

WATER QUALITY IMPACTS FROM LEAKING COAL ASH PONDS AT TWO
SUPERFUND SITES

by
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ABSTRACT

Coal is a fossil fuel used worldwide for energy production. Although coal is a plentiful and cost-efficient source of energy, the by-product of coal production, coal ash, poses environmental and human health risks. My analysis involved the identification and comparison of concentrations of thallium, manganese, and arsenic contamination at two Superfund managed sites that experienced a leak of coal ash ponds. I also examined the potential role that public awareness and risk management approaches undertaken at each site to contain the effect of the contamination may have played in mitigating the extent of the risk impacts. The Kingston Tennessee Valley Authority (TVA) coal ash spill received national media coverage and occurred over a large visible area in a relatively short time frame (December 2008 – December 2014). In contrast, the coal ash spill at Town of Pines received limited media attention and occurred slowly over many years (April 2000 – present). As a result, the spill remained unknown to many residents in neighboring counties. To investigate the efficacy of the implemented mitigation measures, I compared both the risk management approach to containing the spills, and the contaminant concentrations (arsenic, manganese, and thallium) at each site over time. Overall, the TVA coal ash spill received a relatively fast, intensive containment, reflected by contaminant values reduced to below EPA threshold levels within a matter of months. The visible extent of the spill was shared extensively by the media. Conversely, my analysis of the Town of Pines spill, which remained unknown to residents and received limited media attention, highlighted that although concentration values have decreased over a 15-year timeframe, some concentrations remain at harmful levels. The results of my study demonstrate the influence of public awareness and subsequent community pressure on the timeliness of remediation measures and reduction of overall environmental and human health risks from coal ash spills.

INTRODUCTION

In this study, I will examine and compare two Superfund managed sites, the Kingston Fossil Plant in Roane County, Tennessee (operated by the Tennessee Valley Authority ‘TVA’) and the Town of Pines in Indiana. Each site experienced a leak or spill of their coal ash ponds. Coal ash ponds are designed to safely store coal ash, produced as a result of burning coal to make electricity, by adding water to the ash to ensure it does not blow away (Connors 2015). The TVA coal ash spill received national media coverage and occurred over a large visible area in a short timeframe. The leak at the second site, Town of Pines, occurred slowly underground and received limited attention. As a result, the Town of Pines spill remained unknown to many residents in neighboring counties. In order to investigate the efficacy of mitigation measures, I will examine and compare both the risk management approach to containing each spill, and the concentrations of contaminants (arsenic, thallium, and manganese), over time at each site.

Contamination from coal ash ponds may result from inadequate maintenance policies and a historical limited awareness of the leaching capabilities of coal ash. Current remediation efforts heavily focus on site clean-up and conversion to EPA-approved (Environmental Protection Agency) lined ponds. Scientific literature suggests media attention and public awareness of such spills also play a key role in influencing the cost and effort directed toward mitigation measures for coal ash spills. A New Zealand study revealed that spills that were perceived negatively in the media resulted in greater interest from the public, and an overall more ‘effective’ spill response (Chilvers et al. 2016). It is also important to note that such media

attention and public awareness, as with many forms of compliance breaches, may not be welcomed or promoted by the companies that have committed the breaches.

Two key objectives of my study are to (1) determine the key pollutants contained in coal ash, and (2) assess the environmental and human health impacts from the coal ash pollutants. Based on the comparison of the pollutant concentrations at each site, the analysis will enable a determination of the risk management method most effective for remediating a coal ash pond. A driving imperative of this study is to examine the mitigation measures most effective at minimizing environmental and human health harm resulting from coal ash. Consequently, the outcomes of this study can inform proper risk management measures for the continued use of coal fired power plants.

BACKGROUND

Coal Ash

Coal is the most commonly used fossil fuel in the world (World Coal Association 2019). Compared to oil, natural gas, and sources of green energy, coal is also the most affordable source of energy for consumers in terms of power plants that have already been built (Weise 2019). The burning of coal releases gases and particulates that are harmful to the environment, with the primary being carbon dioxide (Turgeon 2012). These gases and particulates are a major contributor to global warming, with coal production being responsible for 79% of the United States' carbon emissions (Turgeon 2012). The process of transforming coal to electricity occurs at coal-fired power plants, including the formation of coal ash as a byproduct of this transformation (Figure 1). Coal ash, also known as fly ash, is a very fine powder which is suspended in the air before filtration with electrostatic precipitators or filter fabric baghouses (EPA 1996). Coal ash is formed from the combustion of pulverized coal. This very fine powder is primarily made up of elements such as lead, arsenic, mercury, cadmium, and uranium (Munawer 2018).

