Health Consultation

Evaluation of Contaminants in Residential Drinking Water Wells near the

PEARCE CREEK DREDGED MATERIAL CONTAINMENT AREA (DMCA)
EARLEVILLE, CECIL COUNTY, MARYLAND

FEBRUARY 15, 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

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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Prepared By:

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Summary

Introduction

In July 2014, the Cecil County Health Department requested ATSDR's assistance to address their concerns regarding elevated levels of metals found in residential drinking water wells near the Pearce Creek DMCA. The health department's concerns focused on two specific issues: (1) Can exposure to individual contaminants (such as aluminum, manganese, and iron) at concentrations exceeding a secondary (non health-based) drinking water standard pose a public health hazard? (2) Are synergistic effects possible from exposure to multiple contaminants at concentrations exceeding secondary drinking water standards? That is, can the combined effect from exposure to a mixture of such contaminants be greater than the sum of the effects from exposure to the contaminants individually?

To address the health department's concerns, ATSDR evaluated environmental data from water samples collected by the health department between 1987 and 2013 from approximately 187 residential wells near the Pearce Creek DMCA. The purpose of ATSDR's evaluation was to determine whether exposure to contaminants (both "primary" and "secondary") in water from these wells could harm people's health. ATSDR also reviewed available scientific literature regarding the effect of chemical interactions on the overall toxicity of contaminant mixtures.

While evaluating drinking water exposures for manganese, ATSDR determined that many residential wells contained manganese at levels of health concern. ATSDR concluded that children and adults who drank water from some residential wells with elevated levels of manganese for many years could potentially experience adverse neurological effects. ATSDR notified the Cecil County Health Department of their findings and issued a letter health consultation on May 27, 2016, that outlined ATSDR's initial conclusions and public health recommendations. In the report, ATSDR recommended that until their homes are connected to the Town of Cecilton municipal water system, residents with private wells (1) use bottled water or treated well water from an appropriate and properly maintained water treatment system for drinking and cooking, and (2) have their treated well water tested regularly. ATSDR also expressed support for the U.S. Army Corps of Engineers (USACE), Maryland Department of Transportation's Port Administration (MPA), Maryland Department of the Environment (MDE), Maryland Department of Health and Mental Hygiene (MDHMH), and Cecil County Health Department's collaborative efforts to provide bottled water to residents. In addition, ATSDR worked with the health department to inform residents about the elevated manganese levels in many area wells.

In response to ATSDR's concerns and recommendations about manganese, MDE advised residents in the Pearce Creek area to use bottled water for drinking and cooking, and announced that MPA and USACE would provide bottled water free of charge to area residents beginning May 28, 2016. MPA and USACE would continue to provide bottled water to area residents until their homes were connected to the Town of Cecilton municipal water system. MDE, USACE, MPA, Maryland Department of Planning (MDP), Maryland Environmental Service (MES), Cecil County, Town of Cecilton, and local, state and federal elected officials had worked together for several years to address the residential well water problems in the area. In the end, a decision was made to extend the Town of Cecilton municipal water system to affected communities near the Pearce Creek DMCA. Funding for the water system extension would be provided by MPA. Connection of individual residents to the water system was expected to be completed by spring 2018.

This health consultation presents the findings of ATSDR's evaluation of all contaminants of concern (in addition to manganese) in residential drinking water wells near the Pearce Creek DMCA. This health consultation is a follow up to previously released recommendations to area residents from the Cecil County Health Department on reducing exposures to chemicals detected in drinking water. The findings of this report strengthen and support the conclusions and recommendations of ATSDR's May 27, 2016 letter health consultation that focused on potential exposures to manganese (Appendix D).

ATSDR conservatively based its evaluation of exposures on the highest contaminant concentration detected in all wells sampled because (1) the number of samples collected from individual wells was insufficient to calculate valid average contaminant concentrations, and (2) the detected contaminant concentrations varied widely both in and among the wells sampled. The highest detected contaminant concentrations may not accurately represent the average, long-term concentrations in these wells.

Conclusions ATSDR reached the following conclusions regarding groundwater contaminants in residential wells near the Pearce Creek DMCA:

Conclusion 1 **Drinking <u>untreated</u> well water from residential wells near the Pearce Creek DMCA could harm people's health.**

Basis for Conclusion Estimated exposures to aluminum, arsenic, cadmium, copper, iron, lead, manganese, sodium, and sulfate at the concentrations found in untreated drinking water from some residential wells were above levels that could harm people's health. Potential harmful health effects from exposure to those chemicals are listed below.

- Aluminum: Neurological or neurodevelopmental effects in children and adults drinking untreated water for 14 days or longer.
- Arsenic: Skin thickening or discoloration in children and adults drinking untreated water for a year or longer, and low increased risk of cancer after drinking water for many years.
- Cadmium: Kidney damage (i.e., increased urinary levels of low molecular proteins) in children and adults drinking untreated water for a year or longer.

- Copper: Nausea, vomiting, stomach cramps, or diarrhea in children and adults drinking untreated water for 14 days or longer.
- Iron: Nausea, vomiting, stomach cramps, or diarrhea in children and adults drinking untreated water for any length of time.
- Lead: Lead was detected in water samples from a number of residential wells. Exposure to lead in drinking water can increase a child's blood lead level. Elevated blood lead levels in children are associated with adverse neurological, behavioral, and developmental effects. Because there is no known safe level of lead in the blood of children, ATSDR recommends reducing lead exposure wherever possible.
- Manganese: Harmful neurological effects in children and adults drinking untreated water for a year or longer.
- Sulfate: Short-term laxative effects such as increased stool mass, volume, and moisture; decreased intestinal transit time; and possibly diarrhea in children and adults drinking untreated water for any length of time.

Conclusion 2 **The levels of some contaminants, especially sodium, in <u>treated</u> drinking water from some residential wells could harm people's health.**

Basis for Conclusion

Water treatment systems used by many residents were generally effective at reducing contaminants to below levels of health concern. However, treatment systems at some residences failed to remove contaminants sufficiently. In addition, the use of sodium chloride salt in ion exchange water treatment units significantly increased the sodium levels in the treated water at some residences.

Sodium intake from treated water at some residences exceeded the recommended intake limit for sodium-sensitive persons, including older adults (51 years and older), African Americans, and individuals with high blood pressure, diabetes or chronic kidney disease. High levels of sodium intake can lead to elevated blood pressure which is a known risk factor for heart and kidney disease.

Aluminum and arsenic were also present at levels that could harm people's health in some treated well water samples.

Conclusion 3 **Individuals exposed to mixtures of contaminants that affect the same target organ systems (for example, manganese, lead, and aluminum for neurological effects; and copper, sulfate, and iron for gastrointestinal effects) in drinking water from some residential wells near the Pearce Creek DMCA may have a greater risk of harmful effects than the risk that would be expected from exposure to any of these contaminants individually.**

Basis for Conclusion ATSDR's evaluation of exposures to individual contaminants in drinking water from residential wells in the Pearce Creek DMCA area indicated that combined exposures to some contaminants may cause harmful non-cancer health effects. The potential harmful effects and associated contaminants are

- gastrointestinal problems in children and adults (copper, iron, and sulfate), and
- neurological, behavioral, or neurodevelopmental effects in children (aluminum, lead, and manganese) and neurological effects in adults (aluminum and manganese).

Scientific studies are somewhat conflicting on the possibility of enhanced or reduced mixtures effects on the nervous system from co-exposure to aluminum, lead, manganese, or other contaminants found in drinking water from residential wells near the Pearce Creek DMCA. The likelihood of mixtures effects would depend on the specific mix and concentration of these chemicals in a given well. In addition, ATSDR could not find any information on possible gastrointestinal mixtures effects related to co-exposures to iron, copper, and sulfate. Without compelling evidence of reduced or enhanced neurological effects from co-exposures to arsenic, lead, and manganese or gastrointestinal effects from co-exposures to iron, copper, and sulfate, ATSDR, by default, assumes the health risks are additive.

Conclusion 4 **Drinking well water containing beryllium, fluoride, nickel, or zinc from residential wells near the Pearce Creek DMCA is not expected to harm people's health.**

Basis for Conclusion Estimated exposures to these substances in drinking water from residential wells were below levels known to harm people's health.

Conclusion 5 **ATSDR cannot determine whether exposure to radiation from naturally-occurring radioactive substances in drinking water from residential wells near the Pearce Creek DMCA could harm people's health.**

Basis for Conclusion Gross alpha particle activity (GAPA) and gross beta particle activity (GBPA) exceeded their respective MCLs in water samples from some residential wells. However, the concentrations of individual radioactive substances were not reported. Without that information, ATSDR cannot estimate the potential cancer risk from exposure to radiation in drinking water from residential wells near the Pearce Creek DMCA.

Next Steps

- ATSDR supports extension of the Town of Cecilton municipal water system to residents near the Pearce Creek DMCA who currently depend on well water for their household water needs.

- Until their homes are connected to the Cecilton municipal water system, ATSDR recommends that residents continue to use bottled water for drinking and cooking. Note: Since May 28, 2016, bottled water has been provided to areas residents by the Maryland Port Administration and the U.S. Army Corps of Engineers. Residents will continue to receive bottled water until their homes are connected to the municipal water system.

- ATSDR recommends that residents who choose to continue using treated well water for drinking and cooking (1) use an appropriate water treatment system, (2) properly maintain the system; and (3) have the treated water tested regularly to ensure that it meets established drinking water standards.

- ATSDR will share this report with appropriate local, state, and federal agencies (including the Cecil County Health Department, MDE, MPA, and USACE).

- ATSDR will continue to work with the Cecil County Health Department, MDHMH, and other public health partners to increase awareness of potential health hazards from exposure to contaminants in area drinking water wells.

Assumptions / Limitations

- ATSDR used contaminant concentrations detected in treated and untreated well water samples from residential wells near the Pearce Creek DMCA for estimating drinking water exposure doses because some residences do not have a water treatment system and may drink untreated well water. In addition, available information about well water treatment systems at individual residences is limited, such as how long the system has been in operation, how well the system is maintained, or how efficient the system is at removing individual chemicals.

- In estimating drinking water exposures doses, ATSDR's assumed that all residents lived in the area year round (365 days per year). The estimated doses for year-round residents are higher than the doses for part-time or seasonal residents, that is, residents who live in the area for only part of the year.

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1 Purpose and Statement of Issues

In July 2014, the Cecil County (Maryland) Heath Department requested ATSDR's assistance to address their concerns about elevated levels of metals found in residential drinking water wells near the Pearce Creek Dredged Material Containment Area (DMCA). The health department's concerns focused on two specific issues: (1) Can exposure to individual contaminants at concentrations exceeding a secondary (non health-based) drinking water standard pose a public health hazard? and (2) Are synergistic effects possible from exposure to multiple contaminants at concentrations exceeding secondary drinking water standards? That is, can the combined effect from exposure to a mixture of such contaminants be greater than the sum of the effects of the individual substances individually?

To address the health department's concerns, ATSDR evaluated environmental data from water samples collected by the health department between 1987 and 2013 from approximately 187 residential wells near the Pearce Creek DMCA. The purpose of ATSDR's evaluation was to determine whether exposure to contaminants in water from these wells could harm people's health. ATSDR also reviewed available scientific literature regarding the effects of chemical interactions on the overall toxicity of contaminant mixtures.

While evaluating drinking water exposures for manganese, ATSDR determined that many residential wells contained manganese at levels of health concern. ATSDR concluded that children and adults who drank water from some residential wells with elevated levels of manganese for many years could potentially experience adverse neurological effects. ATSDR notified the Cecil County Health Department of their findings and issued a letter health consultation on May 27, 2016, that outlined ATSDR's initial conclusions and recommendations to protect the residents' health. In the report, ATSDR recommended that until homes are connected to the Cecilton municipal water system, residents with private wells (1) use bottled water or treated well water from an appropriate and properly maintained water treatment system for drinking and cooking; and (2) have their treated well water tested regularly. ATSDR also expressed support for efforts to provide bottled water to residents and worked with the local health department to inform residents about the elevated manganese levels in many area wells.

In response to ATSDR's concerns and recommendations about manganese, the Maryland Department of the Environment (MDE) advised residents in the Pearce Creek area to use bottled water for drinking and cooking and announced that MPA and USACE would provide bottled water free of charge to area residents beginning May 28, 2016. MPA and USACE would continue to provide bottled to area residents until their homes were connected to the Town of Cecilton municipal water system. MDE, USACE, MPA, Maryland Department of Planning (MDP), Maryland Environmental Service (MES), Cecil County, Town of Cecilton, and local, state and federal elected officials had worked together for several years to address the residential well water problems in the area. Eventually, an agreement was reached to extend the Town of Cecilton municipal water system to the affected communities near the Pearce Creek DMCA. Funding for the water system extension would be provided by MPA. Connection of individual residents to the water system is expected to be completed by spring 2018.

This health consultation presents the findings of ATSDR's evaluation of all contaminants of concern in residential drinking water wells near the Pearce Creek DMCA. The findings of this report strengthen and support the conclusions and recommendations of ATSDR's May 27, 2016, letter health consultation that evaluated drinking water exposures for manganese (see Appendix D).

