at levels above the ES should take steps to obtain an alternative drinking water source.

Boron in Area Groundwater

CONCLUSION	**DHS concludes that drinking well water with elevated levels of boron for a year or longer from Oak Creek and Caledonia private wells is not expected to harm people's health.**
BASIS FOR DECISION	Two homes in the Oak Creek and Caledonia area had boron above the Wisconsin ES. However, the levels did not exceed ATSDR comparison values.
NEXT STEPS	1. As a precautionary measure, residents living in homes with private wells known to contain boron above the ES have been advised by DNR to not use their well for drinking or food preparation. 2. Residents with drinking water containing boron at levels above the ES should take steps to obtain an alternative drinking water source. 3. Residents in the area who rely on private wells for potable water should consider testing their wells for boron.

Copper and Lead in Area Groundwater

CONCLUSION	**DHS concludes that drinking water contaminated with copper and/or lead for a year or more at the highest levels found could harm people's health.**
BASIS FOR DECISION	Fifteen homes in Oak Creek and Caledonia had copper concentrations that exceeded the health-based comparison value (CV), and eight homes had lead concentrations exceeding the CV. These elevated levels are not widespread, nor are they consistent across sampling events, and therefore may be due to the plumbing in the home and not due to groundwater contamination.
NEXT STEPS	Residents living in homes with copper and/or lead levels above their respective Wisconsin Enforcement Standard in their drinking water should not use their water for drinking or food preparation until they have retested their water to determine if the elevated lead and copper levels are from the home's plumbing. The water should be sampled after flushing for 30-60 seconds since flushing is often an effective strategy for reducing levels of copper and lead. If lead or copper levels are still elevated after flushing water through the pipes, the resident should consider steps to correct the problem or secure a permanent alternate water supply. If the copper or lead levels are not elevated after flushing pipes, residents should flush their pipes (let the water run for 30-60 seconds) before drinking the water, and use only cold water for consumption.

Nickel and Zinc in Area Groundwater

CONCLUSION	**DHS concludes that drinking water with levels of nickel or zinc found in area homes for a year or longer is not expected to harm people's health.**
BASIS FOR DECISION	Two homes in the Oak Creek and Caledonia area of concern had levels of nickel and/or zinc in their water samples that exceeded health-based CVs at least once. These elevated levels are not widespread, nor are they consistent

across sampling events, and are therefore not considered to be due to general groundwater contamination. The CVs for nickel and zinc are set to be protective of human health given a lifetime of exposure to these metals. Levels slightly above the CVs have been found on a few occasions, but not often enough to cause adverse health effects.

NEXT STEPS

Residents living in homes with nickel and/or zinc in drinking water at levels above their respective ES should retest their water to determine if elevated nickel and/or zinc are coming from pipes and fixtures within the house.

If nickel and zinc are coming from the plumbing, residents should consider retesting their water after flushing the pipes, to see if that is enough to reduce the level of these metals. If it is, then those residents can use their water for drinking or food preparation after letting the water run from the tap for 30-60 seconds.

If nickel or zinc levels still exceed their respective ES after flushing water through the plumbing, residents should not use their water for drinking or food preparation, and should take steps to obtain an alternative drinking water source while they consult with plumbing and DNR drinking water experts to correct the problem.

LIMITATIONS

Data from the 18 homes that were tested at least once between 1993 and 2009 shows that molybdenum levels in groundwater fluctuate from year to year. One limitation, therefore, in sampling the 100+ homes only once is that the percentage that exceed the CV may be underreported.

Purpose and Health Issues

This *Health Consultation* was prepared in response to a request from the Wisconsin Department of Natural Resources (DNR). In 2009, the DNR learned of 18 private wells in the communities of Oak Creek and Caledonia, Wisconsin, that had exceeded the Wisconsin Enforcement Standard (ES) for molybdenum during routine water sampling between August 1989 and May 2009.

In 2010, the DNR contacted the Wisconsin Department of Health Services (DHS) to request their involvement in developing a groundwater sampling plan for the area surrounding the 18 initial private wells (herein referred to as the *area of concern*). In 2010, more extensive water testing indicated that over two dozen residential wells in the area had molybdenum and two homes had boron above the ES (WI DNR, 2011).

DHS is funded by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) to perform health consultations and public health assessments within the State of Wisconsin. The purpose of this *Health Consultation* is to evaluate the molybdenum and boron exposures experienced by residents in the area since 1989, review the current literature of health effects associated with molybdenum and boron in drinking water, and address the health questions and concerns raised by the public.

BACKGROUND

Site Description

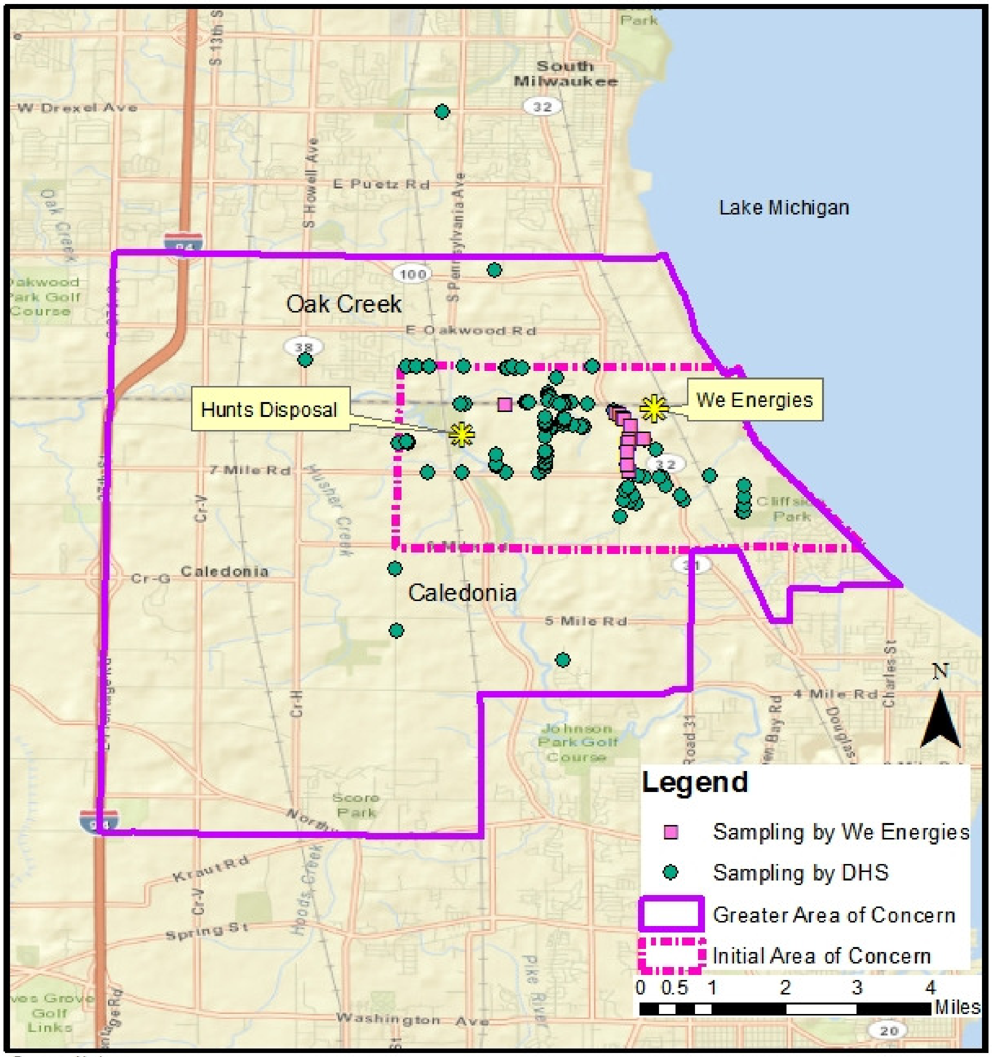
The initial *area of concern* was defined by the DNR and DHS, and based on groundwater data from *We Energies*, to include parts of the City of Oak Creek in Milwaukee County and the Village of Caledonia in Racine County, Wisconsin, that may possibly be affected by molybdenum contamination of groundwater (Figure 1). Many residents within the area of concern rely on private wells as their sole source of potable water. Water from residential wells in the area has been found with molybdenum above the Wisconsin Enforcement Standard (ES).