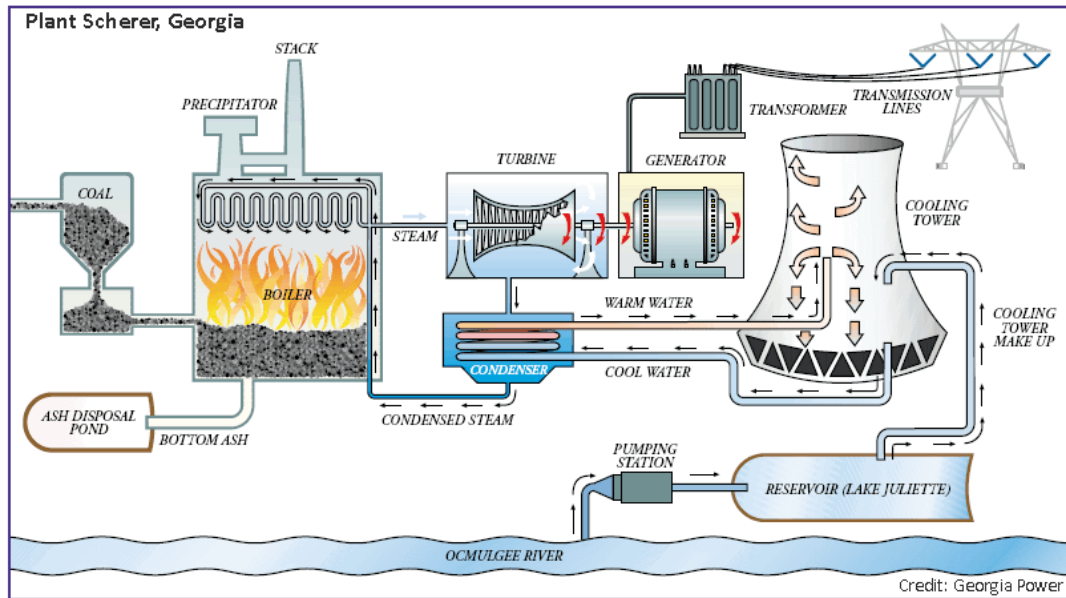


Figure 1: The Process of Creating Electricity in a Coal Fired Power Plant (USGS)

Storage of Coal Ash

Following filtration, the majority of coal ash is stored in surface impoundments or wet ash ponds, with the remaining portion often recycled or put into landfills (EPA 2018). Dry storage of coal ash comprises moving the coal ash into a landfill (EPA 2018). Wet storage of coal ash involves adding water into the coal ash to ensure it does not blow away, then placing the mixture into a surface impoundment (Stenhouse et al 2019). The creation and management of surface impoundments serve to minimize potential human health and environmental risk of exposure to pollutants in coal ash (EPA 2015). Unlined coal ash ponds and poorly maintained coal ash ponds can cause these contaminants to leak into groundwater or flood into local rivers and waterways (Verma et al 2016). Consuming contaminated well water increases the risk of developing cancer, lung disease, kidney disease, gastrointestinal illness, and also negatively affects the nervous system (Smith et al 2013). As of 2012, approximately 48% of the coal ash ponds in the US are lined, with a majority responsible for contaminating nearby drinking water sources (Connors 2015).

Arsenic, manganese, and thallium are the primary pollutants found in coal ash and have been known to contaminate groundwater as a result of coal ash spills. Each of these contaminants can originate from either human-made or natural sources. Arsenic can enter groundwater from several sources, such as industrial activities, pesticides, industrial waste, and via natural processes (USGS 2020). Manganese occurs naturally as a mineral from sediment and rocks, and also originates from industrial waste (USGS 2020). Thallium enters groundwater from soils, but predominantly through waste from pharmaceutical manufacturing, glass, and alloys (USGS 2020).

Superfund Sites

The Superfund program was created by the US federal government in 1980 to manage uncontrolled hazardous waste sites (EPA 1990). The overall strategy of Superfund is described as *“Making sites safe, making sites clean, and bringing technology to bear on the problem – removing contamination from the environment”* (EPA 1990). Contamination may occur in surface waters and in soils, or into underground groundwater pathways that many rely on for drinking water. The toxic waste at Superfund sites can include heavy metals, solvents, organics, pesticides and radioactive wastes (EPA 1990). The process of completing a Superfund site assessment includes an evaluation of potential or confirmed releases of hazardous substances that can pose a threat to the environment or human health (Figure 2) (Superfund Site Assessment Process 2018). There are more than 1,300 sites on the National Priorities List (NPL), and 400 sites have been removed following satisfactory remediation (EPA 2018).