2 Background and Site History

The Pearce Creek DMCA is in Cecil County, Maryland, approximately 7 miles west of the Town of Cecilton on the eastern bank of the Chesapeake Bay near the confluence of the Elk River and the Chesapeake Bay (Figure 1). Several small communities border the DMCA, including West View Shores, Bay View Estates, and Sunset Pointe. Development of the West View Shores community occurred mainly after World War II in the 1940s and 1950s. The development of Bay View Estates, which borders the study area to the southwest, occurred later and at a slower pace than the community of West View Shores. The residents of these communities rely on shallow, private water supply wells to meet their household water needs (USACE 2015).

In 1937, USACE acquired 996 acres of land (the Pearce Creek DMCA property). Perimeter soil dikes were constructed on an area approximately 260 acres. Dredged material was placed in a diked area of the DMCA in 1937 and 1938, and then again beginning in the 1960s until 1993. Placement of dredged material was discontinued in response to concerns that contaminants from the DMCA were degrading the water quality of nearby residential water supply wells (USACE 2015).

After 1993, USACE disposed of dredged materials at open-water sites, such as Pooles Island, located 18 miles to the southwest of the DMCA, in the Chesapeake Bay. In preparation for the closure of all open-water disposal sites in the Chesapeake Bay by the State of Maryland in December 2010, USACE began looking for alternative disposal locations. The Pearce Creek DMCA was the preferred option because of its available capacity and proximity to the Chesapeake and Delaware (C&D) Canal.

In 2014, USACE applied to MDE for a water quality certification which USACE needed to re-open the DMCA. In December 2014, MDE issued the water quality certification to USACE. The certification specified that USACE could not start placing dredged material into the DMCA before

- installing a synthetic liner over the existing surface of the DMCA to prevent infiltration of contaminants into groundwater below the DMCA; and
- initiating construction of an extension of the Town of Cecilton municipal water system to residences in West View Shores, Bay View Estates, and Sunset Pointe, and along Pond Neck Road adjacent to the DMCA.

MPA committed to funding the water line extension once MDE issued the required water quality certification to USACE.

Installation of the DMCA liner began in early 2016 and is scheduled to be completed in early 2017. Disposal of dredged materials into the DMCA is expected to begin in January 2018.

Installation of the water transmission main from Cecilton to the Pearce Creek area is scheduled to be completed in early 2017. Installation of the water distribution system, which will carry water from the transmission main to the local communities, is in progress. Connection of individual residences to the distribution system is expected to begin in spring 2017 and be completed by spring 2018. In accordance with state regulations, all property owners within the service area of the extended water system must connect to the system once it becomes available. In addition, the owner's existing residential well(s) must be capped and abandoned. (Owens J. 2016; Cecil County 2016).

2.1 Previous Environmental Studies/Investigations

Several environmental studies/groundwater investigations were conducted in the Pearce Creek DMCA area after disposal of dredge materials ended in 1993. These results of the studies, which were conducted on behalf of MPA and USACE, showed elevated concentrations of metals (including manganese and iron), sulfate, and chloride, in groundwater near the DMCA and in some residential wells in the nearby West View Shores community. The studies, however, could not determine whether the elevated levels of metals, sulfate, and chloride were caused by contaminants from the DMCA or from some other source.

In 2010 and 2011, the U.S. Geological Survey (USGS), in cooperation with USACE, conducted a comprehensive study of groundwater in the Pearce Creek DMCA area. The purpose of the study was to determine whether (1) the DMCA had affected area groundwater quality, and (2) whether area groundwater contained chemicals at concentrations exceeding maximum allowable or recommended levels established by the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act (SDWA) (USGS 2012).

During the study, USGS collected water quality measurements and water samples at 35 observation wells throughout the study area; and 15 residential water supply wells, mainly in West View Shores and along Pond Neck Road, and two locations on the Elk River and Pearce Creek Lake (USGS 2012).

The findings from USGS's 2010-11 study were presented in a 2012 report titled "Hydrogeologic Framework, Hydrology, and Water Quality in the Pearce Creek Dredge Material Containment Area and Vicinity, Cecil County, Maryland, 2010–11" (USGS 2012). In the report, USGS concluded that the Pearce Creek DMCA Cecil County had degraded local groundwater quality. Several metals, including aluminum, arsenic, beryllium, cadmium, nickel, sodium, and thallium, were detected in the groundwater samples at levels exceeding EPA Maximum Contaminant Levels (MCLs), Health Advisory Levels (HALs), or Secondary Drinking Water Standards (SDWSs). The study also found low pH and high total dissolved solids (TDS) levels in the aquifer which cause metals in overlying soils to be mobilized into groundwater.

2.2 Residential Well Water Sampling (Cecil County Health Department)

From 1987 to 2007, the Cecil County Health Department collected water samples from approximately 56 residential wells near the Pearce Creek DMCA in response to requests from individual homeowners. The samples were analyzed for metals. The health department shared the sampling results for each well sampled with the well's owner.

In 2011, at the request of USGS, the Cecil County Health Department collected water samples from 38 residential wells in the Pearce Creek area. USGS requested that the wells be sampled because of concerns about possible residential well contamination based on the high levels of metals found in nearby monitoring wells during USGS' 2010-2011 groundwater investigation. The 2011 residential well samples were analyzed for metals, including arsenic, beryllium, nickel, and iron. The health department provided the sampling results for each well sampled to the well's owner.

From March through November 2013, the health department sampled approximately 152 of the estimated 241 residential water supply wells in the Pearce Creek DMCA area (see Figure 1.) The samples were analyzed for metals, other inorganics (e.g., minerals), and water quality indictors (e.g., total dissolved solids, turbidity, pH). The sampling results confirmed that residential wells in the Pearce Creek DMCA area were at increased risk of exceeding primary or secondary drinking water standards for some contaminants. The health department informed residents of the contaminant levels in their well water and ways to reduce their potential exposures to well water contaminants, such as proper operation and maintenance of in-home water treatment systems.

In March 2014, the Cecil County Health Department recommended that public water be extended to serve residents of the communities surrounding the Pearce Creek DMCA.

Analytical data from the residential well water samples collected by the health department from 1987 to 2013 are evaluated in Section 3 of this report.

3 Discussion

3.1 Evaluation Process

The process that ATSDR uses to evaluate potential harmful health effects from exposure to environmental contaminants in discussed in Appendix B of this document.

3.2 Environmental Data Evaluation

Between October 1987 and November 2013, the Cecil County Health Department collected approximately 475 water samples from 187 residential water supply wells near the Pearce Creek DMCA. The well water samples were analyzed for metals, other inorganics (e.g., minerals), radionuclides, and water quality indicators (e.g., total dissolved solids, turbidity, pH). The contaminant data from those samples are included in this evaluation.

A number of metals, minerals, and radionuclides were detected in the well water samples (Table 1). For each of the detected substances, ATSDR compared the maximum concentration in all residential well water samples to appropriate comparison values to identify contaminants of potential concern (COPCs). Comparison values (CVs) are chemical and media-specific concentrations in air, soil, and drinking water that are used to identify environmental contaminants that require further evaluation. Health-based CVs, such as ATSDR's environmental media evaluation guideline (EMEGs) and reference dose media evaluation guide (RMEGs), represent estimated contaminant levels in soil, water, or air that people could be exposed to on a daily basis and not experience harmful health effects. When a contaminant is detected at a concentration lower than its CV, exposure to the contaminant is not expected to result in health effects and it is excluded from further evaluation. If a contaminant is detected at a concentration greater than its CV, it is designated as a contaminant of potential concern (COPC) and is retained for further evaluation**.** Additional information about CVs is provided in Appendix B.

As discussed above, contaminants detected at concentrations exceeding an applicable **health**-based CV were designated as COPCs. ATSDR also designated substances detected at concentrations exceeding a **non health**-based CV (i.e., EPA Secondary Maximum Contaminant Level [SMCLs]), as COPCs. ATSDR made this decision because of the Cecil County Health Department's specific concerns about potential health hazards associated with exposure to chemicals in drinking water at concentrations which exceed an EPA SMCL. SMCLs are non-health-based guidelines for contaminants that may cause: (1) cosmetic effects (such as skin or tooth discoloration), (2) aesthetic effects (undesirable taste, odor, or color) in drinking water, or (3) technical effects (damage to water equipment or reduced effectiveness of treatment for other contaminants). Note: In this report, ATSDR does **not** address potential secondary (water quality) effects for contaminants in residential wells near the Pearce Creek DMCA because the health department asked ATSDR to focus its evaluation on health-related effects.

Contaminants detected in well water samples collected by the Cecil County Health Department at concentrations exceeding an applicable CV are shown in Table 1. As discussed above, these contaminants are designated as COPCs and are evaluated in more detail in Sec. 3.4 of this report.

Table 1. Contaminants of Potential Concern (COPCs) in Water Samples Collected by the Ceil County Health Department from Residential Wells near the Pearce Creek DMCA

Contaminant	Max. Detected Conc. (mg/L)	No. of sampled wells with detected contaminant concentrations / No. of sampled wells	Comparison Value (CV)		No. of sampled wells with contaminant concentrations exceeding the CV / No. of sampled wells
			Value	Source	
Aluminum	345	74/153	10	Chronic $EMEG_{child}$	9/153
Arsenic	0.058	32/187	0.000023	CREG	32/187
Beryllium	0.038	54/167	0.02	Chronic $EMEG_{child}$	2/167
Cadmium	0.083	30/176	0.001	Chronic $EMEG_{child}$	30/176
Chloride	1,370	159/176	250	SMCL	22/176
Copper	2.39	22/46	0.1	Intermediate $EMEG_{child}$	16/46
Fluoride	0.99	12/44	0.5	Chronic $EMEG_{child}$	4/44
Gross Alpha Particle Activity (pCi/L)	110	115/155	15	MCL	46/155
Gross Beta Particle Activity (pCi/L)	53.3	79/114	50	MCL	1/114
Iron	298	143/187	0.3	SMCL	83/143
Lead	0.13	15/45	0.015	AL	5/45
Manganese	378	156/186	0.3	LTHA	116/156
Nickel	0.82	59/182	0.1	LTHA	42/59
Sodium	1,413	178/189	20	DWEL	143/189
Sulfate	3,500	157/175	250	SMCL	58/175
Zinc	6.03	127/170	3	Chronic $EMEG_{child}$	4/170

See **Appendix B** for additional information regarding comparison values (CVs).

$EMEG_{child}$ = ATSDR Child Chronic Environmental Media Evaluation Guideline; CREG = ATSDR Cancer Risk Evaluation Guide; LTHA = EPA Long-Term Health Advisory; MCL = EPA Maximum Contaminant Level; AL = EPA Action Level; SMCL = EPA Secondary Maximum Contaminant Level.

Two other substances — nitrate and thallium — were detected in water samples from some residential wells; however, the concentrations did not exceed their applicable CVs. As such, nitrate and thallium will not be evaluated further in this health consultation.

3.3 Exposure Pathways Analysis

An exposure pathway is the way a contaminant moves from its source (where it began) through the environment to a point where people can come into contact with it. A completed exposure pathway is one that contains the following five elements: (1) a **source** of contamination, such as dredged sediments; 2) movement (**transport**) of the contaminant through environmental media, such as groundwater; (3) a **point of exposure** where people come into contact with the contaminated media, such as a residential well; (4) a **route of exposure**, or how people come into contact with the contaminant, such as contaminated well water); and (5) an **exposed population**, or people who come into contact with the contaminant, such as residents who drink contaminated well water.

ATSDR has identified exposure to contaminants (metals, other inorganics, & radionuclides) in drinking water from residential wells near the Pearce Creek as a completed exposure pathway. The five elements of the pathway are summarized in Table 2.

Table 2. Residential Drinking Water Exposure Pathway for Residences near the Pearce Creek DMCA

Exposure Pathway Element					Exposure Time Frame
Contamination Source	**Environmental Transport**	**Exposure Point**	**Exposure Route**	**Exposed Population**	
Dredged materials stored in Pearce Creek DMCA	Movement of contaminants from the dredged materials into groundwater and migration to nearby residential wells	Residences or other locations where water from private wells is consumed	Ingestion (drinking)	Residents in West View Shores, Bay View Estates, Sunset Pointe and along Pond Creek Rd. who drink water from private wells	Past Present* Future†

*Since late May 2016, bottled water has been provided to residents living near the DMCA. However, some residents may still be using well water for drinking and cooking, Therefore, for the purposes of ATSDR's evaluation, ATSDR assumes that residents are currently exposed to contaminants in their well water.

†Exposures to contaminants in residential drinking water wells will end once residences near the Pearce Creek DMCA are connected to the Town of Cecilton municipal water system. Connection of residences to the municipal water system is expected to begin in spring 2017 and be completed by spring 2018.

3.4 Health Effects Evaluation

In this section, ATSDR evaluates exposures to substances identified as COPCs in drinking water from residential wells near the Pearce Creek DMCA to determine whether those exposures can harm people's health. A detailed discussion of ATSDR's evaluation process in provided in Appendix B.