The area of concern is approximately 9 square miles, five and a half miles south of the Milwaukee city limits. The area is defined to the North by E Elm Road, to the West by South Nicholson Rd, to the South by 6 Mile Rd, and Lake Michigan to the East. The area of concern is primarily agricultural and single family residential land use. There is a *We Energies* Power Plant along the eastern border of the area of concern between Douglas Ave (Route 32) and Lake Michigan. *Hunts Disposal*, which is on the EPA National Priorities List, is located along the southern border of the area of concern at 8229 County Line Road. (EPA, 2011)

Due to the small population size it was not possible to demographically characterize the area of concern using existing U.S. Census information. For the purpose of providing some demographics about the community, a greater area surrounding the area of concern was defined using census tracts. About 19,000 people live in the greater area. It is important to note that not all of these people use private wells for their home's water source. The greater area includes three census tracts–two in Racine County and one in Milwaukee County—covering about 46 square miles. The borders of the greater area run along East Ryan Road in Milwaukee County to the North, Rtes 41 (Milwaukee County) and 94 (Racine County) to the West, Lake Michigan to the East and to the South the tract ends at around 2 mile Road in the west and travels east to the

RR tracks, then north to 4 mile, east on 4 mile until Rte 31, north on 31 until about 5 mile, then east on 5 mile to the lake (Figure 1).

Figure 1. Map of Private Well Sampling in Oak Creek and Caledonia, Wisconsin.



Source Notes:
July 2012 World Street Map
Well locations are approximate and were determined by street address, geocoded using ArcMap 10.0

According to information from the U.S. Census, the median age of the population in the greater area was 39 years, with 8% of the population under 5 years of age, and 9% of the population 65 years or older. The median household income was $73,776, which is greater than the Wisconsin average of $50,537. An estimated 2% of families were living below the poverty level, compared to 11% of families in Wisconsin. Unemployment rates in the area are similar to the State of Wisconsin average (4% compared to 6%). (ACS 2005-2009)

Groundwater flow in the area is generally east toward Lake Michigan. However, there are several complicating factors in the area that can affect the direction of groundwater flow. The presence of fractures in the upper bedrock may cause groundwater to flow in different directions as the water follows local fractures. Furthermore, there is a sand layer approximately 40-60 feet deep and 0-40 feet thick that runs underneath the *We Energies* property. This sand layer could create a preferential pathway for contaminants to reach the bedrock. Finally, in the area around *Hunts Disposal*, shallow groundwater in the upper shallow sand above the clay flows toward the Root River located along the western side of the *Hunts Disposal* site.

Site History

In December 2006, the DNR established a Public Health Groundwater Enforcement Standard (ES) for molybdenum of 40µg/L (micrograms per liter), based on a recommendation from DHS (WI DNR, 2011; WI DHS, 2005).

In August 2009, *We Energies* notified the DNR that routine monitoring associated with their landfill permit of private wells in the area had detected molybdenum above the ES since 1993 (labeled: "Sampling by *We Energies*" in Figure 1, above).

In January 2010, the DNR contacted ATSDR cooperative agreement staff at DHS to request DHS involvement in developing a groundwater sampling plan for the area of concern. DNR and DHS agreed that the first step was to study the extent and nature of groundwater contamination in the area. To this end, in 2010, residents with private wells in the communities of Oak Creek and Caledonia, Wisconsin, were offered free well water testing for molybdenum and other metals. DHS and DNR tested water from 124 homes for 19 different parameters. In order to inform residents about the findings from this initial survey of area groundwater , DNR and DHS held two public meetings with area residents (August 24-25, 2010).

In 2011 and 2012, the DNR worked to better understand potential area sources of molybdenum in groundwater, as well as to define the extent of contamination. Potential sources also investigated by DNR included naturally occurring molybdenum, historic landfills, the *We Energies* Oak Creek site, and other coal ash landfills in the area. The DNR also obtained additional groundwater data from the area, including from *Hunts Disposal*, a known historic waste disposal site and Superfund site in Caledonia. The two-year DNR study was unable to determine the origin of elevated molybdenum levels in area groundwater. (WI DNR, 2013)

In January 2013, the DNR, along with DHS and local health officials, began recommending that residents using private wells in the towns of Caledonia, Raymond, and Norway in Racine County, in Muskego in Waukesha County, and Franklin and Oak Creek in Milwaukee County should sample and test their well water for molybdenum.

How the Health Assessment Process Works

The purpose of a health assessment is to answer the question of whether people have been, or are being, exposed to hazardous substances, and whether that exposure is harmful or potentially harmful and should therefore be stopped or reduced. The health assessment process also allows the ATSDR, through its partnership with DHS, to respond to specific community concerns related to hazardous waste sites.

As part of this process, DHS reviews relevant environmental, demographic and toxicological data as well as community members' concerns. To better understand whether health effects are likely to occur within the community, DHS considers how much contamination there is (the concentration), how long the exposure has gone on for (time of exposure), where the contamination is and how people may be exposed to the chemical(s) in question (breathing, eating, drinking, or skin contact), and whether the exposure could result in harmful effects (the toxicity of the contamination).

For this health consultation contaminants found in private well water were compared against health-based drinking water comparison values for non-carcinogenic and carcinogenic effects. These *comparison values* (CV) are levels of contaminants that are not expected to produce any adverse health effects in people exposed for short (two weeks), intermediate (two weeks to a year) or long (more than one year) terms. These are called acute, intermediate and chronic exposure periods, respectively.

ATSDR considers both adults and children when developing CVs. The potential health effects in children are considered separately because in certain situations children are more sensitive and exposed to greater levels of contaminants than adults are.

In some cases, CVs are the same as DNR groundwater quality Enforcement Standards (ES) or other standards under applicable environmental health laws. For example, the CV used for lead in this assessment is also the current ES established by the DNR to protect public health and welfare. The ATSDR CV for molybdenum is the same as the DNR ES. In those cases where ATSDR and U.S. EPA has no CV, the state ES was used as a CV.

Contaminants found at levels above the CVs are included in a list of chemical "contaminants of concern" for the site. Listing a chemical as a contaminant of concern does not mean that it is a health concern; the contaminants of concern are merely those selected for further evaluation to determine their **potential** to cause adverse health effects at a site.