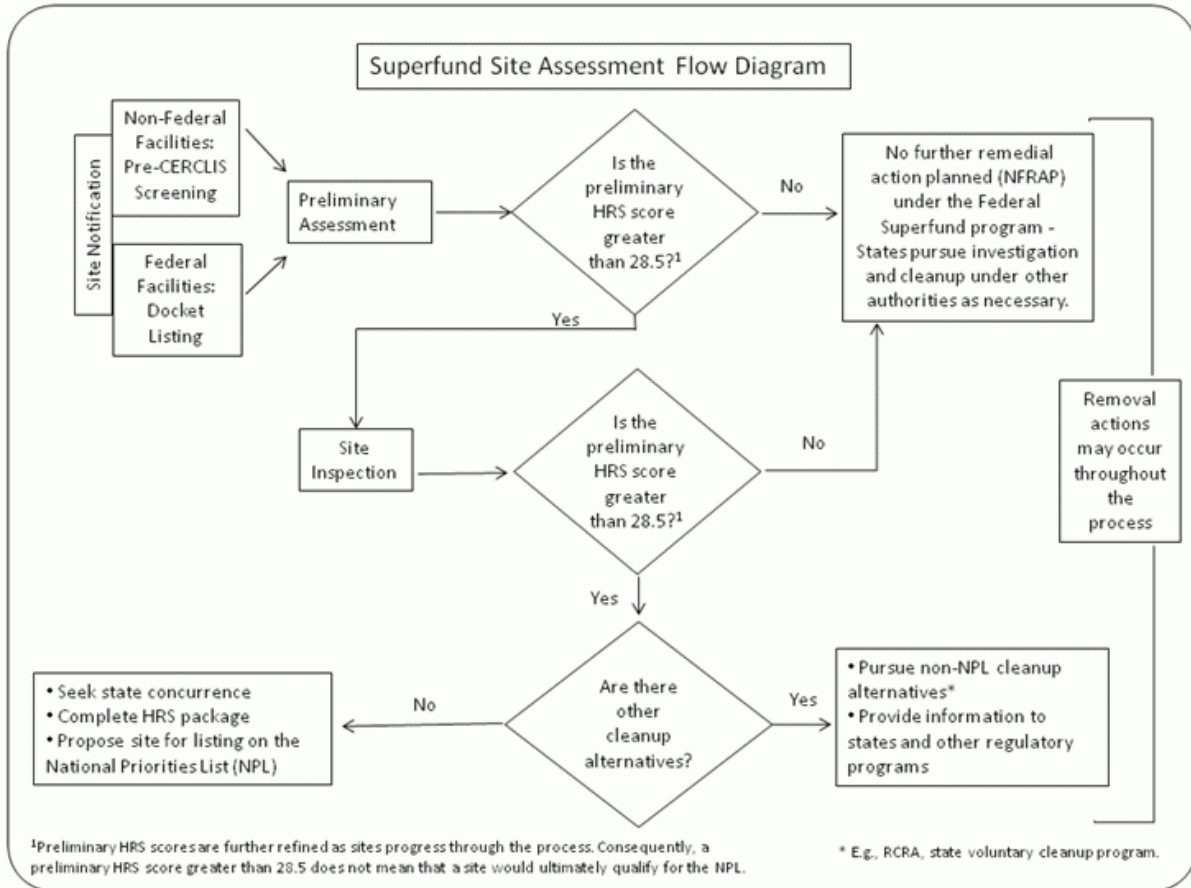


Figure 2: The Process of Completing a Superfund Site Assessment, Displayed in a Flow Diagram (EPA 2018)

Site 1: Kingston Tennessee Valley Authority (TVA)

In the early morning hours of December 22, 2008, the retention wall of a coal ash pond failed at the Tennessee Valley Authority Fossil Plant in Roane County, Tennessee (EPA 2010). The result of this catastrophic failure was a payload of 327 million gallons of water mixed with 5.4 million cubic yards of coal ash flooding into the Emory River. The Emory River joins the Clinch River before converging with the Tennessee River, which is a major source of drinking water for Tennessee Valley residents (Ruhl et al. 2010). The spill reached approximately 300 acres outside of the storage and coal ash dewatering areas.