For each COPC (Table 1), ATSDR calculated exposure doses for consumption (ingestion) of drinking water. Exposure doses were calculated for both children (birth to 12 months) and adults. ATSDR selected birth to 12 months as the default children's age group because children in this age group have the highest water ingestion rate to body weight ratio, and, therefore, the highest calculated exposure doses.

An exposure dose is an estimate of the amount of a contaminant that gets into a person's body over a specific period of time. ATSDR's dose calculations and exposure assumptions are discussed in more detail in Appendix C. In calculating the exposure dose, ATSDR used the <u>highest</u> contaminant concentration detected in all residential well water samples regardless of whether the sample was collected before treatment ("untreated" sample) or after treatment ("treated" sample)

To evaluate possible **non-cancer** health effects. ATSDR compared the contaminant exposure dose to an appropriate health guideline, such as an ATSDR MRL or EPA RfD. A health guideline is an estimate of daily exposure to a substance over a specified duration that is unlikely to cause harmful, non-cancer health effects in humans. Exposure doses below the health guideline value are not expected to result in adverse health effects and are excluded from further consideration. Exposure doses greater than the health guideline are compared to known health effect levels (or doses that cause harmful health effects) identified in ATSDR toxicological profiles or EPA's Integrated Risk Information System (IRIS). ***Comparison of exposure doses to known health effect levels is the basis for determining whether the exposures are likely to harm people's health.***

Note: Some of the substances identified as COPCs in groundwater near the Pearce Creek DMCA (*e.g.,* chloride, iron, sodium) are essential minerals. To evaluate potential health effects from exposure to essential minerals, ATSDR used tolerable upper intake levels (ULs) developed by the National Institute of Medicine (IOM). The IOM defines a UL as the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population (IOM 1997). ATSDR estimated dietary intakes of minerals from drinking water only. ULs are based on intake from all sources, including food and drinks. Typically, drinking water by itself is not a significant source of these minerals.

To estimate **cancer** risk for known cancer-causing contaminants, such as arsenic, the estimated contaminant exposure dose for a population is multiplied by the contaminant's EPA cancer slope factor (CSF). The calculated risk is often called an excess or increased cancer risk because it represents the additional risk above the existing background cancer risk. In the United States, the background cancer risk (or the probability of developing cancer at some point during a person's lifetime) is about 1 in 2 (45%) for men and 1 in 3 (39%) for women.

The estimated increased cancer risk is a conservative, "worst-case" risk based on the available science. The actual increased cancer risk can be significantly lower (up to several orders of magnitude) than the estimated increased risk.

A more detailed discussion of ATSDR's cancer evaluation process is provided in Appendix B.

3.4.1 Aluminum:

Aluminum was detected in water samples from 74 of 153 residential water wells near the Pearce Creek DMCA at concentrations ranging from 0.1 to 345 mg/L. The detected aluminum concentration in nine wells exceeded the ATSDR health-based child chronic CV of 10 mg/L.

3.4.1.1 Non-cancer Effects Evaluation

Aluminum is a silvery white metal and the most abundant metal in the earth's crust. In the environment, it is always found combined with other elements such as oxygen, silicon, and fluoride. It is found in virtually all food, water, air, and soil. The average adult in the U.S. consumes about 7-9 milligrams (mg) of aluminum per day in their food. For the general population, the intake of aluminum from food and water is low compared to that consumed by people taking aluminum-containing medications such as antacids, buffered aspirin, and antidiarrheal medications (ATSDR 2008)

Low-level oral exposure to aluminum from food, air, or water is generally not be harmful. Exposure to high levels of aluminum, however, can harm people's health. Studies of patients with kidney disease have shown that accumulation of aluminum in the brain as a result of long-term dialysis treatment can cause a neurological disease characterized by gradual loss of motor, speech, and cognitive function. Some studies have found weak associations between living in areas with elevated aluminum levels in drinking water with an increased risk of Alzheimer's disease; other studies, however, have not found such associations (ATSDR 2008).

Studies in animals have shown that the nervous system is the most sensitive target of aluminum toxicity, and most of the studies have focused on neurotoxicity and neurodevelopmental toxicity. The most commonly observed effects are impaired performance on neurobehavioral tests of motor, sensory, and cognitive function (ATSDR 2008).

The estimated aluminum exposure dose from consuming residential well water with the highest detected aluminum concentration (345 mg/L) is 49.3 mg/kg-day for children (birth to 12 months of age) and 13.4 mg/day for adults (over 21 yrs. of age.) These aluminum doses exceed both the chronic and intermediate-duration MRL of 1 mg/kg-day (ATSDR 2008).

The MRL for chronic-duration exposures (1 year or longer) was derived from a Lowest Observed Adverse Effects Level (LOAEL) of 100 mg/kg-day for neurological effects in mice identified in a study conducted by Golub et al (ATSDR 2008).

The MRL for intermediate-duration exposures (14 to 365 days) was based on a No Observed Adverse Effects Level (NOAEL) of 26 mg/kg-day for neurobehavioral effects in mice identified in a study conducted by Golub & Germann. The intermediate MRL is protective for neurological effects, neurodevelopmental effects, and delays in maturation (ATSDR 2008).

For the highest detected aluminum concentration (345 mg/L), the estimated child exposure dose (49.3 mg/kg-d) was higher than the intermediate NOAEL (26 mg/kg-d) and just two times below the chronic LOAEL. The child exposure dose for the second highest detected concentration (40.91 mg/L) was lower than both the intermediate NOAEL and chronic LOAEL. ***Therefore, children drinking water from residential wells near the Pearce Creek DMCA with aluminum at the highest detected concentration (345 mg/L) for 14 days or longer could experience neurological or neurodevelopmental effects.***

The estimated adult exposure dose for the highest detected aluminum concentration (345 mg/L) was lower than both the intermediate NOAEL and chronic LOAEL. ***Therefore, adults drinking water with aluminum concentrations found in residential wells near the Pearce Creek DMCA are not likely to experience adverse non-cancer health effects.***

3.4.1.2 Cancer Effects Evaluation

The Department of Health and Human Services (DHHS) and EPA have not evaluated the carcinogenic potential of aluminum in humans. However, aluminum has not been shown to cause cancer in animals.

3.4.2 Arsenic:

Arsenic was detected in water samples from 32 of 187 wells at concentrations ranging from 0.002 to 0.058 mg/L. The detected concentrations exceeded the child chronic EMEG of 0.003 mg/L in 27 wells.

3.4.2.1 Non-cancer Effects Evaluation

Arsenic is a naturally occurring element that is found in soil, water, air, and food. The concentration of arsenic in natural surface water and groundwater is generally about 0.001 mg/L (1 µg/L), but may be much higher in areas of the U.S. with unusually high natural levels of arsenic in rock. The average concentration of arsenic in drinking water across the U.S. is about 0.002 mg/L (2 µg/L) (ATSDR 2007a).

The estimated arsenic dose from consuming water with the highest detected arsenic concentration (0.058 mg/L) is 0.00829 mg/kg-day and 00224 mg/kg-day for children and adults, respectively. These doses exceed the ATSDR arsenic chronic MRL of 0.0003 mg/kg-d.

The chronic MRL for arsenic (0.0003 mg/kg/day) is based on a study that found skin lesions in people exposed to various levels of arsenic in their drinking water over a long period of time. The NOAEL of 0.0008 mg/kg/day was divided by a factor of 3 for human variability to obtain the MRL of 0.0003 mg/kg-day. Hyperpigmentation (skin discoloration) and keratosis (skin thickening) were found at an arsenic dose of 0.014 mg/kg-day. These effects were observed following several decades of exposure (ATSDR 2007a).

The estimated child (0.00829 mg/kg-day) and adult (0.00224 mg/kg/day) exposure doses for the highest detected arsenic concentration (0.058 mg/L) exceeded the chronic NOAEL. As previously discussed, the NOAEL is the highest dose for which no harmful (adverse) health effects were observed in a long-term (chronic) human study. ***Therefore, children and adults drinking water containing arsenic at the highest detected concentration (0.058 mg/L or 58 µg/L) for a year or longer could experience skin thickening or discoloration.***

3.4.2.2 Cancer Effects Evaluation

Arsenic is classified as a human carcinogen. This classification is based on animal and human studies that indicate an increased risk for developing cancers of the skin, lung, bladder, kidney, liver, and prostate from consuming arsenic-containing water.

Arsenic was detected in water samples from 32 wells at concentrations ranging from 0.002 to 0.058 mg/L. The detected concentrations in all 32 wells exceeded ATSDR's cancer comparison value (CREG) of 0.000023 mg/L (0.023 µg/L). The cancer comparison value corresponds to an increase in the incidence of skin cancer of one in one-million in addition to the background lifetime cancer risk of one in two for men and one in three for women in the U.S. (American Cancer Society, 2013).

The estimated increased cancer risk for consumption of well water with the maximum detected arsenic concentration (0.058 mg/L) was 14 in 10,000, which is higher than EPA's target risk range of one in 10,000. A cancer risk of 14 in 10,000 means an additional 14 cases of cancer in 10,000 people in addition to the background risk (1 in 2 for men and 1 in 3 for women). This estimated risk assumes daily, year-round exposure to the maximum detected arsenic concentration of 0.058 mg/L for 33 consecutive years (as an adult). Note: Thirty three (33) years is the estimated 95th percentile U.S. residential occupancy period (ROP), that is, the number of years a person lives at the same residence (EPA 2011). The estimated cancer risk would be lower for children and adults that drink less well water, use bottled water to supplement the drinking water from their well, or live in the same home less than 33 years.

3.4.3 Beryllium

Beryllium was detected in water samples from 54 of 167 residential wells near the Pearce Creek DMCA at concentrations ranging from 0.001 to 0.038 mg/L. Only two wells contained beryllium at concentrations higher than the ATSDR child chronic CV of 0.02 mg/L.

The detected beryllium concentration exceeded the EPA MCL (0.004 mg/L) in samples from 18 wells.

3.4.3.1 Non-cancer Effects Evaluation

Beryllium is a naturally occurring element in water and soil. The average concentration in drinking water from different parts of the U.S. is about 0.19 µg/L (or 0.00019 mg/L). Less than 1% of the beryllium in food and drinking water is absorbed by gastrointestinal tract (ATSDR 2007a).

The estimated beryllium dose from consuming water with the highest detected beryllium concentration (0.038 mg/L) was 0.0054 mg/kg-day for children (birth to 12 months of age) and 0.0015 mg/kg-day for adults (over 21 yrs. of age.) The estimated beryllium child dose exceeded the ATSDR chronic duration MRL of 0.002 mg/kg-d; the adult dose, however, did not exceed the MRL.

ATSDR derived the MRL for beryllium from a benchmark dose (defined as the 95% lower confidence limit of the dose corresponding to a 10% increase in the incidence of small intestinal lesions in dogs) of 0.56 mg/kg-day (ATSDR 2007a.). The highest estimated beryllium exposure dose for children and adults was more than 100 and 350 times lower, respectively than the beryllium benchmark dose. ***Therefore, ATSDR concludes that exposure to beryllium in drinking water at the levels detected in residential wells near the Pearce Creek DMCA is not likely to cause adverse non-cancer health effects in children or adults.***

3.4.3.2 Cancer Effects Evaluation

Oral exposure to beryllium is not known to cause cancer. ATSDR's toxicological profile for beryllium (1) found no studies regarding cancer in humans after oral exposure to beryllium or its compounds, and (2) noted that oral exposure to beryllium has not been found to cause cancer in animals.

Exposure to beryllium via inhalation is believed to cause cancer in humans; however, inhalation of beryllium in drinking water from residential wells near the Pearce Creek DMCA is not an exposure pathway of concern.

3.4.4 Cadmium:

Cadmium was detected in water samples from 30 of 176 wells near the Pearce Creek DMCA at concentrations ranging from 0.0026 to 0.083 mg/L. The detected cadmium concentration exceeded the ATSDR health-based child chronic CV (0.001 mg/L) in 30 wells and the adult chronic CV (0.0035 mg/L) in 24 wells.

3.4.4.1 Non-cancer Effects Evaluation

Cadmium is a naturally occurring element found in water and soil.

Food is the largest potential source of cadmium exposure for non-smoking members of the U.S. population. Average cadmium levels in U.S. foods range from 2 to 40 parts per billion (ppb). The level of cadmium in most drinking water supplies is less than 1 ppb (µg/L). The current average dietary intake of cadmium in adult Americans is about 0.0004 mg/kg/day (ATSDR 2012b).

Numerous studies indicate that the kidney is the main target organ of toxicity following extended oral exposure to cadmium, with effects similar to those seen following inhalation exposure. Elevated incidences of kidney effects (protein in the urine) have been found in numerous epidemiologic studies of residents in cadmium-polluted areas (ATSDR 2012b).

The estimated cadmium dose from consuming water with the highest detected cadmium concentration (0.083 mg/L) was 0.0119 mg/kg-day for children (birth to 12 months of age) and 0.00321 mg/kg-day for adults (over 21 yrs. of age.) These estimated child and adult cadmium doses exceed the ATSDR MRL of 0.0001 mg/kg-day and the EPA RFD of 0.0005 mg/kg-day (EPA 1992).