For each contaminant of concern, a dose (the amount someone consumes) is calculated based on the maximum concentration measured in private well water. The resulting doses are compared with ATSDR minimal risk levels (MRLs) and U.S. EPA reference doses (RfDs) in the ***Health Effects Evaluation*** section to determine whether the estimated doses might cause adverse health effects. This information is also used to identify appropriate health actions for the community.

Sources of Private Well Water Test Results

This health consultation examines data from two separate sources: 1) private well water sampling conducted by *We Energies* and their consultants from 1989 to 2010; and 2) private well water sampling conducted by DHS and DNR during 2010. DHS/DNR samples were collected by homeowners in sampling kits provided by the Wisconsin State Laboratory of Hygiene (WSLH). Homeowners were instructed to flush water through the system before sampling. *We Energies* sampling was also done after flushing water through the system. In both cases, water was collected as close to the well as possible.

Both sampling programs tested for similar parameters. Both included sampling for indicators of groundwater-impact from fly ash leachate, including boron, molybdenum, selenium and sulfates, as well as other parameters. Data from the two different sampling sources were examined in multiple ways and it was determined that combining the two data sources would not alter the overall conclusion of the health consultation.

We Energies Sampling of Private Wells, 1989-2010
We Energies has one active and two closed coal ash landfills in the Oak Creek and Caledonia areas. When the active landfill was opened in 1989, *We Energies* began monitoring private wells within a ½ mile radius of the landfill on a regular schedule as part of an agreement with the local municipalities (WI DNR, 1987).

From 1989 to 2010, 34 private wells were sampled for dissolved metals, including boron and molybdenum.[1] These are the most likely contaminants to exist in groundwater near a fly ash and bottom ash fill site like the *We Energies* site. All water samples were tested for dissolved metals, and in 12 homes tested during 2009 and 2010, total molybdenum was included in the testing (NRT, 2010).

We Energies did not test each of the 34 homes during each sampling round. In addition, each sampling round and home could vary in the list of contaminants tested. Therefore, in the data discussion below, the number of homes tested for each contaminant will vary.

DHS/DNR Sampling of Private Wells, 2010
As part of a sampling plan agreed upon between DNR and DHS, in February 2010 Oak Creek and Caledonia community members using potable water from private wells were offered free well water sampling kits. Samples were sent to the Wisconsin State Laboratory of Hygiene (WSLH) and analyzed for indicators of groundwater impacts from fly ash leachate, including molybdenum and boron. Between February and October 2010, people from 124 homes with private wells submitted water samples under the DNR/DHS program. Total metal concentrations were analyzed by the WSLH.

Discussion

This Health Consultation evaluated data from 511 water samples[2] taken from 145 private wells in the Oak Creek and Caledonia communities from 1989 to 2010. Seven chemical contaminants were identified above their respective comparison values: molybdenum, boron, copper, iron[3], lead, nickel, and zinc (Table 1).

The list of contaminants detected in groundwater includes the range detected (in micrograms per liter or µg/L), years sampled, frequency of detection, as well as the comparison values for each contaminant and the number of homes where a comparison value was exceeded at least once. Identification as a contaminant of concern indicates that additional evaluation is required to determine the potential for exposure, but does not necessarily indicate that this exposure will lead to health effects. In the Health Effects Evaluation section, DHS evaluates the potential for health effects from the contaminants of concern. Unless otherwise noted, all "dissolved"

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[1] Molybdenum concentration data were only available starting in 1993.
[2] The groundwater data reviewed by DHS/ATSDR for this health consultation were presented as total concentrations, dissolved concentrations, and total recoverable concentrations. Total and Total recoverable were considered together. Total levels should be the same or slightly higher than the dissolved levels in the same sample, since water can have dissolved and undissolved compounds present in the water. See Appendix B for more information on testing for Total versus Dissolved molybdenum.
[3] The comparison value for iron is a secondary enforcement standard, which is based not on health effects but on changes to the look, smell and taste of water.

concentrations were results from *We Energies* and their consultants, and "total" concentrations were results from the DNR/DHS testing.

Table 1. Private Well Testing in Oak Creek and Caledonia, Wisconsin, 1989-2010.

Metal	Test	Range Detected (µg/L)	Years Sampled	Frequency of Detection^	Comparison Value-CV (µg/L)	Number of Homes with Contaminant ≥ CV
Molybdenum	Dissolved	ND – 160*	1993-2010	91/204	40[a,b]	24/31
	Total±	ND – 120*	2009-2010	137/160		23/131
Boron	Dissolved	50 - 720	1989-2010	360/360	1000[b]	0/30
	Total	11 – 1190*	2010	147/147		2/124
Copper	Dissolved	ND - 73	1989-2009	60/297	100[c]	0/24
	Total	ND – 2550*	2010	104/147		15/124
Iron	Dissolved	ND - 530	1989-2009	329/352	300[d]	7/24
	Total	ND - 4,200*	2010	129/147		84/124
Lead	Dissolved	ND – 12	1989-2009	43/297	15[b,e]	0/24
	Total	ND – 345*	2010	18/147		8/124
Nickel	Total	ND – 165*	2010	13/147	100[a,b]	1/124
Zinc	Dissolved	ND – 440	1989-2009	195/297	2,000[a]	0/24
	Total	ND - 40,400*	2010	138/147		2/124

Notes: ND – not detected
* Exceeds comparison value
[a] EPA Lifetime Health Advisory Level (LHA)
[b] DNR Enforcement Standard (ES)
[c] ATSDR Child Intermediate Environmental Media Evaluation Guide (EMEG)
[d] EPA National Secondary Drinking Water Regulations and DNR WI NR 809 Secondary Enforcement Standard
[e] US EPA maximum contaminant level (MCL)
^ *We Energies* did not test each of the 34 homes during each sampling round. In addition, each sampling round and home could vary in the list of contaminants tested. Therefore, the number of homes tested for each contaminant will vary.
± In 2009 and 2010, We Energies tested 12 homes concurrently for total and dissolved levels. Total levels have been included with the WI DHS/DNR sampling results.
Data Source: NRT 2010 and samples taken in 2010 by DHS and DNR.

MOLYBDENUM

From 1993 to 2010, a total of 349 samples from 142 homes were tested for molybdenum (as total and dissolved). The highest level of molybdenum in a private well water sample was 160 µg/L. Molybdenum levels exceeded the CV at least once in 41 of the homes tested (29%). Conversely, 23 of the homes tested (16%) never had a detectable level of molybdenum.

The *We Energies'* data allow comparison of molybdenum levels by year. Overall, molybdenum levels were elevated in 43% of the *We Energies*' water samples. During one year, 100% of water samples exceeded the molybdenum CV. Appendix C includes more information and data showing annual variations in molybdenum levels. The CV used for molybdenum was the EPA lifetime health advisory level for molybdenum, which is the same as the Wisconsin Groundwater Quality Enforcement Standard (ES) of 40 ppb.

BORON
Between 1989 and 2010, 144 private wells were tested for boron. All of the water samples taken between 1989 and 2010 had detectable levels of boron, ranging in concentrations from 11 µg/L to 1,190 µg/L. Boron levels exceeded the comparison value of 1,000 µg/L in 2 homes (1.4%). Boron levels in private wells primarily ranged between 200 and 600 µg/L; only 3 homes had a boron concentration above 700 µg/L.