The Kingston TVA coal ash spill is considered one of the largest environmental disasters in the history of the US (EPA 2010). Although this was a catastrophic environmental pollution event, the site was never listed as a Superfund site, but was managed as though it were one by the EPA. Following the TVA spill, the EPA developed the *Coal Ash Surface Impoundment Integrity Assessment Program* (2018). This project was driven by EPA findings that improperly constructed or managed coal ash disposal sites were linked to cases of human health impairment as a result of exposure to contaminated surface or groundwater. An important outcome of the severity of the TVA disaster was the EPA's consequential evaluation of the condition and safety of coal ash ponds across the country (EPA 2018).

Site 2: Town of Pines Superfund Site

The second site I examined in this study involved the leaking of coal ash ponds, owned by the Northern Indiana Public Service Company (NIPSCO), into groundwater in the Town of Pines, Indiana. NIPSCO had disposed coal ash into surface impoundments in the Town of Pines, at a site called Yard 520 (EPA 2016) from the early 1980s to the early 2000s. Between the years 2000 and 2003, homeowners reported a 'bad taste' in their private well water and lodged complaints with the Indiana Department of Environmental Management (IDEM) and the EPA (EPA 2016). The homeowners' private wells were tested several times with elevated levels of benzene, arsenic, and manganese, among other contaminants considered common pollutants in coal ash, detected (EPA 2002). It was later determined that the elevated concentrations were derived from Yard 520. Yard 520 was subsequently turned into a Superfund site (IDEM 2000) and remediation efforts are ongoing.

The Town of Pines has approximately 800 residents and is located 2 miles south of Lake Michigan, and 2 miles south of Michigan City (Figure 4) (EPA 2002). The specific area of

concern known as Yard 520, is a small nondescript parcel of land along U.S. Highway 12, measuring approximately 2.24 square miles (Figure 5, 6). As 100% of the Town of Pines' residents obtain their drinking water from private wells, the potential contamination from the leaking coal ash ponds prompted the Superfund designation (EPA 2016).



Figure 3: TVA Fossil Plant location (see red arrow) and the Emory and Clinch Rivers (Rozwara 2020)

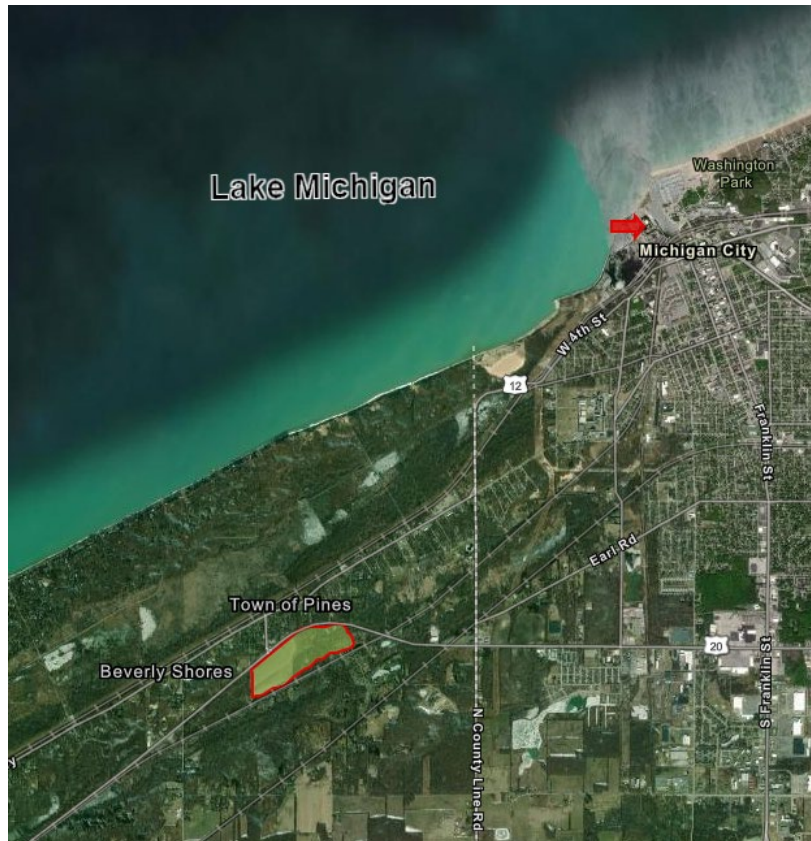


Figure 4: The Town of Pines Superfund site location (red outlined, green area), and NIPSCO Michigan City Power Plant at the Red Arrow (Rozwara 2020)



Figure 5: Yard 520 Lies Along U.S. Highway 12 (Rozwara 2020)



Figure 6: Yard 520, an Unassuming, Unmarked Superfund Site (Rozwara 2020)

Differences in Detection and Public Notification of the Spills Across Sites

The EPA recognizes that ‘community engagement’ is essential to the success for Superfund clean-ups, stating that “community members need to be involved in all phases of the cleanup so that the contamination is addressed in a way that protects people and the environment” (EPA 2013). Although both the TVA and Town of Pines sites involve instances of significant water pollution due to coal ash spills, there are contrasts in the detection, public notification, and community involvement in the management of the spills. These differences are important to consider, particularly as they relate to the impact on the overall result of the contamination and cleanup.