ATSDR derived the chronic oral MRL for cadmium (0.0001 mg/kg-d) from several large-scale environmental exposure studies by calculating the urinary cadmium level corresponding to a probability of 10% excess risk of kidney effects (i.e., low molecular weight protein in the urine). The dietary cadmium intake corresponding to the lower confidence limit of the calculated urinary cadmium level, or $UCDL_{10}$, was 0.00033 mg/kg-d. The $UCDL_{10}$ was divided by an uncertainty factor of three for human variability resulting in a chronic-duration oral MRL of 0.0001 mg/kg-day (ATSDR 2012b).

For the highest detected cadmium concentration (0.083 mg/L), the calculated cadmium exposure doses for children (0.0119 mg/L) and adults (0.00321 mg/kg-day) exceeded the $UCDL_{10}$ of 0.00033 mg/kg/day used to derive the MRL. ***Therefore, children and adults who drink water from residential wells near the Pearce Creek DMCA with cadmium at the highest detected concentration (0.083 mg/L) for a year or longer could experience early signs of kidney damage (i.e., increased urinary levels of low molecular proteins).***

3.4.4.2 Cancer Effects Evaluation

Available evidence from human and animal studies is inconclusive regarding potential cancer risks from long-term exposure to cadmium by ingestion (ATSDR 2012b).

A number of occupational studies have found evidence of an increased risk of lung cancer in workers following prolonged inhalation exposure to cadmium. Studies in rats also provide strong evidence of increased lung cancer risk from chronic inhalation of cadmium. However, inhalation of cadmium in drinking water from residential wells near the Pearce Creek DMCA is not an exposure pathway of concern.

3.4.5 Chloride

Chloride was detected in water samples from 159 of 176 wells near the Pearce Creek DMCA at concentrations ranging from 3 to 1,370 mg/L. The detected chloride concentrations exceeded the EPA non-health based SMCL of 250 mg/L (to prevent taste problems) in 22 of the 159 wells (EPA 2012).

3.4.5.1 Non-cancer Effects Evaluation

Chloride is widely distributed in nature usually as the compounds sodium chloride (NaCl), calcium chloride (CaCl), and potassium chloride (KCl). Chloride is an essential element and helps regulate the volume and electrolyte balance of body fluids (IOM 2005).

The Food and Nutrition Board of the National Research Council has developed chloride tolerable upper intake level (ULs) of 1,500 mg/day for children (1 to 3 years old) and 3,600 mg/day for adults. (IOM 2005). The ULs for chloride are based on the ULs for sodium because almost all dietary chloride comes with sodium added during the processing or consumption of foods.

A child (age 1 to 3 yrs.) and adult drinking well water with the highest detected chloride concentration (1,370 mg/L) would consume about 422 and 1,681 mg of chloride per day, respectively. These intake levels are well below the ULs of 1,500 and 3,600 mg per day for young children and adults, respectively. ***Therefore, exposure to chloride in drinking water at the levels found in residential wells near the Pearce Creek DMCA is not likely to cause adverse non-cancer health effects in children or adults***.

3.4.5.2 Cancer Effects Evaluation

Chloride is an essential nutrient and is not considered to be carcinogenic.

3.4.6 Copper:

Copper was detected in water samples from 22 of 46 residential wells near the Pearce Creek DMCA at concentrations ranging from 0.05 to 2.39 mg/L. In 16 of the 22 wells, the copper concentration exceeded the ATSDR health-based child intermediate CV (0.1 mg/L). The detected concentration exceeded the EPA drinking water action level (AL) of 1.3 mg/L in one well.

3.4.6.1 Non-cancer Effects Evaluation

Copper is a naturally occurring element found in soil and water. It is an essential nutrient required for good health. However, exposure to high doses of copper can cause nausea, vomiting, stomach cramps, or diarrhea. Ingestion of very high levels of copper can cause liver damage in individuals with Wilson's disease, idiopathic copper toxicosis (ICT), and children with Indian childhood cirrhosis (ICC) (ATSDR 2004c).

The greatest potential source of copper exposure is through drinking water, especially in water that is first drawn in the morning after sitting in copper piping and brass faucets overnight.

The estimated exposure dose from consuming residential well water with the highest detected copper concentration (2.39 mg/L) is 0.342 mg/kg-day for children (birth to 1 yr. old) and 0.0925 mg/kg-day for adults. These copper doses exceed the ATSDR MRL for intermediate exposures (14 to 365 days) of 0.0001 mg/kg-d.

The intermediate MRL was based on the results of a 2003 study by Araya *et al*. of gastrointestinal effects in men and women ingesting copper sulfate in drinking water for 2 months. The MRL was derived from the reported NOAEL of 0.042 mg/kg/day for gastrointestinal effects (nausea, vomiting, abdominal pain, or diarrhea.) A LOAEL of 0.091 mg/kg-day for gastrointestinal effects was also reported by the same study (ATSDR 2004c).

For the highest detected well water copper concentration (2.39 mg/L), the estimated child dose (0.342 mg/kg-d) and adult dose (0.0925 mg/kg-d) exceeded both the intermediate NOAEL and LOAEL. The estimated adult doses for the other detected copper concentrations (0.41 mg/L and lower) were below both the intermediate NOAEL and LOAEL. ***Therefore, children and adults who drink water from residential wells near the Pearce Creek DMCA with copper at the highest detected concentration (2.39 mg/L) for 14 days or longer could experience nausea, vomiting, stomach cramps, or diarrhea.***

3.4.6.2 Cancer Effects Evaluation

EPA has not classified copper as a human carcinogen because no adequate human or animal cancer studies are available (ATSDR 2004c).

3.4.7 Fluoride

Fluoride was detected in water samples from 12 of 44 wells near the Pearce Creek DMCA at concentrations ranging from 0.1 to 0.99 mg/. In 4 of the 12 wells, the fluoride concentration exceeded the ATSDR health-based chronic CV for children (0.5 mg/L).

3.4.7.1 Non-cancer Effects Evaluation

Fluorides are naturally-occurring components of rocks and soil. Small amounts of fluorides are found in air, water, plants, and animals. People are exposed to fluoride in drinking water, food, and dental products. In particular, fluorides are frequently added to public drinking water supplies and to toothpastes and mouth rinses to prevent tooth decay. The optimal range of fluoride in drinking water is 0.7 to 1.2 mg/L (ATSDR 2003). In well water, fluoride concentrations generally range from 0.02 to 1.5 mg/L, but often exceed 1.5 mg/L in parts of the U.S. with naturally high fluoride levels. People can also be exposed to fluoride in fruits and vegetables grown in fertilized soil and in food and beverages prepared with fluoridated water (ATSDR 2003).

Small amounts of fluoride are vital for healthy teeth and bone. Excessive long-term, oral intake, however, can result in harmful health effects, including dental fluorosis (discolored or pitted teeth in children who consume excess amounts of fluoride prior to tooth eruption.) Excess intake of fluoride can also cause an increased prevalence of bone fractures, especially hip fractures, in the elderly and skeletal fluorosis. Signs of skeletal fluorosis range from increased bone density to severe deformation, known as crippling skeletal fluorosis. Reported cases of crippling skeletal fluorosis are found almost exclusively in developing countries and are often associated with malnutrition (ATSDR 2003).

The estimated fluoride doses from consuming water with the highest detected fluoride concentration (0.99 mg/L) were 0.141 mg/kg-day for children (birth to 12 months of age) and 0.038 mg/kg-day for adults (over 21 yrs. of age.) The estimated child exposure dose exceeded the ATSDR MRL of 0.05 mg/kg-d. The MRL, however, was based on increased rates of bone fractures in older adults, and, as such, is not applicable to children (ATSDR 2003). In addition, the highest detected fluoride concentration (0.99 mg/L) was lower than (1) EPA's MCL of 4 mg/L, which was established to prevent severe skeletal fluorosis, and (2) EPA's secondary MCL (SMCL) of 2 mg/L to protect against moderate dental fluorosis (discoloration of the tooth enamel) in young children (EPA 2009).

The estimated adult fluoride exposure dose associated with the highest detected concentration (0.99 mg/L) was lower than the ATSDR MRL for protection against increased rates of bone fractures in older adults.

The estimated fluoride child exposure dose associated with the highest detected concentration (0.99 mg/L) exceeded EPA's proposed oral drinking water RfD (0.07 mg/kg-d), but the adult dose was below the proposed RfD. The proposed RfD was developed to protect children against dental fluorosis and adults for skeletal fluorosis and fractures (EPA 2010).

The Institutes of Medicine (IOM) have developed a tolerable upper intake level (UL) of 0.7 mg/d (0.11 mg/kg-d) for young children to protect against development of dental fluorosis. The IOM have also developed a UL of 10 mg/d (0.13 mg/kg-d) for adults based on the risk of developing early signs of skeletal fluorosis (IOM 2006). The estimated fluoride child and adult exposure doses associated with the highest detected concentration (0.99 mg/L) are less than one and a half times their respective ULs.

Because the highest estimated fluoride dose for children is only slightly higher than EPA's proposed RfD and the IOM's UL, and the highest dose for adults is below ATSDR's MRL and EPA's proposed RfD, ***exposure to fluoride in drinking water at the levels found in residential wells near the Pearce Creek DMCA is not expected to cause adverse non-cancer health effects in children or adults.***

3.4.7.2 Cancer Effects Evaluation

Most of the studies of people living in areas with fluoridated water or naturally high levels of fluoride in drinking water have not found any association between fluoride and cancer risk. The weight of evidence indicates that fluoridation of water does not increase the risk of developing cancer. Animal studies were inconclusive as to whether fluoride can cause cancer. The International Agency for Research on Cancer (IARC) has determined that the carcinogenicity of fluoride to humans is not classifiable. (ATSDR 2003.)

3.4.8 Iron:

Iron was detected in water samples from 143 of 187 wells near the Pearce Creek DMCA at concentrations ranging from 0.1 to 298 mg/L. In 83 of the 143 wells, the iron concentration exceeded the EPA SMCL (0.3 mg/L) (EPA 2012).

3.4.8.1 Non-cancer Effects Evaluation

Iron is an essential nutrient which is necessary for the production of heme, a component of hemoglobin, an important blood protein for transporting oxygen in the body. Excess intake of iron, however, may cause gastrointestinal effects including abdominal pain, vomiting, and diarrhea. Long-term excessive intake may lead to heart, pancreas, liver, and kidney damage. Excessive iron accumulation in the body, known as secondary iron overload, can suppress the body's immune system. Secondary iron overload most often occurs in children from taking in too much iron in mineral supplements, in individuals with liver disease who undergo repeated blood transfusions, and in individuals with the liver disease hemochromatosis that increases the rate of iron absorption (EPA 2006, WHO 1996).

The Food and Nutrition Board of the National Research Council has developed a tolerable upper intake level (UL) for iron based on reported gastrointestinal effects from ingestion of iron supplements. The UL for children (birth to 13 yrs. old) and adults is 40 and 45 mg/day, respectively. (IOM 2001).

Drinking water from the residential well with the highest level of iron (298 mg/L) would add approximately 330 mg of iron to an adult's daily diet and approximately 920 mg of iron to a child's (birth to 1 yr. old). These increased intakes of iron greatly exceed the established ULs.

EPA has developed a provisional RfD of 0.7 mg/kg-day based on an LOAEL of 1 mg/kg-day for adverse gastrointestinal effects which are commonly associated with therapeutic use of iron supplements. Clinical studies have shown that adverse gastrointestinal effects are associated with oral iron therapy regardless of the duration of treatment, and the symptom severity does not change over the course of treatment (EPA 2006).

The estimated iron exposure doses associated with the highest detected drinking water concentration (298 mg/L) for children and adults are 43 and 12 mg/kg-d, respectively. These doses greatly exceed EPA's provisional RfD and the LOAEL for adverse gastrointestinal effects. ***Therefore, children and adults who drink water from residential wells near the Pearce Creek DMCA with iron at the highest detected concentration (298 mg/L) could experience nausea, vomiting, stomach cramps, or diarrhea.*** Also, a rare inherited genetic disease called hemochromatosis is associated with iron overload in a small percentage of people. ***Anyone with elevated levels of iron in their well water who are on a reduced-iron diet to treat this condition should consult their health care professional to discuss this additional iron intake***.

3.4.8.2 Cancer Effects Evaluation

Iron is an essential nutrient is not considered to be carcinogenic.

3.4.9 Lead

Lead was detected in water samples from 15 of 45 residential wells near the Pearce Creek DMCA at concentrations ranging from 0.007 to 0.13 mg/L (7 to 130 µg/L). The detected lead concentration in 5 of the 15 wells exceeded the EPA public water supply action level (AL) of 15 µg/L (or 0.015 mg/L) (EPA 2009). Lead in the water samples could have come from lead in the groundwater itself or from lead in the residences' plumbing system.

3.4.9.1 Non-cancer Effects Evaluation

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. Lead and lead alloys are commonly found in pipes, storage batteries for cars and other vehicles, weights, shots and ammunition, and devices to shield X-rays. In the past, lead compounds were used as a pigment in paints, dyes, ceramic glazes, and in caulk. The amount of lead used in these products has been reduced in recent years to minimize lead's harmful effects on people and animals. Prior to 1996, tetraethyl lead and tetramethyl lead were used in the U.S. as gasoline additives. Today, lead can be found throughout the environment because of human activities, including burning fossil fuels, mining, manufacturing, and past uses (ATSDR 2007b).