COPPER
Copper exceeded the DNR drinking water Enforcement Standard (ES) of 1,300 µg/L in one home in February 2010 (2,550 µg/L). This home was sampled twice more (once in April, 2010 and once in September, 2010). Before collecting each subsequent sample, more time was spent flushing the pipes. The copper level decreased with each subsequent sampling. During the September 2010 sampling event, the pipes were flushed for 15 minutes and the home's copper level was 5 µg/L, well under the CV.

The second highest concentration of copper detected in any home's water sample was 795 µg/L. This concentration is below the ES, but still above the ATSDR comparison value for copper. Fifteen homes had copper concentrations in the water samples above the ATSDR comparison value of 100 µg/L. The US EPA and DNR ES is more than ten times greater than the ATSDR comparison value (1,300 µg/L versus 100 µg/L, respectively). The ATSDR comparison value is based on a lifetime exposure risk, whereas the ES is based on an acute exposure level. Because 15 homes had copper concentrations over the ATSDR comparison value, there will be further discussion of the health effects of copper in the Health Effects Evaluation section below.

LEAD
There is no known safe level of lead, and therefore neither ATSDR nor EPA have set a CV for lead. DHS used the lead ES as a CV. Lead concentrations in water samples exceeded the CV of 15 µg/L in eight homes. Elevated lead concentrations ranged from 35 µg/L to 345 µg/L, with a median of 46 µg/L. In three of the eight homes where initial sampling found an elevated lead level, a subsequent sample had a lead level below the CV. In five homes with initial high lead concentrations in water samples, no additional sampling was done. One home had an initial non-detect of lead and subsequent sampling indicated an elevated lead level (35 µg/L). Elevated lead concentrations most likely come from the homes' plumbing systems. Additional sampling is needed to confirm the source of lead in homes with elevated lead levels in water.

IRON
EPA's Secondary Standard for iron in drinking water was used as a CV. The National Secondary Drinking Water Regulation for iron is the same as the WI NR 809 Secondary Standard for iron. These secondary standards are non-enforceable guidelines established to address cosmetic and aesthetic effects of substances present in drinking water supplies. Ninety one homes out of the 145 tested (63%) have levels of iron in water exceeding the secondary standard. When iron is present at concentrations above the secondary standard (300 µg/L), the taste, look and odor of water will be affected. These aesthetic changes are usually unpleasant to people and makes it unlikely that residents will be drinking this water.

Iron contamination in groundwater is a common non-hazardous nuisance to the water supply. Iron is the fourth most common metal in the earth's crust. While high levels of iron in water supplies are not expected to adversely affect health, high iron levels in water can negatively impact the taste and appearance of water, and can signal the presence of nuisance bacteria.

NICKEL

EPA has set a Lifetime Health Advisory level for nickel in water of 100 µg/L. This level was used as a CV for nickel. Nickel was found above the CV in one home. In this home, the water also exceeded the CVs for molybdenum, lead, and zinc, and iron. The residents of this home were advised to not use their water for drinking or food preparation, and the water was sampled again several months later. Before sampling a second time, the homeowner ran the water for 2 hours prior to sampling. The results of the second sampling revealed significant decreases in lead and iron levels (both were below their respective CVs during the second sampling round). The molybdenum concentration decreased from 43 µg/L during the first sampling round to 37 µg/L during the second sampling. Nickel and zinc remained above their respective CVs during both sampling rounds.

ZINC

EPA has set a Lifetime Health Advisory for zinc of 2,000 µg/L. This level was used as a CV for zinc. Zinc levels exceeded the CV in two homes. In the first home, described in the paragraph above, nickel also exceeded the CV. During a second round of sampling in this home four months later, the zinc level was still above the CV but at a level that was only one fourth of the original level (the zinc in water decreased from 40,400 µg/L to 11,700 µg/L).

In the other home where zinc exceeded the CV, well water sampling in February 2010 returned not only an exceedance for zinc, but for lead, iron, and copper. The residents were alerted to the high levels, and the home was tested twice more, once in April and once in September 2010. Both follow-up tests showed decreases in lead, copper and zinc to levels below the respective CVs. Zinc levels dropped from 17,400 µg/L in the first sample to 44 µg/L and 18 µg/L in the two follow-up tests, respectively. Zinc concentrations in the follow-up tests were therefore 400 to 1,000 times lower than the first sample.

Health Effects Evaluation

The potential for exposed persons to experience adverse health effects depends on:

- the concentration of chemical(s) to which a person is exposed;
- how often and for how long a person is exposed; and
- the toxicity of the chemical.

In this section, the chemical contaminants of concern found in area groundwater are reviewed to determine if they are of health concern.

As mentioned above, DHS screened contaminant concentrations detected in wells against health-based guidelines (called comparison values or CVs) derived by ATSDR, U.S. EPA and DNR. The contaminants of concern (those found above the CVs) included molybdenum, boron, copper, lead, nickel, and zinc.

To determine residents' estimated exposures to the contaminants of concern, DHS calculated exposure doses and compared them to existing dose guidelines from ATSDR and U.S. EPA. In this case, DHS used Minimum Risk Levels (MRLs, derived by ATSDR) and Reference Doses (RfDs, derived by U.S. EPA). Both MRLs and RfDs are estimates of daily human exposure to a hazardous substance that is likely to be without appreciable risk over a specified duration of exposure. To be protective of public health, DHS calculated doses using conservative assumptions. It was assumed that all residents may be exposed to the highest measured concentration detected in the wells over the nearly twenty years of testing.

Exposure dose estimates were made for both adults and children. Adults were estimated to weigh 70 kilograms (approximately 155 pounds) and children 30 kg (66 pounds). It was also assumed that adults drink 2 liters of water a day, and children drink 1 liter of water a day.

For molybdenum, the ingestion dose calculated was also compared against the dietary recommended daily allowance for molybdenum, as well as the tolerable upper intake level of this essential nutrient.

Exposure doses were calculated using the following equation:

$$ED_I = \frac{C \times IR \times EF}{BW}$$

Where:

ED_I	=	ingestion exposure dose (milligrams per kilogram of body weight per day, *mg/kg-day*)
C	=	contaminant concentration (milligrams per liter – *mg/L*)
IR	=	ingestion rate (liters per day – *L/day*)
EF	=	exposure factor (unitless)
BW	=	body weight (in kilograms – *kg*)

This calculation was performed for each contaminant of concern, and a brief description of potential health implications follows.

MOLYBDENUM

Molybdenum is a naturally occurring metallic element found in the earth's surface and various ores. In its pure form molybdenum is virtually insoluble in water, but in nature this element is found in a number of different compounds with varying solubility. It is an essential nutrient in humans and animals.

The highest reported value of molybdenum in area wells was 160 µg/L. Using this value to calculate dose:

Adults

$$ED_I = \frac{0.16 \text{ mg/L} \times 2 \text{ L/day} \times 1}{70 \text{ kg}} = 0.0046 \text{ mg/kg-day}$$

Children

$$ED_I = \frac{0.16 \text{ mg/L} \times 1 \text{ L/day} \times 1}{30 \text{ kg}} = 0.0053 \text{ mg/kg-day}$$

Because the ATSDR does not have an oral MRL for molybdenum, the U.S. EPA oral RfD of 0.005 mg/kg-day was used for comparison. The RfD is based on a lifetime exposure. The doses calculated from the highest concentrations of molybdenum in adults and children were similar to the oral RfD.