Site 1: Town of Pines

Town of Pines involves a slow leaching of coal ash into the groundwater that serves as drinking water for the town's residents. The leaching happened over several years preceding the year 2000. It was initially only detected by those residents located within the watershed of the plant who used private well water in early 2000. Once residents began to realize their well water had a foul taste, they penned several complaints to IDEM's Drinking Water Section (IDEM 2002). This led to IDEM sampling and resampling residents' wells over the period of one month. As the samples indicated the presence of volatile organic compounds, IDEM then contacted the EPA to investigate the site. At this point, except for those residents who noticed the foul-tasting water from their wells, the public was largely unaware of the spill (EPA 2013). The EPA's subsequent investigation led to the determination of Superfund site status. Once the area was deemed a superfund site, town meetings were held to explain what was going on with the site, but still the media attention and public awareness stayed confined to within the boundaries of the small town. As mentioned earlier, the superfund site itself, shown above in Figure 5 and 6, is a nondescript, unnamed spot of land on the side of a highway.

Site 2: TVA

On the other hand, TVA comprised a catastrophic spill of coal ash into surface waters of the Emory River, in a matter of minutes, and was clearly visible to any bystanders (Figure 7). Within minutes of the spill occurring, both TVA officials and emergency management agencies were on the scene to assist those residents who were likely to be affected by the spread of the coal ash. As the media coverage was extensive, including receiving nationwide media attention, the spill was very difficult to ignore. Due to these differences, public awareness by local

residents at the two sites varied. TVA was at the forefront of environmental news, while the Town of Pines was hidden behind the scenes.



Figure 7: Aerial View of the Coal Ash Spill at the Tennessee Valley Authority's Kingston Power Plant, indicating extent and visible nature of the spill (Sturgis 2014)

Mitigation Measures at Each Site

The TVA and Town of Pines sites are subject to different containment and risk management measures. The following outlines the specific management approach taken at each site from the initial spill through to present day.

Town of Pines: The most recent update at the Town of Pines Superfund site was in September of 2016 and was addressed in a document entitled “Record of Decision – Town of Pines Groundwater Plume” (EPA 2016). The selected groundwater remediation plan involves conducting phytoremediation in one particular area of groundwater contamination, and long-term groundwater monitoring. In addition, the installation of private drinking water wells has been banned on specific properties, or within a designed groundwater management area via a restrictive ordinance and/or environmental covenants (*CERCLA ID #INN000508071*). The coal company involved, NIPSCO, is making additional systematic changes in the coming years. NIPSCO (which is owned by NiSource), has documented plans to remove coal ash material from the Michigan City plants onsite ponds, in compliance with the Coal Combustion Residuals (CCR) rule, and replace it with clean fill to improve groundwater quality (NIPSCO 2020). Approximately 26,000 cubic yards is slated for reuse, while the remaining 144,000 cubic yards are to be transported to an Indiana Department of Environmental Management (IDEM) approved lined landfill at another plant in Wheatfield, IN (Colias-Pete 2020). Furthermore, NIPSCO plans to retire 100% of their remaining coal-fired generation by 2028 (R.M Schahfer Generating Station by 2023 and Michigan City Generating Station by 2028), and transition to cleaner energy sources such as wind, solar, and battery-storage technology (NIPSCO 2020).

TVA: As mentioned above, although the TVA spill site was not declared an official Superfund managed site, it was managed by the EPA as though it had this status. While the

Town of Pines remediation efforts are ongoing, the TVA remediation process was finalized in 2015. The clean-up of the TVA Site was divided into three distinct phases using time and non-time critical removal action authority (EPA 2014). The first phase (completed in 2010) was an 18-month time-critical removal action that included the mechanical excavation, hydraulic dredging, rapid materials handling and disposal of 3.5 million cubic yards of ash from the Emory River. The second phase (conducted between May 2010 – December 2014) was a non-time critical removal action that included a mechanical excavation of approximately 2.3 million cubic yards of ash in the north and middle Swan Pond Embayment's of Watts Bar Reservoir. The third and final phase (completed in December 2014) was also a non-time critical removal action that involved a comprehensive human health and ecological risk assessment of the approximately 500,000 cubic yards of ash that was not removed from the Emory River.