In general, lead levels in lakes, rivers, and groundwater used to supply the public with drinking water are very low. However, lead can leach into drinking water from leaded pipes and soldered joints found in public drinking water systems and in older houses, apartment buildings, and public buildings.

ATSDR has not developed an MRL for lead because no safe blood lead level in children has been identified. Permanent neurological damage and behavioral disorders have been shown to be associated with blood lead levels at or below 5 micrograms per deciliter (ug/dL). (CDC 2015). In 2012, CDC adopted a reference value based on the 97.5th percentile blood lead level of children (ages 1-5 years) in the U.S. (currently 5 ug/dL) to identify children with elevated blood lead levels (CDC 2012b).

Lead can affect almost every organ and system in the body. The most sensitive target for lead toxicity is the nervous system, especially in children. Elevated blood lead levels in children can result in adverse neurological, behavioral, and developmental effects, including lower intelligence quotient (IQ) scores; problems with visual-motor integration and fine motor skills; problems related to decreased attention, and decreased height and delays in puberty (ATSDR 2007b).

Prenatal exposure of babies to lead from their mother can result in premature birth, reduced birthweight, reduced growth rate, and learning and behavior problems (ATSDR 2007b).

Adults exposed to lead over many years have an increased risk of kidney problems; high blood pressure; heart disease; anemia; weakness in fingers, toes or ankles; and nervous system problems. (ATSDR 2007b).

Lead in drinking water can contribute to a child's blood lead level. Because there is no known safe level of lead in the blood, ATSDR recommends reducing lead exposure wherever possible. Homeowners with lead in their well water can reduce their lead exposure by using a water filtration system to remove lead or by drinking bottled water.

3.4.9.2 Cancer Effects Evaluation

ATSDR has found "no conclusive proof that lead causes cancer in humans" (ATSDR 2007b).

The Department of Health and Human Services (DHHS) has determined that lead and lead compounds are "reasonably anticipated to be human carcinogens" based on limited evidence from studies of humans and sufficient evidence from animal studies. The U.S. EPA classifies lead as a probable carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic lead is probably carcinogenic in humans. The U.S. EPA has not developed a cancer slope factor for lead, so it is not possible to estimate a numerical increased cancer risk from exposure to lead in drinking water.

3.4.10 Manganese:

Manganese was detected in water samples from 156 of 186 residential wells near the Pearce Creek DMCA at concentrations ranging from 0.05 to 378 mg/L. The detected concentrations exceeded the EPA manganese long-term health advisory level (LTHA) of 0.3 mg/L (EPA 2012) in 116 of the 156 wells and exceeded the ATSDR RMEG for children of 0.5 mg/L in 105 of the 156 wells.

ATSDR's evaluation of the potential health effects from exposure to manganese in drinking water from residential wells near the Pearce Creek DMCA can be found in the May 27, 2016, letter health consultation to the Cecil County Health Department. The letter health consultation is included in Appendix D of this report.

3.4.11 Nickel

Nickel was detected in water samples from 59 of 182 residential wells at concentrations ranging from 0.013 to 0.82 mg/L. The detected nickel concentrations exceeded the EPA LTHA (0.1 mg/L) in 42 of the 59 wells and exceeded the ATSDR RMEG for children (0.2 mg/L) in 23 of the 59 wells.

3.4.11.1 Non-cancer Effects Evaluation

Nickel is a very hard metal that occurs naturally in soil. Background levels in soil vary widely depending on local geology, but typically range between 4 and 80 parts per million (ppm). Nickel concentrations in surface water and groundwater usually range from 0.003 to 0.010 mg/L (3 to 10 µg/L). Nickel levels in drinking water in the U.S. generally range from 0.00055 to 0.025 mg/L (0.55 to 25 µg/L) and average between 0.002 and 0.0043 mg/L (2 and 4.3 µg/L) (ATSR 2005a).

The estimated nickel dose from consuming water with the highest nickel concentration detected (0.82 mg/L) was 0.117 mg/kg-day for children (birth to 12 months of age) and 0.0317 mg/kg-day for adults (over 21 yrs. of age.) The estimated child and adult doses exceeded the EPA RfD (0.02 mg/kg-d). The highest estimated nickel exposure doses for children and adults were more than 400 and 1,500 times lower, respectively than the LOAEL (50 mg/kg-day) and more than 40 to 150 times lower, respectively, than the NOAEL (5 mg/kg-d)***. Therefore, exposure to nickel in drinking water at the levels found in residential wells near the Pearce Creek DMCA is not expected to cause adverse non-cancer health effects in children or adults.***

3.4.11.2 Cancer Effects Evaluation

Oral exposure to nickel is not known to cause cancer. ATSDR's toxicological profile for cancer (1) found no studies regarding cancer in humans after oral exposure to nickel or its compounds, and (2) states that oral exposure to nickel has not been found to cause cancer in animals.

Inhalation exposure to nickel is believed to cause cancer in humans; however, inhalation of nickel in drinking water from residential wells near the Pearce Creek DMCA is not an exposure pathway of concern.

3.4.12 Sodium:

Sodium was detected in 178 of 178 residential wells near the Pearce Creek DMCA at concentrations ranging from 2.2 to 1,413 mg/L. The detected concentrations exceeded EPA's guidance level of 20 mg/L for individuals restricted to a total sodium intake of 500 mg/day in 143 of the 178 wells (EPA 2003a).

Sodium is a naturally occurring element found in water and soil. It is an essential nutrient which is needed for proper muscle and nerve function and for maintenance of body fluids. It is also is involved in regulating blood pressure.

The average sodium intake for individuals aged 2 years and older living in the U.S is more than 3,400 mg per day. The largest source of sodium intake is from consumption of sodium chloride (salt) in processed food and food served in restaurants.

The "Dietary Guidelines for Americans 2010" issued by the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (DHHS) recommend limiting sodium intake to less than 2,300 mg per day. Individuals 51 years and older, African-Americans, and those who have high blood pressure, diabetes or chronic kidney disease should limit their sodium intake to less than 1,500 mg per day (USDA 2010). An estimated 75% of adults in the U.S. exceed the recommended daily sodium intake.

High levels of sodium intake can lead to elevated blood pressure which is a known risk factor for heart and kidney disease. The Food and Nutrition Board of the National Research Council has developed a tolerable upper intake level (UL) of 1,500 mg/day for young children (1 to 3 years old) and 2,300 mg/day for most adults. (IOM 2005)

3.4.12.1 Non-Cancer Effects Evaluation

A child (age 1 to 3 yrs. old) and an adult drinking well water with the highest detected sodium concentration (1,413 mg/L) would consume about 1,300 and 4,400 mg of sodium per day, respectively. For children, the sodium intake from the water by itself would not exceed the child UL (1,500 mg/day). For adults, however, the sodium intake from the water by itself would exceed the USDA recommended sodium intake limit for most adults (2,300 mg/d) and the sodium intake limit for sodium-sensitive persons, including individuals 51 years and older, African-Americans, and those who have high blood pressure, diabetes or chronic kidney disease (USDA 2010).

Since many adults exceed the USDA recommended daily sodium intakes from their diet alone, residential well users in the Pearce Creek area, especially those who are sodium sensitive, should monitor the amount of sodium in their well water. Individuals with concerns about their sodium intake should talk to their health care provider.

3.4.12.2 Cancer Effects Evaluation

Sodium is an essential nutrient and is not considered to be carcinogenic.

3.4.13 Sulfate

Sulfate was detected in 157 of 175 residential wells near the Pearce Creek DMCA at concentrations ranging from 2.9 to 3,500 mg/L. The detected sulfate concentrations exceeded the EPA SMCL (250 mg/L) in 58 of the 157 wells.

3.4.13.1 Non-Cancer Effects Evaluation

Sulfate is a naturally occurring substance and is present in air, minerals, soils, water, plants, and food. Sulfate is present in surface water and groundwater at widely varying concentrations. The highest concentrations, however, are usually found in groundwater. Sulfate concentrations greater than 500 mg/L have been found in some well waters in rural areas of the U.S. The sulfate concentrations in about 95% of public water supplies are less than 500 mg/L (EPA 2003b).

High concentrations of sulfate in drinking water can cause laxative effects such as increased stool mass, increased stool volume, increased stool moisture, decreased intestinal transit time, or osmotic diarrhea. The effects generally occur at sulfate concentrations greater than 500 mg/L to 1000 mg/L, depending on whether other osmotically-active substances, such as magnesium sulfate, are present. Osmotic diarrhea is of particular concern for children due to the increased risk of dehydration (IOM 2005).

In February 2003, EPA's Office of Water issued a drinking water advisory for sulfate which recommended (1) reducing sulfate concentrations to below 250 mg/L – the EPA Secondary Drinking Water Standard – to prevent taste problems, and (2) a health-based advisory value of 500 mg/L to protect against acute laxative effects (EPA 2003b).

Sulfate was detected at concentrations exceeding 500 mg/L in 41 of 175 residential wells near the Pearce Creek DMCA. ***Adults and children drinking water from residential wells with sulfate concentrations greater than 500 mg/L could experience short-term laxative effects such as increased stool mass, volume, and moisture; decreased intestinal transit time; and possibly diarrhea.***

3.4.13.2 Cancer Effects Evaluation

Sulfate is a required nutrient and is not known to be carcinogenic.

3.4.14 Zinc

Zinc was detected in water samples from 127 of 170 residential wells near the Pearce Creek DMCA at concentrations ranging from 0.05 to 6.03 mg/L. In 4 of the 127 wells, the zinc concentration exceeded the ATSDR child intermediate CV (3 mg/L). The detected concentrations exceeded the EPA MCL (5 mg/L) in one well only.

3.4.14.1 Non-Cancer Effects Evaluation

Zinc is an essential nutrient for proper growth and development. Excess intake of zinc, however, may cause adverse health effects including acute gastrointestinal effects and nausea, impaired immune function, changes in lipoprotein and cholesterol levels, and reduced copper status (leading to early copper deficiency) (ATSDR 2005b).

The estimated exposure dose from consuming residential well water with the highest detected zinc concentration (6.03 mg/L) is 0.860 mg/kg-day for children and 0.233 mg/kg-day for adults. The adult dose is lower than both ATSDR's intermediate MRL and EPA's RfD. The child dose, however, exceeds the ATSDR MRL and EPA RfD.

The ATSDR intermediate MRL was based on a study of adult women by Yadrick et. al. (1989) that found a significant decrease in erythrocyte superoxide dismutase (ESOD) levels, a precursor event to the more severe symptoms seen with zinc-induced copper deficiency. The MRL was derived from the reported NOAEL of 0.83 mg/kg-day (ATSDR 2005b). The estimated exposure dose for adults (0.233 mg/kg-d) from consuming residential well water with the highest detected zinc concentration does not exceed the NOAEL.

The EPA RfD for zinc (0.3 mg/kg-d) was based on a LOAEL of 0.91 mg/kg-day for reduced copper status and decreases in ESOD activity in healthy adult women. The estimated exposure dose for adults (0.233 mg/kg-d) from consuming residential well water with the highest detected zinc concentration does not exceed the LOAEL.

The ATSDR MRL and EPA RfD are based on adverse health effects in adult women, and, therefore, do apply to children.

The Food and Nutrition Board of the National Research Council has developed tolerable upper intake levels (ULs) for zinc based on the adverse effect of zinc on copper metabolism (i.e., reduced copper status.) The UL for children (0-6 months old) is 4 mg/d (or 0.7 mg/kg-d). The estimated exposure dose for children (0.86 mg/kg-d) from consuming residential well water with the highest detected zinc concentration is only slightly (1.2 times) higher than the child UL (IOM 2006).

According to ATSDR's Toxicological Profile for Zinc (p. 5), the zinc intake levels that cause adverse health effects are much higher (approximately 10-15 times) than the Recommended Daily Allowance (RDA). For older children (7-12 months old), the RDA is 3 mg/d (or about 0.33 mg/kg-d), so the intake level necessary to cause adverse health effects would be about 3 to 5 mg/kg-day (ATSDR 2005c). These intake levels are significantly higher than 0.86 mg/kg-day estimated exposure dose for children from consuming residential well water with the highest detected zinc concentration.

Because the highest estimated zinc dose for adults is lower than ATSDR's MRL and EPA's RfD, exposure to zinc in drinking water at the levels found in residential wells near the Pearce Creek DMCA is not likely to cause adverse noncancer health effects in adults. Likewise, exposure to zinc is not likely

to cause adverse non-cancer health effects in children because the highest estimated exposure dose for children is significantly lower than levels reported to harm children's health.

3.4.14.2 Cancer Effects Evaluation

Zinc is an essential nutrient and is not known to cause cancer.

3.4.15 Radiation (Alpha and Beta Particle Activity)

Drinking water samples collected by the Cecil County Health Department in 2013 were analyzed for general radioactivity —gross alpha particle activity (GAPA) and gross beta particle activity (GBPA).