The US EPA oral RfD is based on an epidemiological study of residents in an Armenian geoprovince. In that study, individuals exposed to high levels of dietary molybdenum had gout-like symptoms (i.e. joint pain in the hands and feet). The lowest observed adverse effect level (LOAEL) in this study was 0.14 mg/kg-day. The RfD was derived using an uncertainty factor of 30 (10 for use of a LOAEL and 3 for protection of sensitive human populations). (EPA, 1992)

The ingestion exposure dose for children based on the highest molybdenum concentration ever found in area private well water (160 µg/L) is at the RfD, but below the LOAEL that the RfD was based upon.

In 2013, DHS conducted a review of the scientific literature related to molybdenum toxicity, including a critical review of the study used by EPA to set the RfD. Although the association between molybdenum exposure and human gout-like symptoms is biologically plausible, DHS had significant concerns regarding the reliability of the Armenian study used to establish health guidelines. DHS recommended calculating a different advisory level for molybdenum based on a study by Fungwe et al. In this study, reproductive and developmental effects were observed in rats given ≥ 10 mg/L molybdenum in drinking water (a dose of approximately 1.6 mg/kg-day). The no observed adverse effect level (NOAEL) for this study was 0.9 mg/kg-day. (WI DHS, 2013)

The Food and Nutrition Board (FNB) has established a recommended dietary allowance for adults of 0.045 milligrams of molybdenum per day (mg/day). This is the average amount of molybdenum needed to be consumed per day by the majority of healthy adults. (FNB, 2001) The typical US diet results in about 0.100 mg of molybdenum consumption per day. As a result, molybdenum deficiencies are very rare in the US.

FNB of the Institute of Medicine also determined the highest average daily molybdenum intake level that is not likely to pose an increased risk of adverse health effects, or tolerable upper intake level (UL) for molybdenum in children and adults. The UL translates into a dose of about 0.03 mg/kg-day. Namely:

- for children 1 to 3 years of age, it is equal to 0.3 mg/day;
- children 4 to 8 years of age - 0.6 mg/day;
- children 9 to 13 years of age - 1.1 mg/day;
- adolescents 14 to 18 years of age - 1.7 mg/day; and
- adults - 2.0 mg/day. (FNB, 2001)

As intake increases above the UL, the potential risk of adverse effects may increase.

The calculated adult and child exposure doses, based on the highest molybdenum level found in Oak Creek or Caledonia area wells, are ten times less than the tolerable upper intake level for molybdenum.

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and the EPA have not classified molybdenum as to its human carcinogenicity. No human studies are available.

Based on the LOAEL, an individual drinking water at the maximum level over their lifetime would not be expected to exhibit gout. However, there are limitations to this, because we do not know if this LOAEL level is transferable to children, as they can be more sensitive than adults. As a protective measure, DHS recommends that people do not consume water at or above the groundwater quality enforcement standard for molybdenum (40 µg/L).

BORON

Although boron was detected in every well sample, only two wells ever had boron detected above the enforcement standard. Using the highest value detected, 1,190 µg/L, to calculate dose:

Adults

$$ED_I = \frac{1.19 \text{ mg/L} \times 2 \text{ L/day} \times 1}{70 \text{ kg}} = 0.034 \text{ mg/kg-day}$$

Children

$$ED_I = \frac{1.19 \text{ mg/L} \times 1 \text{ L/day} \times 1}{30 \text{ kg}} = 0.040 \text{ mg/kg-day}$$

Acute exposure to very high concentrations of boron (about 30,000 mg of boron as boric acid[4]) has been shown to affect the stomach, intestines, liver, kidney, and brain. The MRL is a level below which health effects are not expected, even in sensitive populations. The ATSDR MRL for both acute (1-14 days) and intermediate (14 to 364 days) exposures to boron is 0.2 mg/kg-day. The U.S. EPA oral RfD for chronic lifetime exposure to boron is 0.2 mg/kg-day. The daily doses estimated for both children and adults based on the highest concentration of boron are below the MRL and RfD.

The oral MRLs are based on findings in animal studies (ATSDR, 2010). The acute MRL is based on investigations that report prenatal developmental effects such as reduced fetal body weight or minor skeletal changes in rabbits. The no observed adverse effect level (NOAEL) in these studies was 22 mg/kg-day and the lowest observed adverse effect level (LOAEL) was 44 mg/kg-day. The intermediate MRL and the EPA RfD are also based on developmental effects, although in rats. The intermediate MRL and the RfD are based on a $BMDL_{05}$[5] of 10.3 mg/kg-day.

The Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and the US EPA have not classified boron as to its human carcinogenicity. No human studies are available. One animal study found no evidence of cancer after lifetime exposure to boric acid in food.

The doses calculated from the maximum detection of boron in the residential wells sampled do not exceed the acute or intermediate MRL or the RfD. *Based on the RfD, an individual drinking water at the maximum level over their lifetime would not be expected to have negative health*

[4] The average daily intakes of boron in adult men and women are 1.28 and 1.0 mg/day respectively.

[5] $BMDL_{05}$: The 95% lower confidence limit on the benchmark dose associated with a 5% reduction in fetal body weight.

impacts from boron exposure. As a protective measure, DHS recommends that people do not consume water at or above the groundwater quality enforcement drinking water standard for boron (1 mg/L).

COPPER

Copper is a naturally occurring metal, found in all plants and animals, and an essential nutrient to health in all known living organisms at low levels. The recommended dietary allowances for copper are between 0.34 mg/day (for children aged 1 to 3 years) and 0.9 mg/day (for adults). (FNB, 2001)

The greatest potential source of copper exposure in the general population is through drinking water. The CV chosen for comparison was the ATSDR child intermediate Environmental Media Evaluation Guide (EMEG) for copper of 100 µg/L. EMEGs are estimated contaminant concentrations that are not expected to result in adverse non-carcinogenic health effects. No acute (short-term) adverse health effects are expected from drinking water with copper levels below the U.S. EPA maximum contaminant level (MCL) and DNR enforcement standard of 1,300 µg/L.

Exposure to high levels of copper can result in vomiting, diarrhea, stomach cramps, and nausea. The effects of copper exposure will increase in severity with increasing copper levels and length of exposure. Long-term exposures (more than 2 weeks) to very high levels of copper has been found to cause liver and kidney damage in some people. Children under one year of age are more sensitive to copper because it is not easily removed from their system. Likewise, people with liver damage will also be more susceptible to copper toxicity. EPA does not classify copper as a human carcinogen because there are no adequate human or animal studies. (ATSDR, 2004)

15 homes had water samples with a copper level that exceeded the chronic CV for copper of 100 µg/L at least once. Only 1 home had a copper level that exceeds the EPA drinking water standard for copper (1,300 µg/L). Using the highest level (2,550 µg/L) of copper found to calculate dose:

Adults

$$ED_I = \frac{2.55 \text{ mg/L} \times 2 \text{ L/day} \times 1}{70 \text{ kg}} = 0.07 \text{ mg/kg-day}$$

Children

$$ED_I = \frac{2.55 \text{ mg/L} \times 1 \text{ L/day} \times 1}{30 \text{ kg}} = 0.085 \text{ mg/kg-day}$$

The acute (1 hour to 14 days) and intermediate (14 to 365 days) MRLs for copper are both 0.01 mg/kg-day. The MRL is based on a NOAEL of 0.042 mg/kg-day and a LOAEL of 0.091 mg/kg-day. The MRL was derived using an uncertainty factor of 3 (for protection of sensitive human populations).