Although the TVA remediation is considered complete, mitigation measures are still being undertaken, with continuous monitoring of the river system and groundwater to ensure contamination risk remains low. Overall, this project cost \$1,178,000,000 and took a total of 6,700,000-person hours to complete (EPA 2014). Following this, an ecological restoration was completed, and several recreation enhancements were added to the area. The restoration included 5 miles of restored shoreline, 2 miles of revegetated shoreline, more than 70 acres of wetlands/native vegetation restored, and 3.5 miles of walking trails completed (Figure 8).



Figure 8: Images of the Coal Ash Spill at the Tennessee Valley Authority's Kingston Power Plant Before (December 2008) and After (December 2014) Clean-Up and Restoration (EPA 2014)

METHODS AND ANALYTICAL APPROACH

Summary

I undertook an analysis of the concentration values for coal ash pollutants (from groundwater samples for Town of Pines and surface water samples for TVA) to measure any differences over time. This analysis included data measured at the time of each initial incident, and also at a later date (unique for each site) following the initial spill/leak. At the initial scan, concentrations of manganese, arsenic, and thallium were identified and compared against regulatory thresholds for drinking water corresponding to those particular contaminants. Following this first step, the second set of concentration data (obtained in the period spanning months to years after each initial incident) was also examined to determine the extent of any increase or decrease over the years, and a comparison of those concentrations to regulatory thresholds.

In addition, my analysis also comprised a screening-level human health risk assessment for manganese levels at the Town of Pines. As discussed in further detail below, although it is recognized that contaminated groundwater is unlikely to be consumed directly without first undergoing any form of treatment, the evaluation was considered valuable to provide an indication of potential risk for those residents with sub-standard home water treatment systems.

Determination of Harmful Pollutants in Coal Ash

Although the mixture of chemicals in coal ash blends is commonly tailored according to the particular reuse purpose, there are certain chemicals that are consistently contained in each

blend (ACAA 2019). The three chemicals, or hazards, focused on in this analysis include arsenic, manganese, and thallium.

Arsenic is a naturally occurring element that comes in two forms, pure arsenic and inorganic arsenic (EPA 1994). Pure arsenic, a grey colored metal, is not detected in coal ash, whereas inorganic arsenic, arsenic combined with other elements, is generally detected in coal ash. Coal ash generally comprises combining arsenic with either oxygen, chlorine, sulfur, carbon, or hydrogen, to develop inorganic arsenic. It is produced primarily as a by-product of the burning of fossil fuels. As arsenic is ubiquitous throughout the environment, all individuals are exposed to low levels of arsenic, such as through cigarette smoke (EPA 1994).

Risks to human health from arsenic exposure vary based on the route of exposure, as well as the type of arsenic encountered. Organic arsenic is typically less toxic than inorganic arsenic (EPA 1994). Arsenic commonly enters the body through ingestion of food or water, but it can also enter through inhalation or dermally. Most arsenic that is ingested is quickly absorbed through the stomach and intestines and enters the blood stream from there, converted by the liver to a less toxic form and excreted in urine. Arsenic does not normally accumulate in the body except at high exposure levels, and large doses of inorganic arsenic can be fatal (EPA 1994). Long-term exposure to inorganic arsenic can increase the risk of bladder or lung cancer, liver damage, neurotoxicity, and Alzheimer's disease (Kravchenko and Lyerly 2018).

Manganese is a naturally occurring element found in air, soil, and water (EPA 2016). Approximately 0.1% of the Earth's crust consists of manganese. Though manganese is naturally occurring in soil, human activity is primarily the source of manganese contamination in water as it is used in the manufacturing of iron and steel alloys. Manganese is an essential nutrient for humans and other animals. However, chronic exposure to high doses may be harmful.

Manganese predominantly affects the central nervous system, with neurological effects generally observed, such as the disabling syndrome known as “manganism” (EPA 2016). Symptoms of manganism include weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless “mask-like” facial expression, and slow clumsy movement of the limbs.

Thallium is a soft, bluish-white metal that is widely distributed in trace amounts throughout the Earth’s crust (U.S. Public Health Service 1992). In its pure form, thallium is odorless and tasteless. As a metal, it persists in the environment and does not break down into simpler substances (U.S. Public Health Service 1992). Thallium was used in rat poison until 1972, when it was determined to also be harmful to humans. Exposure to thallium can occur via inhalation, food, and water ingestion. Large amounts of thallium ingested in a short amount of time can affect the nervous system, lungs, heart, liver, and kidneys (U.S. Public Health Service 1992). Longer-term exposure to thallium includes symptoms such as paresthesia, numbness of toes and fingers, the “burning feet” phenomenon, and muscle cramps.