GAPA was detected in water samples from 115 of 155 residential wells at concentrations ranging from 2 to 109.7 picocuries per liter (pCi/L). The detected GAPA concentrations in 46 of the 115 wells exceeded the EPA MCL of 15 pCi/L. GAPA includes radium, but does not include radon or uranium (EPA 2001).

GBPA was detected in water samples from 79 of 114 residential wells at concentrations ranging from 4 to 53.3 pCi/L. The detected GBPA concentrations in 79 of the 114 wells exceeded the EPA MCL of 50 pCi/L (EPA 2001).

Exposure to radiation over many years is associated with an increased risk of cancer (EPA 2001). GAPA and GBPA measurements are intended to provide information on the presence of radiation in drinking water, not to identify the specific contaminants (radionuclides). To assess the potential increased risk from exposure to radiation, the concentrations of the individual radionuclides are required. ***Because sampling data for individual radionuclides are not available, ATSDR cannot estimate the potential cancer risk from exposure to radiation in drinking water from residential wells near the Pearce Creek DMCA.***

3.4.16 Chemical Mixtures (Interactions)

Potential health effects from exposure to environmental contaminants are usually evaluated on a chemical-by-chemical basis. Because exposure often involves a mixture of chemicals, it is important to consider potential toxicological interactions (or joint toxic action) of the chemicals that make up the mixture. These interactions are generally classified as additive, greater than additive, or less than additive.

If the chemicals in the mixture act in an additive manner, the harmful effects of the chemical mixture would be the same as the sum of the effects of the individual contaminants. Mathematically, the additive nature of chemical interactions is often presented as 2 + 3 = 5.

Sometimes, a mixture of chemicals acts in a greater than additive manner, which is referred to as a synergistic effect or synergism. When two chemicals interact synergistically, one chemical enhances the effect of the other chemical. Mathematically, a chemical mixture with a synergistic effect is often presented as 2 + 3 = 8 (or 6 or 12, depending upon the strength of the synergistic effect between the two chemicals).

A chemical mixture that acts in a less than additive manner is referred to as an antagonistic effect, or antagonism. In this case, one of the chemicals reduces or protects against the effect of the other chemical. An antagonistic effect might be presented mathematically as 2 + 3 = 4.

Relatively few studies have been conducted to assess potential toxic interactions at environmentally-relevant (i.e., low) doses of chemicals. A series of important studies on the toxicity of low dose chemical mixtures was conducted by the TNO Nutritional and Food Research Institute in the Netherlands (Jonker et al. 1990; Jonker et al. 1993). In these experiments, rats were dosed with mixtures of four chemicals at doses below their individual no observed adverse effect level (NOAEL), at their NOAEL, and at their lowest observed effect level (LOAEL). The results of these experiments indicated that there was no discernable toxic response until the dose levels of the individual chemicals approached or exceeded their individual adverse effect threshold (LOAEL). However, when the chemicals were administered at their individual LOAEL doses, there was clear evidence of additive toxic effects.

The results of other studies, however, indicate that exposure to mixtures of chemicals that affect the same target organs, when the chemicals are administered at doses close to their individual threshold (LOAEL) can produce additive toxic effects. For example, rats exposed to a mixture of subthreshold doses of 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene experienced signs of liver toxicity (Stacey 1989). In an oral feeding study, rats dosed with cadmium and lead (at doses that did not significantly affect hemoglobin and hematocrit levels when given individually) had significant decreases in hemoglobin and hematocrit levels when these doses were given together (Mahaffey and Fowler 1977). A series of studies initiated by the NIEHS on a mixture of 25 groundwater contaminants from hazardous waste sites indicated that toxic effects can result from long-term exposure to contaminant mixtures in which each of the contaminants are present at subthreshold doses (Yang 1994).

ATSDR's evaluation of exposures to individual contaminants in drinking water from residential wells in the Pearce Creek DMCA area indicated that exposures to some of the contaminants may cause harmful non-cancer health effects because the doses are close to or above the contaminant's effect (threshold) level. The non-cancer health effects associated with these chemicals are

- skin conditions in children and adults (arsenic),
- kidney damage in children and adults (cadmium),
- gastrointestinal issues in children and adults (copper, iron, and sulfate), and
- neurological, behavioral, or neurodevelopmental effects in children (aluminum, lead, and manganese) and neurological effects in adults (aluminum and manganese).

ATSDR has developed a number of interaction profiles for chemical mixtures frequently addressed in ATSDR's public health evaluations. The purpose of an interaction profile is to evaluate data on the toxicology of the "whole" priority mixture (if available) and on the joint toxic action of the chemicals in the mixture. The joint toxic actions include additivity, antagonism, synergy, and other interactions. These documents commonly use a weight-of-evidence approach to evaluate the influence of interactions on the overall toxicity of the mixture. The weight-of evidence evaluations are qualitative in nature, although ATSDR recognizes that observations of toxicological interactions depend greatly on exposure doses and that some interactions appear to have thresholds.

Two of ATSDR's Interaction Profiles —Arsenic, Cadmium, Chromium, Lead (May 2004) and Lead, Manganese, Zinc, and Copper (May 2004) — address some of contaminants of concern, namely arsenic, cadmium, copper, lead, and manganese, in residential wells near the Pearce Creek DMCA. These two profiles, however, do not include interaction information for the other contaminants of concern — aluminum, iron, and sulfate.

Copper, as well as iron, has been shown to impede the gastrointestinal absorption of lead, which may reduce the toxicity of the lead co-exposure. Co-exposure of cadmium and lead has been shown to result in an antagonistic response (i.e., resulting in an effect less than what would be expected from lead exposures alone) while a potentiating interaction of lead on arsenic neurological effects has been reported (although, based on our evaluation, neurological effects are not expected from exposure to arsenic alone). Co-exposure of manganese and lead resulted in an increased concentration and retention of lead in the brain of rats and adversely affected cognitive function in an additive manner in these rats (Pohl et al. 2010). These results are somewhat conflicting regarding the possibility of enhanced or reduced mixtures effects on the nervous system. The likelihood of mixtures effects would depend on the specific mixture and concentration of these chemicals in the given residential well. Moreover, ATSDR could not find any information on the possible gastrointestinal mixtures effect related to co-exposures to iron, copper, and sulfate. Without compelling evidence of reduced or enhanced neurological effects from co-exposures to arsenic, lead, and manganese or gastrointestinal effects from co-exposures to iron, copper, and sulfate, ATSDR, by default, assumes the health risks are additive (that is, neither enhanced nor reduced). Therefore, people exposed to mixtures of contaminants in drinking water from residential wells near the Pearce Creek DMCA that effect similar target organs (manganese, lead, and, aluminum for neurological effects and copper, sulfate, and iron for gastrointestinal effects) may have a greater risk of harmful effects than the risk that would be he expected from exposure to any of these contaminants individually.

3.5 Community Health Concerns

Some residents in the Pearce Creek area have expressed concern about elevated levels of contaminants in their well water.

On May 28, 2016, representatives from ATSDR's Region 3 office attended a public meeting in Chesapeake City, MD, hosted by MDE, MPA, USACE, and the Cecil County Health Department. During the meeting, ATSDR's representatives answered questions from residents about possible health hazards from exposure to manganese in drinking water from residential wells and discussed steps residents could take to reduce their potential exposure, such as using bottled water for drinking or cooking.

At the meeting, MDE announced that MPA and USACE would provide bottle water to residents in the Pearce Creek DMCA area starting immediately, and continuing until their homes are connected to the Town of Cecilton municipal water system.

These actions by ATSDR, the Cecil County Health Department, MPA, USACE, MDE, and USACE have helped address many of the residents' health concerns. ATSDR will continue to work with the Cecil County Health Department, MDHMH, and other public health partners, and community members to address health concerns about exposure to contaminants in area residential wells.

3.6 Assumptions/Limitations

Limitations associated with ATSDR's public health evaluation of contaminants in drinking water from residential wells near the Pearce Creek DMCA include the following:

- Sampling data is not available for approximately 90 of the estimated 235 residential water supply wells near the Pearce Creek DMCA. Contaminant concentrations in some of those wells may be greater than the highest concentrations detected in the wells sampled by the Cecil County Health Department.
- ATSDR conservatively based its evaluation of exposures on the highest contaminant concentration detected in all wells sampled because (1) the number of samples collected from individual wells was insufficient to calculate valid average contaminant concentrations and (2) the detected contaminant concentrations vary widely from well to well and from sample to sample. The maximum detected contaminant concentrations may not accurately represent the average, long-term concentrations in these wells.
- ATSDR used contaminant concentrations detected in treated and untreated well water samples from residential wells near the Pearce Creek DMCA for estimating drinking water exposure doses because some residences do not have a water treatment system and may drink untreated well water. In addition, available information about well water treatment systems at individual residences is limited, such as how long the system has been in operation, how well the system is maintained, or how efficient the system is at removing individual chemicals.
- In estimating drinking water exposures doses, ATSDR's assumed that all residents lived in the area year round (365 days per year). These estimated doses for year-round residents are higher than the doses for part-time or seasonal residents, that is, residents who live in the area for only part of the year.

4 Conclusions

After evaluating contaminant concentrations detected in residential well water samples collected by the Cecil County Health Department from 1987 through 2013, ATSDR reached the following conclusions:

1. **Drinking <u>untreated</u> well water from residential wells near the Pearce Creek DMCA could harm people's health.**

   Estimated exposures to aluminum, arsenic, cadmium, copper, iron, lead, manganese, sodium, and sulfate at the concentrations found in untreated drinking water from some residential wells were above levels that could harm people's health. Potential harmful health effects from exposure to those chemicals are listed below.

   - Aluminum: Neurological or neurodevelopmental effects in children and adults drinking untreated water for 14 days or longer.
   - Arsenic: Skin thickening or discoloration in children and adults drinking water for a year or longer, and low increased risk of cancer after drinking untreated water for many years.
   - Cadmium: Kidney damage (i.e., increased urinary levels of low molecular proteins) in children and adults drinking untreated water for a year or longer.
   - Copper: Nausea, vomiting, stomach cramps, or diarrhea in children and adults drinking untreated water for 14 days or longer.
   - Iron: Nausea, vomiting, stomach cramps, or diarrhea in children and adults drinking untreated water for any length of time.
   - Lead: Lead was detected in water samples from a number of residential wells. Exposure to lead in drinking water can increase a child's blood lead level. Elevated blood lead levels in children are associated with adverse neurological, behavioral, and developmental effects. Because there is no known safe level of lead in the blood of children, ATSDR recommends reducing lead exposure wherever possible.
   - Manganese: Harmful neurological effects in children and adults drinking untreated water for a year or longer.
   - Sulfate: Short-term laxative effects such as increased stool mass, volume, and moisture; decreased intestinal transit time; and possibly diarrhea in children and adults drinking untreated water for any length of time.

2. **The levels of some contaminants, especially sodium, in <u>treated</u> drinking water from some residential wells could also harm people's health.**

   Water treatment systems used by many residents were generally effective at reducing contaminants to below levels of health concern. However, treatment systems at some residences failed to remove contaminants sufficiently. In addition, the use of sodium chloride salt in ion exchange water treatment units significantly increased the sodium levels in the treated water at some residences.

Sodium intake from treated water at some residences exceeded the recommended intake limit for sodium-sensitive persons, including older adults (51 years and older), African American, and individuals with high blood pressure, diabetes or chronic kidney disease. High levels of sodium intake can lead to elevated blood pressure which is a known risk factor for heart and kidney disease.

Aluminum and arsenic were also present at levels that could harm people's health in some treated well water samples.

3. **Individuals exposed to mixtures of contaminants that affect the same target organ systems (for example, manganese, lead, and aluminum for neurological effects; and copper, sulfate, and iron for gastrointestinal effects) in drinking water from some residential wells near the Pearce Creek DMCA may have a greater risk of harmful effects than the risk that would be expected from exposure to any of these contaminants individually.**

ATSDR's evaluation of exposures to individual contaminants in drinking water from residential wells in the Pearce Creek DMCA area indicated that combined exposures to some contaminants may cause harmful non-cancer health effects. The potential harmful effects and associated contaminants are

- gastrointestinal problems in children and adults (copper, iron, and sulfate), and
- neurological, behavioral, or neurodevelopmental effects in children (aluminum, lead, and manganese) and neurological effects in adults (aluminum and manganese).

Scientific studies are somewhat conflicting on the possibility of enhanced or reduced mixtures effects on the nervous system from co-exposure to aluminum, lead, manganese, or other contaminants found in drinking water from residential wells near the Pearce Creek DMCA. The likelihood of mixtures effects would depend on the specific mix and concentration of these chemicals in a given well. In addition, ATSDR could not find any information on possible gastrointestinal mixtures effects related to co-exposures to iron, copper, and sulfate. Without compelling evidence of reduced or enhanced neurological effects from co-exposures to arsenic, lead, and manganese or gastrointestinal effects from co-exposures to iron, copper, and sulfate, ATSDR, by default, assumes the health risks are additive.

4. **Drinking well water containing beryllium, fluoride, nickel, or zinc from residential wells near the Pearce Creek DMCA is not expected to harm people's health.**

Estimated exposures to these substances in drinking water from residential wells were below levels known to harm people's health.