The exposure doses calculated above from the highest concentration of copper found (2,550 µg/L) are 7 times the MRL for adults and 8 times the MRL for children. Drinking water at this copper level may pose a health hazard. However, this home's water was retested twice more after February 2010, in April 2010 and again in September 2010. In both subsequent testing rounds, the copper level was significantly different from the original sampling event (530 µg/L and 5 µg/L, respectively). During the original sampling event (February, 2010), the water was run for 2-3 minutes before collecting the sample. In April, the water was run for 5 minutes before collecting the sample. Finally in September, the sample was collected from the tap right at the well, and the water was run for 15 minutes before collecting the sample. Therefore, it is reasonable to conclude that the highest level of copper found (2,550 µg/L) is not representative of the general condition of the groundwater in the area, nor of the potential exposure to copper in residents at that address.

Using the second highest copper level (795 µg/L) found in Oak Creek and Caledonia homes to calculate exposure dose, the dose calculated is 0.027 mg/kg-day for children and 0.02 mg/kg-day for adults. These calculated ingestion exposure doses are above the MRL but below the NOAEL of 0.042 mg/kg-day that the MRL was based upon. The second highest level of copper found is above the CV, but below the EPA MCL for acute effects from copper. *Based on the NOAEL and the EPA MCL for copper, an individual drinking water at 795 µg/L for one year would not be expected to have adverse health effects from copper exposure.*

LEAD

Lead naturally occurs in small amounts as a metal in the earth's crust. Lead was used as an additive in some gasoline in the US until as late as 1995. Today, lead is often found in paint and varnish in homes built before 1978. Additionally, lead can be found in solder and in plumbing. Often, lead in drinking water where no contamination source is expected is due to the plumbing in a home.

A total of 8 homes out of 142 had lead levels that exceeded the CV for lead. The highest concentration of lead detected in any water sample was 345 µg/L, and no subsequent sampling was conducted. Using this concentration, the resulting dose would be:

Adults

$$ED_I = \frac{0.345 \text{ mg/L} \times 2 \text{ L/day} \times 1}{70 \text{ kg}} = 0.01 \text{ mg/kg-day}$$

Children

$$ED_I = \frac{0.345 \text{ mg/L} \times 1 \text{ L/day} \times 1}{30 \text{ kg}} = 0.012 \text{ mg/kg-day}$$

No MRL or RfD exists for lead. Neither EPA nor ATSDR has established a comparison value for acute exposure, arguing that some effects appear to be without a low exposure threshold (EPA, 2004). However, the FDA provides the following limits on daily lead intake: for adults, 75 µg/day; for pregnant women, 25 µg/day; and for children age five and under, 6 µg/day (NSF 2003). Using these numbers to calculate doses, we get an ingestion dose of 0.001mg/kg-day for adults; 0.0004 mg/kg-day for pregnant women; and 0.0006 mg/kg-day for children.

The U.S. EPA has established a drinking water action level for lead of 0.015 mg/L. Exposure to lead in water can elevate blood lead levels in children and adults (ATSDR, 2007). Elevated blood lead levels have been associated with neurological, behavioral, immunological, and developmental effects in young children. There is no known "safe" blood lead level in children or the developing fetus. In 2012, the Centers for Disease Control and Prevention (CDC) accepted the Advisory Committee on Childhood Lead Poisoning Prevention recommendation and used a childhood reference level for blood lead based on the National Health and Nutrition Examination Survey (NHANES) 97.5th percentile of the population blood lead level in children ages 1 to 5 (currently 5 micrograms per deciliter (µg/dL)) to identify children with blood lead levels that are much higher than most children's levels (CDC, 2012).

Considering the exceedance of the FDA daily limit on lead intake for children and that there is no required role for lead in the body, *DHS concludes that exposure to the lead concentrations exceeding the drinking water quality enforcement standard could present a potential health threat to people in homes with elevated lead in water. DHS recommends that all homes with lead concentrations in water exceeding the enforcement standard be retested and residents take actions to obtain a safe source for drinking water.*

NICKEL

Nickel is a common metal used in many household items including plumbing fixtures (ATSDR, 2005a). In some cases, nickel alloys in plumbing leach into drinking water, particularly when the pipes have not been recently used. Nickel is not a nutrient in humans, and there is no Recommended Dietary Allowance (RDA) set for nickel. Small amounts of nickel can be found in some foods and food supplements.

Consuming water with very high levels of nickel can cause gastrointestinal upset. In one case, workers who accidently drank water with a nickel concentration of 250 mg/L had nausea, abdominal cramps, vomiting, and diarrhea (Sunderman et al. 1988). By comparison, in the Oak Creek and Caledonia areas, the highest concentration of nickel found in a home's water was 0.165 mg/L, or 1,000 times less than the concentration above. Using the highest concentration of nickel found to calculate dose:

Adults

$$ED_I = \frac{0.165 \text{ mg/L} \times 2 \text{ L/day} \times 1}{70 \text{ kg}} = 0.005 \text{ mg/kg-day}$$

Children

$$ED_I = \frac{0.165 \text{ mg/L} \times 1 \text{ L/day} \times 1}{30 \text{ kg}} = 0.006 \text{ mg/kg-day}$$

EPA's chronic oral RfD for Nickel is 0.02 mg/kg/day. The doses calculated from the maximum detection of nickel in the residential wells sampled do not exceed the chronic RfD. *Based on the RfD, an individual drinking water at the maximum level found over their lifetime would not be expected to have any negative health impacts from nickel exposure.*

ZINC

Zinc is one of the most common elements in the earth's crust and, in small amounts, an essential nutrient to humans. In the U.S., the average zinc intake per day from a normal diet is between 0.17 and 0.54 mg/kg-day in children and between 0.07 and 0.23 mg/kg-day in adults. The Recommended Dietary Allowance of zinc ranges from 3 mg/day in infants and children up to 3 years old to 8 mg/day for adult women and 11 mg/day for adult men (FNB, 2001).

If large doses of zinc (10–15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decreased levels of high-density lipoprotein (HDL) cholesterol (ATSDR, 2005b).