Thresholds – Drinking Water Source and Private Well Water Usage

A key part of my analysis involved comparing the concentrations of samples detected at the sites, with established regulatory thresholds for those contaminants to assess the potential exposure risk posed by the substances. The EPA’s Maximum Contaminant Level (MCL) for drinking water contaminants was used as the exposure threshold for this analysis. MCLs are standards that are set by the US EPA for drinking water quality, defining the legal threshold limit of the amount of a substance allowed in public water systems under the Safe Drinking Water Act (SDWA) (EPA 2020). Highlighted below are the MCLs for arsenic, thallium and manganese (Table 1). The principle behind the establishment of MCLs is to ensure drinking water sources do not contain harmful levels of contaminants that can pose human health risks from

consumption at levels exceeding the threshold. As described above, the spill at the TVA site occurred into surface water, and samples were taken from surface water points. It is recognized that although the surface waters involved are an upstream drinking water source for residents of that community, drinking water treatment occurs prior to consumption by residents. However, the rivers impacted by the TVA site are also heavily used for recreation.

The prolific reliance on private well water in the Town of Pines, and the lack of MCLs for private well water are important to consider. The samples for the Town of Pines spill were obtained from private wells. According to the EPA, private well owners are responsible for the safety of their own water (EPA 2020). Furthermore, the EPA does not regulate private well water use, nor provide any standards or criteria for drinking water quality (EPA 2020). The contamination of groundwater in the Town of Pines, the direct source of 100% of residents drinking water from private wells, also provides an interesting point of comparison between the two sites in terms of concentrations detected and mitigation measures implemented.

Table 1: The U.S EPA Drinking Level Threshold Values for Thallium, Arsenic, and Manganese (EPA 2020).

Contaminant	EPA Maximum Contaminant Levels (MCL) - Drinking Level Threshold (mg/L)
Thallium	0.002
Arsenic	0.01
Manganese	0.05

Contaminant Concentration Data

For the Kingston TVA Coal Ash Spill site, the initial sampling occurred over several days following the incident on December 22, 2008, and the final sampling was undertaken on April 22, 2009. The EPA conducted the first set of sampling, while the Tennessee Department of Health conducted the second set of sampling. For the Town of Pines site, the initial sampling occurred in September 2000, and the final sampling was undertaken over May 6-8, 2015. The Indiana Department of Environmental Management conducted the first set of sampling, while the EPA conducted the second set of sampling.

Table 2: Average concentrations (mg/L) of Thallium and Arsenic from 22 site samples from the TVA Site (from 2008 and 2009)(EPA 2009, Tennessee Department of Health 2010).

	Thallium 2008	Thallium 2009	Arsenic 2008	Arsenic 2009
Average Concentration (mg/L)	0.02	0.00022	0.05	0.00098

Table 3: Average concentrations (mg/L) of Arsenic and Manganese from fifty-five sites in two documents from the Town of Pines Site (from 2000 and 2015) (IDEM 2000, EPA 2015).

	Arsenic 2000	Arsenic 2015	Manganese 2000	Manganese 2015
Average Concentration (mg/L)	94.3	207.5	902.9	2.45

Table 4: Maximum concentrations of Thallium, Arsenic, and Manganese detected in groundwater samples at TVA (in 2008 and 2009) and Town of Pines (in 2000 and 2015) sites and EPA Maximum Contaminant Level (MCL) drinking water thresholds.

	Thallium (max. conc.) (mg/L)	Thallium (EPA MCL) (mg/L)	Arsenic (max. conc.) (mg/L)	Arsenic (EPA MCL) (mg/L)	Manganese (max. conc.) (mg/L)	Manganese (EPA MCL) (mg/L)
TVA 2008	0.02	0.002	0.05	0.01	N/A	0.05
TVA 2009	0.00087	0.002	0.0046	0.01	N/A	0.05
Town of Pines 2000	N/A	0.002	1180	0.01	3970	0.05
Town of Pines 2015	N/A	0.002	2490	0.01	34	0.05

Contaminant Concentrations Across Sites and Years

The concentrations of arsenic and thallium detected in the Tennessee, Clinch, and Emory Rivers post TVA spill on December 28th, 2008 and April 25th, 2009 were evaluated. The results of the analysis revealed that from the days following the spill, to months into the future, the levels of arsenic and thallium in the water were significantly decreased (Table 2).