5. **ATSDR cannot determine whether exposure to radiation from naturally-occurring radioactive substances in untreated drinking water from residential wells near the Pearce Creek DMCA could harm people's health.**

Gross alpha particle activity (GAPA) and gross beta particle activity (GBPA) exceeded their respective MCLs in water samples from some residential wells. However, the concentrations of individual radioactive substances were not reported. Without that information, ATSDR cannot estimate the potential cancer risk from exposure to radiation in drinking water from residential wells near the Pearce Creek DMCA.

5 Recommendations

- ATSDR supports extension of the Town of Cecilton municipal water system to residents near the Pearce Creak DMCA who currently depend on well water for their household water needs.
- Until their homes are connected to the Cecilton municipal water system, ATSDR recommends that residents continue to use bottled water for drinking and cooking. Note: Since May 28, 2016, bottled water has been provided to areas residents by MPA and USACE. Residents will continue to receive bottled water until their homes are connected to the municipal water system.
- ATSDR recommends that residents who choose to continue using well water for drinking and cooking (1) use an appropriate treatment system to treat their well water, (2) properly maintain the treatment system; and (3) have the treated water tested regularly to ensure that it meets established drinking water standards.

6 Public Health Action Plan

- Completed Actions
    - ATSDR evaluated the potential health effects from exposure to manganese in drinking water from residential wells near the Pearce Creek DMCA in a May 27, 2016, letter health consultation to the Cecil County Health Department. In the report, ATSDR concluded that children and adults who drank water from some residential wells with elevated levels of manganese for many years could experience adverse neurological effects. ATSDR recommended that until their homes are connected to the municipal water system, residents with private wells (1) use bottled water or treated well water from an appropriate and properly maintained water treatment system; and (2) have their treated well water tested regularly. ATSDR also expressed support for efforts to provide bottled water to residents and inform residents about the elevated manganese levels in many area wells.
    - On May 28, 2016, representatives from ATSDR’s Region 3 office attended a public meeting hosted by MDE, MPA, USACE, and the Cecil County Health Department. During the meeting, ATSDR’s representatives answered questions from residents about possible health hazards from exposure to manganese in drinking water from residential wells and discussed steps residents could take to reduce their potential exposure, such as using bottled water for drinking or cooking

- Current/Future Actions
    - ATSDR will share this report with appropriate local, state, and federal agencies (including the Cecil County Health Department, MDE, MPA, and USACE).
    - ATSDR will continue to work with the Cecil County Health Department, MDHMH, and other public health partners to increase awareness of potential health hazards from exposure to contaminants in area drinking residential wells.

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8 Report Preparation

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Appendix A: Figures

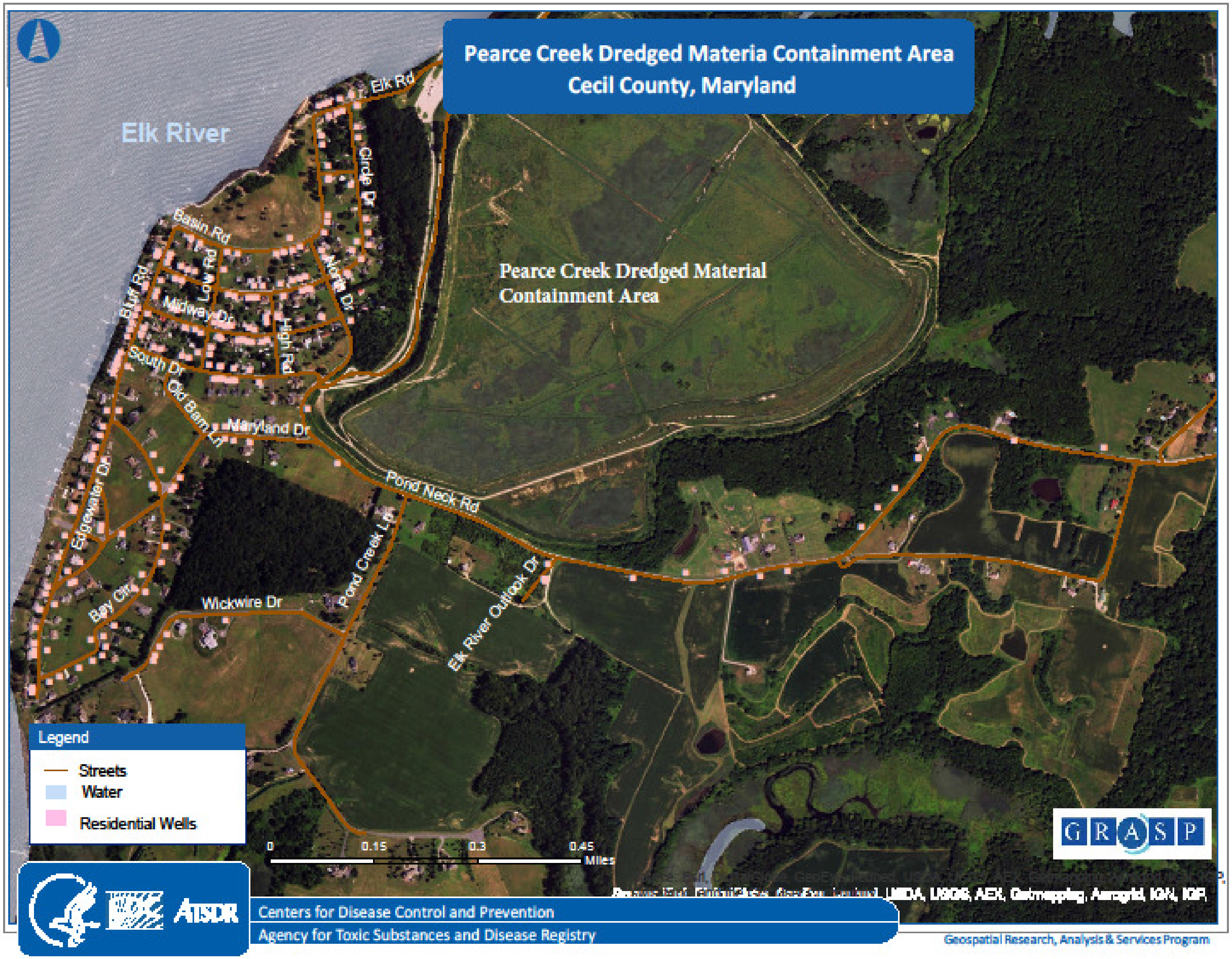

Figure 1. Location of Pearce Creek Dredged Material Containment Area (DMCA) and Nearby Residential Water Supply Wells

PRJ ID 04798 | AUTHOR: J. Anderson

Appendix B: Overview of ATSDR's Evaluation Process

The process that ATSDR uses to evaluate potential health effects from exposure to environmental contaminants is described below.

I. Screening Environmental Data

ATSDR conducts a screening analysis of environmental data by comparing contaminant concentrations to appropriate comparison values (CVs). CVs are chemical and media-specific concentrations in air, soil, and drinking water that are used to identify environmental contaminants that require further evaluation. Health-based CVs, such as ATSDR's environmental media evaluation guideline (EMEGs) and reference dose media evaluation guide (RMEGs), represent estimated contaminant levels in soil, water, or air that people could be exposed to on a daily basis and not experience harmful health effects.

If the maximum concentration of a contaminant is below an applicable health-based CV, exposure to the contaminant is not expected to harm human health and it is excluded from further evaluation. If the maximum concentration of a contaminant exceeds an applicable health-based CV, the contaminant is designated as a contaminant of potential concern (COPC) and is retained for a more detailed, site-specific evaluation.

CVs can be based on either carcinogenic or non-carcinogenic health effects. ATSDR's CVs for non-cancer effects are derived from ATSDR' Minimal Risk Levels (MRLs) or the U.S. Environmental Protection Agency's (EPA's) Reference Doses (RfDs). ATSDR's cancer–based CVs are calculated from EPA's Oral Cancer Slope Factor (CSF).

When a cancer and non-cancer CV exit for the same chemical, the lower of these values is used in the environmental data comparison to be conservative (protective of public health).

The following health-based CVs were used in ATSDR's assessment of contaminants in drinking water from residential wells near the Pearce Creek DMCA.

- **Reference Media Evaluation Guides (RMEGs**) are estimated contaminant concentrations in a media where noncancer health effects are unlikely. RMEGs are derived from EPA's reference dose (RfDs).
- **Environmental Media Evaluation Guides (EMEGs**) are concentrations of contaminants in water, soil, or air unlikely to produce any appreciable risk of adverse, non-cancer effects over a specified duration of exposure. EMEGs are derived from ATSDR minimal risk levels (MRLs) factoring in default body weights and ingestion rates. ATSDR computes separate EMEGs for acute (≤14 days), intermediate (15–364 days), and chronic (>365 days) exposures.

- **Cancer Risk Evaluation Guides (CREGs)** are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in one million persons exposed over a lifetime. CREGs are calculated from U.S. Environmental Protection Agency (EPA) cancer slope factors (CSFs).
- **Maximum Contaminant Levels (MCLs)** are enforceable standards set by EPA for the highest level of a contaminant allowed in drinking water. MCLs are set as close to MCL goals (MCLGs, the level of a contaminant in drinking water below which there is no known or expected risk to health) as feasible using the best available treatment technology and taking cost into consideration.

ATSDR also used the following **non** health-based CVs to screen contaminants in residential wells near the Pearce Creek DMCA.

- **Secondary Maximum Contaminant Levels (SMCLs)** are EPA non-enforceable water quality guidelines criteria for contaminants in drinking that may cause (1) aesthetic effects (undesirable tastes, odors, or color), (2) cosmetic effects (such as skin or tooth discoloration), (3) technical effects (damage to water equipment or reduced effectiveness of treatment for other contaminants).

II. Evaluating Health Effects

Contaminants identified as COPCs, that is contaminants whose maximum concentrations exceeded an applicable comparison value (CV), are further evaluated to determine whether site-specific exposures to the contaminants may be a public health hazard (that is, may cause adverse health effects).

ATSDR calculates exposure doses to estimate the amount of the contaminant that gets into a person's body. The exposure dose is typically expressed as milligrams of contaminant per kg of body weight per day (mg/kg-day).

The equations and exposure assumptions used to estimate drinking water exposure doses and example calculations are provided in Appendix C.

A. <u>How non-cancer health effects are evaluated</u>

After calculating estimated exposure doses for COPCs, ATSDR compares the doses to appropriate health guidelines. Health guidelines are protective of health and developed for both noncarcinogenic and carcinogenic health effects.

Health guidelines for noncarcinogenic effects are derived from human or experimental animal data and modified, if necessary, by a series of "uncertainty" (safety) factors to ensure that the guidelines are set as levels well below levels that could cause adverse health effects. Health guidelines for ingestion exposures are expressed in mg/kg-day.

ATSDR used the following health guidelines in evaluating adverse, non-cancer health effects from ingestion of contaminants in drinking water from residential wells near the Pearce Creek DMCA:

- **Minimal Risk Level (MRLs) – Developed by ATSDR**

  An ATSDR minimal risk level (MRL) is an estimate of daily human exposure to substance that is likely to be without a measurable risk of harmful (adverse), non-cancerous health effects for a specified exposure duration. MRLs for oral (ingestion) exposure are units of mg/kg-day)

- **Reference Doses (RfDs) – Developed by EPA**

  An EPA reference dose (RfD) is an estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that in unlikely to cause harm in humans. RfDs are in units of mg/kg-day.

If the estimated exposure dose for a chemical is less than an applicable health guideline, the exposure is unlikely to cause non-cancer health effects. If the exposure dose is greater than the health guideline, the exposure dose is compared to substance-specific toxicological values, such as observed adverse effect levels. These toxicological values are derived from human and animal studies that are summarized in ATSDR's Toxicological Profiles and EPA's Integrated Risk Information System (IRIS). **Comparing site-specific exposure doses to doses shown in toxicological studies to cause adverse health effects is the primary basis for determining whether the exposures are likely to harm human health.**

B. <u>How cancer risks are evaluated</u>

The estimated cancer risk from exposure to known cancer-causing contaminants is calculated by multiplying the estimated contaminant exposure dose by the contaminant's EPA cancer slope factor (CSF). The calculated risk value is often referred to as the "excess" or "increased" population cancer risk because it represents the possible risk over and above the existing background cancer risk in a population. In the U.S., the background cancer risk is approximately 1 in 2 (45%) for men and 1 in 3 (39%) for women.

An estimated increased cancer risk from lifetime exposure to a carcinogenic contaminant of 1×10^{-6}, for example, represents the possibility of one additional (or "excess") cancer case in a population of one million. A "one-in-a-million" risk is generally regarded as an insignificant increased risk.

The estimated increased cancer risk is a conservative, "worst case" risk. The actual (true) increased risk is unknown, but may be significantly lower, perhaps by several orders of magnitude.

The equations and exposure assumptions used to estimate increased cancer risks and example calculations are provided in Appendix C.

Appendix C: Exposure Dose and Cancer Risk Calculations

As discussed in Appendix B, ATSDR estimated drinking water ingestion doses for each contaminant of potential concern (COPC), that is, each contaminant detected at concentrations greater than an applicable comparison value (CV), in water samples from residential wells near the Pearce Creek DMCA.