Using the highest zinc level found to calculate dose:

Adults

$$ED_I = \frac{40.4\ \text{mg/L} \times 2\ \text{L/day} \times 1}{70\ \text{kg}} = 1.15\ \text{mg/kg-day}$$

Children

$$ED_I = \frac{40.4\ \text{mg/L} \times 1\ \text{L/day} \times 1}{30\ \text{kg}} = 1.35\ \text{mg/kg-day}$$

The chronic and intermediate MRLs and EPA's RfD for zinc are all 0.30 mg/kg-day. The RfD is based on a LOAEL of 0.91 mg/kg-day. The calculated exposure doses in children and adults are 4 to 5 times the MRL and RfD. The calculated dose is above the LOAEL as well. However, only one sampling event in one home returned such a high level of zinc, and the next highest level of zinc detected in the same home's water a few months later was over three times lower. Doses based on this lower zinc concentration are 0.33 mg/kg-day for adults and 0.39 mg/kg-day. *Based on the observation that the highest level of zinc was not indicative of all zinc exposures in that home, and a comparison of the next highest dose to the MRL, RfD and LOAEL, DHS concludes that zinc does not present a potential health threat to human health at the levels found in the Oak Creek and Caledonia private wells. As a protective measure, DHS recommends that people not consume water at or above the enforcement standard for zinc (2 mg/L), and that residents with zinc concentrations above the enforcement standard should determine the source of their elevated zinc levels and take actions to obtain a safe source for drinking water.*

Children's Health Considerations

Children can be more vulnerable to the impacts of chemical exposures for a number of reasons related to their development and behavior. A child's lower body weight, higher intake rate and faster metabolism can all play a part and result in children getting a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are great enough during critical growth stages, the developing body systems of children can be permanently damaged. Parents of small children are naturally concerned about environmental hazards. Children are dependent on adults for access to clean drinking water. Therefore, adults need as much information as possible in order to make informed choices about their children's health.

MOLYBDENUM

More study is needed to understand the potential health effects of molybdenum exposure on very young children. There is concern that infants may be more sensitive and less able to handle excess amounts of molybdenum. For this reason, uncertainty factors are applied in the calculation of an RfD. These uncertainty factors should be adequate to protect sensitive populations like infants.

BORON

It is not known whether children differ from adults in their susceptibility to the effects of boron, or if boron exposure causes birth defects. Low birth weights, birth defects, and developmental delays have occurred in newborn animals whose mothers were orally exposed to high doses of boron (as boric acid) during pregnancy. The doses that produced these effects in pregnant animals are more than 800 times higher than the average daily intake of boron in food by adult women in the U.S. population, and more than 600 times the dose from drinking water at the highest concentration found in Oak Creek and Caledonia private wells. For other health effects, it is likely that children would be affected in the same way as adults.

LEAD

Lead is of particular concern to children's health as it is toxic even in very small amounts to children's development. Children are more sensitive to the health effects of lead than adults. There is no known safe blood lead level in children. High blood lead levels may lead to anemia, kidney damage, colic, muscle weakness, and brain damage, as well as behavior and cognitive effects. It is extremely important, therefore, to minimize any lead exposures to children. Lead exposure from contaminated drinking water related to a home's plumbing can be reduced by running the cold water tap for 60 seconds after the pump turns on before using the water for drinking or food preparation.

COPPER

Excessive copper exposure has been shown to cause similar problems in adults as in children, including gastrointestinal effects. Children may be more sensitive to the gastrointestinal effects caused by copper, however, because of their higher metabolism rates (ATSDR, 2004).

NICKEL

It is not known whether children are more susceptible to the effects of nickel than adults are. It is likely, however, that children who have been exposed to nickel will experience similar types of health effects as adults exposed to nickel. Nickel can cross the placenta and be transferred to an infant through a mother's breast milk. However, human studies that looked at how nickel can harm the fetus were inconclusive (ATSDR, 2005a).

ZINC

Excessive zinc exposure has been shown to cause similar health problems in adults as in children, including gastrointestinal effects (nausea, vomiting) and occasional neurologic symptoms. However, it is not known if children are more sensitive to the effects of zinc exposure than adults are (ATSDR, 2005b).

Community Health Concerns

Community members have expressed concerns regarding molybdenum and other metals in their drinking water and the source of that contamination. Representatives from DHS, DNR and the local health department have addressed community members' concerns through public availability sessions in August 2010, as well as through door-to-door communication with area residents in September 2011. This health consultation should further aid in responding to community concerns by providing a summary of findings from the area groundwater sampling prior to 2011.

Conclusions

Between 1989 and 2010, drinking water from private wells was tested from 145 homes for indicators of groundwater impacted by fly ash leachate, including boron and molybdenum.

1) *Molybdenum* levels exceeded the CV at least once between 1993 and 2010 in 41 homes (29%). From these results, DHS concludes:
    a) Groundwater in the Oak Creek and Caledonia area of concern is elevated for molybdenum. Molybdenum concentrations vary by location and from season to season and year to year.
    b) The level of molybdenum in drinking water is above the Wisconsin Enforcement Standard, but is not expected to harm the health of adults and older children. However, infants may be more sensitive and less able to handle excess amounts of molybdenum.
    c) The extent of the contamination has not been conclusively defined.

2) *Boron* levels exceeded the enforcement standard in two homes in 2010. DHS concludes:
    a) The levels of boron detected, although above the enforcement standard, are not expected to harm people's health.

3) *Lead* levels above the enforcement standard were detected in 15 area homes.
    a) Drinking water with lead concentrations exceeding the enforcement standard could present a health threat to human health.

4) *Copper* was detected above the enforcement standard in one home in 2010.
    a) One sample showed high levels of copper, but much lower levels were detected in subsequent tests. In general, copper levels seen are not expected to harm people's health.

5) *Nickel* was detected above the enforcement standard in one home in 2010.
    a) The levels of nickel detected in the one home in the area in 2010, although above the ES, are not expected to harm people's health.

6) *Zinc* was detected above the enforcement standard in two homes in 2010.
    a) In both homes with zinc exceedances, much lower levels were detected in subsequent tests. In general, zinc levels seen were not expected to harm people's health.

Recommendations

1) DHS recommends that all private well owners in the Oak Creek and Caledonia areas test their wells for molybdenum in addition to yearly tests for nitrates and bacteria.
2) As a protective measure for children and other sensitive populations, DHS recommends that well owners with elevated levels of molybdenum or boron not use their well for drinking or food preparation, and take steps to obtain a safe drinking water source. This could include bottled water or connecting to a local municipal water system.

3) DHS recommends that all residents with elevated lead, copper, nickel and zinc levels in water not use their water for drinking and food preparation and take steps to obtain a safe drinking water source.
4) DHS recommends that all well owners with lead, copper, nickel, or zinc in water exceeding the EPA and DNR enforcement standard retest their water in order to distinguish between plumbing and groundwater sources of the metal. Residents should collect two samples of their water:
   a. The first sample should be collected first thing in the morning, or after the water has been undisturbed in the home's plumbing for several hours. This water sample will help evaluate which metals are being leached from the plumbing into standing water.
   b. The second water sample should be collected after water has been flushed from the faucet for 60 seconds after the pump kicks on. This sample will help evaluate if the source of the metal is outside of the home's plumbing.
5) DHS recommends that all homeowners with lead, copper, nickel or zinc in water exceeding the ES sample their wells again to determine the source of contamination.
   a. If lead, copper, nickel, or zinc levels are from area groundwater (not from the home's plumbing), residents should consider steps to correct the problem or secure a permanent alternate water supply.
   b. If the metals are from the home's plumbing, residents should flush their pipes (let the water run for 30-60 seconds) before drinking the water, and use only cold water for consumption.
6) DHS recommends that residents with elevated levels of lead in their drinking water discuss their well test results with their health care provider.
   a. Residents may also want to share this assessment or a fact sheet on lead with their health care provider. More information on lead can be found on the ATSDR website at: http://www.atsdr.cdc.gov/.
   b. The health care provider may recommend blood lead testing of adults or children in the home, and record this information in their medical record.
7) DHS recommends that DNR consider further testing for molybdenum in area groundwater in order to define the extent of molybdenum contamination in the area.