For **non-cancer** health effects, ATSDR calculated drinking water ingestion doses for two groups: (1) adults and (2) children less than 12 months of age (because children in this age group typically have the highest drinking water exposure doses.) Drinking water ingestion exposure doses are expressed in units of milligrams per kilogram per day (mg/kg-day).

For **cancer** health effects, ATSDR calculated estimated cancer risks for adults only.

Estimated drinking water exposure doses are expressed in units of milligrams per kilogram per day (mg/kg-day).

- Equation for estimating **non-cancer exposure doses** from ingestion of contaminants in drinking water:

  D = (C x IR x EF) / BW

  Where,

  D = exposure dose (mg/kg-day)
  C = contaminant concentration (mg/L)
  IR = drinking water ingestion rate (L/day)
  BW = body weight (kg)
  EF = exposure factor (unitless) = (F x ED) / (AT x 365 days/yr.)
  F = exposure frequency (days/yr.)
  ED = exposure duration (yrs.)
  AT = averaging time (yrs. x 365 days/yr.) = ED (yrs. x 365 days/yr.) for non-cancer health effects

The exposure parameter values used to calculate non-cancer exposure doses are shown in Table C-1.

Example non-cancer, drinking water exposure dose calculation for a child (birth to 12 months) exposed daily to aluminum at a concentration of 345 mg/L:

D = (C x IR x EF) /BW = (CR x IR x F x ED) / (AT x BW) = CR x IR / BW
= (345 mg/L x 1.113 L/day) / 7.8 kg
= 49.3 mg/kg-day

Table C-1: Exposure Parameter Values for Estimating Drinking Water Ingestion Doses

Exposure Parameter	Children (birth to 1 yr.)	Adults (21 yrs. & older)
Drinking Water Ingestion Rate (IR) (L/day)	1.11	3.09
Exposure Frequency (F) (days/yr.)	365	365
Exposure Duration (ED) (yrs.)	1	33*
Averaging Time (AT) (yrs. x 365 days/yr.) For non-cancer effects: For cancer effects:	 1 NA	 33* 78†
Body Weight (BW) (kg)	7.8	80
*95th percentile residential occupancy period (yrs.) †Average life expectancy (yrs.) **Reference**: ATSDR 2014.		

- Equation for estimating **increased cancer risk** from ingestion of carcinogenic contaminants in drinking water:

Increased Cancer Risk = D x CSF = (C x IR x EF) x CSF / BW = (C x IR x F x ED) x CSF / (BW x AT)

Where,

D = exposure dose (mg/kg-day)
CSF = cancer slope factor $(mg/kg/day)^{-1}$
C = contaminant concentration (mg/L)
IR = drinking water ingestion rate (L/day)
BW = body weight (kg)
EF = exposure factor (unitless) = (F x ED) / AT
F = exposure frequency (days/yr.)
ED = exposure duration (yrs.)
AT = averaging time (days x 365 days/yr.)

The exposure parameter values used to calculate increased cancer risk are shown in Table C-1.

Example cancer risk calculation for an adult exposed daily to arsenic in drinking at a concentration of 0.058 mg/L for 33 years (CSF for arsenic = 1.5 $(mg/kg\text{-}day)^{-1}$):

Estimated increased cancer risk = (C x IR x F x ED) x CSF / (AT x BW)
= (0.058 mg/L x 3.09 L/day x 365 days/yr. x 33 yrs.) x 1.5 $(mg/kg\text{-}day)^{-1}$ / (80 kg x 78 yrs. x 365 days/yr.)
= 1.4×10^{-3} (or 14 in 10,000)

Appendix D: ATSDR Letter Health Consultation for Manganese (May 27, 2016)

Letter Health Consultation

Earleville Private Groundwater Well Quality

PEARCE CREEK DREDGED MATERIAL CONTAINMENT AREA (DMCA)

CECIL COUNTY, MARYLAND

MAY 27, 2016

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.

LETTER HEALTH CONSULTATION

Earleville Private Groundwater Well Quality

PEARCE CREEK DREDGED MATERIAL CONTAINMENT AREA (DMCA)

CECIL COUNTY, MARYLAND

Prepared By:

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

Agency for Toxic Substances and Disease Registry
Region 3
1650 Arch Street, 3HS00
Philadelphia, PA 19103

May 27, 2016

Frederick C von Staden
Director, Environmental Health
Cecil County Health Department
401 Bow Street
Elkton, MD 21921

Dear Mr. von Staden,

You requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate levels of metals found in residential drinking water wells near the Pearce Creek Dredged Material Containment Area (DMCA) site in Cecil County, Maryland. ATSDR found that some of the levels of manganese detected in private wells in this area could be of public health concern. We are providing this letter to document and explain the scientific basis of our understanding of the public health implications of exposure to manganese in groundwater in the Pearce Creek site area of Cecil County. We also provide recommendations about how to reduce or eliminate exposure. ATSDR will follow up this letter with a full health consultation report containing a comprehensive review of all the chemicals detected in private water wells in this area. As discussed, ATSDR supports all the involved agencies in their actions to (1) inform the public about high levels of metals in private well water; (2) provide public water to private well users in this area of Cecil County, and (3) offer bottled water to these private well users until public water is available.

Manganese is a naturally occurring substance found in many types of rock, soil, groundwater, and food. Several studies have found that mean levels of manganese in public drinking water range from 4 micrograms per liter (ug/L) to 32 ug/L. As reported in the ATSDR Toxicological Profile for Manganese, analyses of the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) database indicate that the median concentration of manganese was 16 ug/L for surface water and 5 ug/L for groundwater from 20 watersheds and 16 drainage basins in the United States.[1] Regional groundwater quality issues have been identified in the Delmarva Peninsula, which includes the Pearce Creek site area. For example, a USGS report on historical background water quality of the Delmarva Peninsula identified naturally occurring water-quality problems throughout the surficial aquifer in this region, including elevated iron and manganese concentrations and low pH. Additionally, many of the wells in the Delmarva Peninsula did not meet the drinking-water standard or criterion for hardness and nitrate.[2]

ATSDR reviewed the data you provided on treated and untreated water from private drinking water wells in the Pearce Creek area sampled from 1987-2013. The reported manganese water concentrations ranged from less than 50 to 378,000 ug/L. There is variability reported in the manganese levels in the same

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[1] Agency for Toxic Substances and Disease Registry (ATSDR). 2012. Toxicological profile for Manganese. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=102&tid=23.
[2] United States Geological Survey (USGS). 1991. Water-Quality Assessment of the Delmarva Peninsula, Delaware, Maryland, and Virginia Analysis of Available Ground-Water-Quality Data Through 1987. Available at: http://pubs.usgs.gov/wsp/2355b/report.pdf.

private wells sampled over time and across the group of private wells sampled in this site area. There are both seasonal and full time residents in this area, which raises uncertainty about exposure durations.

Many of these residential wells (approximately 155) had manganese levels in excess of the EPA secondary maximum contaminant level (SMCL) for manganese in public drinking water supplies of 50 μg/L. ATSDR does not consider exposures to manganese levels at or below the SMCL a public health concern. The manganese SMCL is based on aesthetic water quality parameters and is not a health-based level. Black to brown colored water, black staining, and a bitter metallic taste will be the noticeable effects when manganese levels exceed 50 μg/L.[3] Despite these noticeable water quality effects, studies show that people do drink water containing manganese at levels well above 50 ug/L either because they become accustomed to it and/or they do not have alternative drinking water sources available to them.

The EPA Lifetime Health Advisory (LTHA) for manganese in drinking water is 300 ug/L. According to EPA, this level represents a concentration that is not likely to cause harmful effects over a lifetime of exposure.[4] ATSDR used EPA's LTHA level as a preliminary health-based screening value for the levels of manganese detected in the Pearce Creek area private water wells. The reported concentration of manganese exceeded the EPA LTHA in approximately 115 of the residential wells sampled from 1987 through 2013.

Manganese exposure at an average concentration 793 ug/L has been shown to be associated with reduced full-scale, performance, and verbal raw scores in children in Bangladesh who consumed drinking water with high levels of manganese for 10 years.[5] In a more recent study, Wasserman et al. (2011) reported that manganese exposures >500 ug/L (mean of 725 ug/L) resulted in lower perceptual reasoning and working memory scores after 8 years or more of exposure.[6] Compared to adults, infants and children have higher intestinal absorption of manganese, as well as lower biliary excretion of manganese. Thus, children are especially susceptible to any negative neurotoxic effects of manganese.

For this site-specific evaluation, ATSDR used the scientific literature to develop a Lowest Observed Adverse Effect Level (LOAEL) of 0.07 mg/kg/day to compare with the estimated exposure doses for manganese in drinking water in the Pearce Creek site area. We then used this information to generate a summary table of protective public health recommendations for private well water users for your consideration (see Table 1). ATSDR calculated exposure doses for several age groups (infants, children, adults) to develop these recommendations using age-specific maximum intake assumptions. Although some residents only live in the site area on a seasonal basis, to develop our site-specific recommendations and exposure doses we conservatively assumed that people were drinking the water every day over many years. We summarized the toxicological studies we used to select the 0.07 mg/kg/day LOAEL in Table 2. The three studies investigating manganese exposure in children with neurological endpoints in Table 2 had estimated LOAELs ranging from 0.06 to 0.08 mg/kg/day. ATSDR selected the mid-range LOAEL to use in this evaluation. Based on our evaluation of the available sampling information for private wells

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[3] Environmental Protection Agency (EPA). 2012. Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals. Available at: http://water.epa.gov/drink/contaminants/secondarystandards.cfm

[4] Environmental Protection Agency (EPA) 2012. 2012 Edition of the Drinking Water Standards and Health Advisories. Available at: https://www.epa.gov/dwstandardsregulations/drinking-water-contaminant-human-health-effects-information.

[5] Wasserman GA, Liu X, Parvez F, et al. Water manganese exposure and children's intellectual function in Araihazar, Bangladesh. Environ Health Perspect. 2006;114(1):124-129.

[6] Wasserman, G. A., Liu, X., Parvez, F., Factor-Litvak, P., Ahsan, H., Levy, D., … Graziano, J. H. (2011). Arsenic and manganese exposure and children's intellectual function. Neurotoxicology, 32(4), 450–457.

from this site area, ATSDR concludes that there may be neurological health concerns for infants and children consuming water with elevated levels of manganese on a daily basis over many years.

Conclusion and Recommendations:

Based on our initial review of manganese concentrations detected in residential wells near the Pearce Creek DMCA site, some private wells have manganese levels of public health concern, particularly for infants and children. ATSDR supports extension of the Cecilton municipal water system to residents near the Pearce Creek DMCA who currently depend on well water for their household water needs, and the provision of bottled water until public water is available. We also note that several other inorganics, including aluminum, iron, sodium, and sulfate, are also present at high levels in some wells; we will evaluate these substances further in our full health consultation to follow.

Until homes in the site area are connected to the municipal water system, ATSDR recommends that:

- All private well owners, wherever they live, test their drinking water on a regular basis.[7]
- Private well users with manganese levels at 300 ug/L or less conduct routine private water well monitoring, including analyses for manganese.
- Private well users with manganese levels at 300 ug/L to 500 ug/L have infants (birth to 1 year) use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
- Private well users with manganese levels exceeding 500 ug/L have infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
- Private well users with manganese levels exceeding 1,000 ug/L use bottled water or appropriate and properly maintained water treatment system with bi-annual water quality monitoring.

If you have any additional questions, feel free to contact me.

Sincerely,

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cc: Dr. Sharon Williams-Fleetwood, ATSDR
Dr. Clifford Mitchell, Maryland Department of Health and Mental Hygiene
Mark Mank. Maryland Department of the Environment

[7] Centers for Disease Control and Prevention. Drinking Water. Private Wells. Well Testing. Available online at: http://www.cdc.gov/healthywater/drinking/private/wells/testing.html.

Table 1: General Pearce Creek Public Health Recommendations for Manganese in Drinking Water Summary Table*

Manganese (ug/L)	Recommendation
300 ug/L or less	Routine private water well monitoring, including analyses for manganese.
300 ug/L to 500 ug/L	Infants (birth to 1 year) use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>500 ug/L	Infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>1,000 ug/L	All age groups use bottled water or appropriate and properly maintained water treatment system with bi-annual water quality monitoring.

Table 2: Summary of Manganese Drinking Water Studies with Neurological Endpoints Used in the Selection of a LOAEL (mg/kg/day) for Evaluation Purposes

LOAEL	Reference	Population	Exposure Duration (yrs)	Endpoint
0.06	Kondakis 1989[8]	Adult	50	Neurological
0.06	Woolf 2002[9]	Children	5	Neurological
0.07	Wasserman 2006	Children	10	Neurological
0.08	Wasserman 2011	Children	8+	Neurological

[8] Kondakis XG, Makris N, Leotsinidis M, Prinou M, Papapetropoulos T. Possible health effects of high manganese concentration in drinking water. Arch Environ Health. 1989;44(3):175-178.

[9] Woolf, A., Wright, R., Amarasiriwardena, C., & Bellinger, D. (2002). A child with chronic manganese exposure from drinking water. Environmental Health Perspectives, 110(6), 613–616.