Public Health Action Plan

1) DHS will consult and collaborate with DNR to advise the public on well test results and future testing needs.
2) DHS will continue to provide technical assistance to DNR as more groundwater sampling is conducted in order to determine the source of contamination through isotope analysis. Isotope analysis will include analyzing additional samples from homes and different fly ash landfills in the area.

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Appendix A. Glossary of Terms (including conclusion category summary)

This glossary defines words used by ATSDR in communications with the public. It includes many of the terms used in this document. For terms not found below, see the ATSDR online glossary at: http://www.atsdr.cdc.gov/glossary.html or the EPA online glossary at: http://www.epa.gov/OCEPAterms/.

µg/L: micrograms per liter. 1,000 µg/L = 1 mg/L (milligram per liter)

Acute: Occurring over a short time [compare with chronic].

Acute exposure: Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Carcinogen: A substance that causes cancer.

Chronic: Occurring over a long time [compare with acute].

Chronic exposure: Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV): Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the health assessment process. [see ATSDR discussion of derivation of comparison values at http://www.atsdr.cdc.gov/hac/PHAManual/appf.html.]

Concentration: The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant: A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Detection limit: The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

DHS: Wisconsin Department of Health Services

DNR: Wisconsin Department of Natural Resources

Dose (for chemicals that are not radioactive): The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

EPA: United States Environmental Protection Agency.

Enforcement Standard (ES): a numerical value expressing the concentration of a substance in groundwater which is adopted under Wisconsin Administrative Code s. 160.07, Stats., and s. NR 140.10 or s. 160.09, Stats., and s. NR 140.12.

Exposure: Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment: The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway: The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater: Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Hazard: A source of potential harm from past, current, or future exposures.

Health consultation: A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Ingestion: The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation: The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure: Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Lowest-observed-adverse-effect level (LOAEL): The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism: The conversion or breakdown of a substance from one form to another by a living organism.

mg/kg: Milligram per kilogram. 1 mg/L = 1,000 µg/L

mg/kg-day: Milligrams per kilogram per day.

Minimal risk level (MRL): An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose]. [see ATSDR discussion of derivation of comparison values at http://www.atsdr.cdc.gov/hac/PHAManual/appf.html.]

No-observed-adverse-effect level (NOAEL): The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

Point of exposure: The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population: A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb: Parts per billion. For contaminants in water, 1 µg/L = 1 ppb.

Public availability session: An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public health action: A list of steps to protect public health.

Public health assessment (PHA): An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public meeting: A public forum with community members for communication about a site.

Receptor population: People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD): An EPA estimate, with uncertainty factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans. [see ATSDR discussion of derivation of comparison values at http://www.atsdr.cdc.gov/hac/PHAManual/appf.html.]

RfD [see reference dose]

Risk: The probability that something will cause injury or harm.

Route of exposure: The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Sample: A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Source of contamination: The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Substance: A chemical.

Surface water: Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Toxicological profile: An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology: The study of the harmful effects of substances on humans or animals.

Uncertainty factor: Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Appendix B. Total versus Dissolved Levels of Molybdenum in Area Groundwater

Molybdenum is found in the soil, bedrock, and groundwater in various different forms. The different compounds of molybdenum have different solubility in water. When testing tap water in a home, total molybdenum is typically used instead of dissolved. This is because a result for total molybdenum will give us information on both sources of molybdenum in the water being consumed in that home (both dissolved and not-dissolved). Furthermore, calculating estimated exposure doses from dissolved molybdenum levels may not reflect the total exposure to molybdenum through contaminated groundwater.

As part of the *We Energies* testing, water samples from twelve homes were tested concurrently for dissolved and total levels of molybdenum. On average, total molybdenum levels were about one third higher than dissolved molybdenum levels. The results of concurrent dissolved and total molybdenum testing are shown in Table 2, below.

Table 2. Concurrent dissolved and total levels of Molybdenum in *We Energies'* testing of private well water samples in Oak Creek and Caledonia, Wisconsin, 2009-2010.

Well	Date	Mo, diss	Mo, tot	%Difference
R17	11/23/2009	0.014	0.024	42%
R24	9/25/2009	ND	0.006	-
R25	11/16/2009	0.032	0.042	24%
R26	11/11/2009	0.025	0.043	42%
R27	9/25/2009	0.089	0.12	26%
R28	12/17/2009	0.032	0.045	29%
R29	1/27/2010	0.025	0.036	31%
R29	1/27/2010	0.025	0.035	29%
R31	12/16/2009	0.03	0.043	30%
R32	12/10/2009	0.021	0.035	40%
R33	10/30/2009	0.021	0.03	30%
R34	12/18/2009	ND	ND	-
R35	12/10/2009	0.0053	0.01	47%

Mo, tot: Total Molybdenum concentration, in mg/L

Mo, diss: Dissolved Molybdenum concentration, in mg/L

ND: no-detect, level of molybdenum in water is below the detection limit.

Appendix C. Annual Variations in Molybdenum Levels in Area Groundwater

From year to year, the percentage of samples which exceeded the Wisconsin Enforcement Standard for dissolved molybdenum ranges from none to 100%.

Table 3. Summary of private well water sampling results for Dissolved Molybdenum by year for *We Energies* sampling from 1993-2010.

Year	Dissolved Molybdenum Concentrations (mg/L)			% Samples > ES	# Homes >ES	Total Number of Samples
	Min	Max	Median			
1993	ND	0.06	0.04	70%	14	20
1994	ND	0.16	0.065	83%	5	6
1995	0.07	0.14	0.1	100%	18	18
1996	ND	0.12	0.045	67%	4	6
1997	ND	0.042	0.031	17%	3	18
1998	0.012	0.042	0.0335	17%	1	6
1999	0.007	0.05	0.031	22%	4	18
2000	0.02	0.043	0.0415	67%	4	6
2001	ND	0.057	0.03	24%	4	17
2002	0.027	0.049	0.0425	67%	4	6
2003	0.024	0.056	0.045	69%	11	16
2004	0.02	0.036	0.029	0%	0	5
2005	0.009	0.039	0.032	0%	0	15
2007	0.008	0.052	0.039	50%	7	14
2008	0.013	0.036	0.033	0%	0	5
2009	ND	0.089	0.032	29%	7[6]	24
2010	0.025	0.025	0.025	0%	0	2
Totals	**ND**	**0.16**	**0.036**	**43%**	**20**	**202**

mg/L: milligrams per liter
Min: minimum concentration detected
Max: maximum concentration detected
ES: Wisconsin drinking water enforcement standard
ND: not detected

[6] There were only 23 homes tested in 2009, one home was tested twice.

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Completing the survey should take less than 5 minutes of your time. If possible, please provide your responses within the next two weeks. All information that you provide will remain confidential.

The responses to the survey will help ATSDR determine if we are providing useful and meaningful information to you. ATSDR greatly appreciates your assistance as it is vital to our ability to provide optimal public health information.

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