The concentrations of arsenic and manganese sampled at the Town of Pines from October 17th, 2000 to May 6th, 2015 were evaluated (Table 3). These results show that the levels dropped considerably for manganese, but they were still above drinking water thresholds. For arsenic, the levels actually increased from the first to second date and were still above drinking water thresholds.

I then listed the maximum concentrations at each site for each time period and compared each one to the drinking water threshold for that contaminant (Table 4). For TVA the first set of sampling data indicates that thallium and arsenic were above the threshold, and

then at the second sampling were noticeably below the threshold. For Town of Pines, manganese levels dropped considerably from the first to second date but were still above the drinking water threshold. For arsenic, both dates were noticeably above the drinking water threshold. This indicates a continuing human health risk.

Ground Water – Unacceptable Human Health Risk for Private Well Water Users?

Scientists recognize that the actual concentration of a contaminant detected in a field sample following a catastrophic spill event into groundwater may be well above the drinking water MCL for the contaminant. With that it is also understood that most residents who source their drinking water from private wells ensure some form of water treatment system will be installed to reduce exposure to contaminants in groundwater. Water treatment systems for homes comprise filtration, distillation, and disinfectant systems (CDC 2015). In the US, more than 15 million households rely on private wells for drinking water. The level of contaminants that were detected in the Town of Pines did not likely reflect the amount of contaminant actually consumed due to some form of treatment system. However, it is important to note the ‘bad taste’ residents reported to the IDEM indeed led to the EPA investigation. And, residents are still being supplied bottled water to this day.

I conducted a  screening-level human health risk assessment, based on the concentrations of manganese detected at the Town of Pines (2015 groundwater samples) to demonstrate the risk that untreated consumption of groundwater via private well, containing high levels of manganese may have posed to residents in the Town of Pines (Appendix). A screening-level human health risk assessment is an assessment that provides a general indication of whether there is a potential risk to human health and helps identify these areas of concern at a site (DTSC 2020). The exposure scenario was based on the consumption of 3.7 L

(Institute of Medicine 2005) of water containing a cross-section of concentration levels of manganese detected, per adult male (weighing 70 kg). The endpoint was the EPA's MCL for manganese in drinking water (0.05 mg/L). The results of this screening assessment (listed in further detail in the Appendix) highlight that each concentration greatly exceeded the acceptable level of risk. Although all concentrations were well in excess of the threshold, one sample recording 34 mg/L of manganese in groundwater in 2015, equated to a dietary risk quotient of 3500% of the acceptable daily intake for manganese.

DISCUSSION

My results from the analysis of concentrations highlight the contrast between the reduction in overall concentration of the three contaminants at each site. Overall, the drastic TVA coal ash spill resulted in a quick intensive clean up, with contaminant values being reduced below levels that can present unacceptable human health risks within a matter of months. This is evidenced by sample collection occurring days after the spill highlighting high concentrations of both arsenic and thallium and contrasting with samples collected just months later showing low to negligible concentrations of those chemicals. On the other hand, the results from the Town of Pines demonstrate less effective mitigation measures, with the data showing that between the 15-year time period the contaminant values decreased only for manganese, but overall were still above the hazard level for human health. The outcomes of this analysis clearly demonstrate that the differences in overall mitigation efforts may have played a significant role in the overall reduction of contaminant concentrations.

Media Attention – An Unexpected Health Risk

Public knowledge of a coal ash spill, as well as the clearly visible reach of its impact, may factor into the ultimate management of a Superfund site. The ‘advantage’ that the TVA spill had in contrast to the Town of Pines spill, was that it occurred into surface water, and the sheer magnitude of the damage was easily visible and captured in images (Figure 8). As a result, the TVA spill gained significant media attention and stoked a lot of concern among nearby residents. Immediately, TVA, along with state and local emergency management agencies were appointed and actively assisted local residents (EPA 2014). A swift and comprehensive clean-up

ensued just days to months after the spill. As the results of this analysis highlight, the consequences for surrounding affected water sources were as favorable as possible given the circumstances.

However, the company's desire for damage control may have led to the health of their workers being put at risk. In an effort to visibly show that the coal ash released into the environment was not harmful, TVA did not require clean-up workers to wear masks or hazmat suits (Bourne 2019). Importantly, coal ash that is inhaled into the lungs is much more harmful than when it is ingested in food or water. Ten years following the spill itself, more than 200 workers are now suing TVA's main contractor, Jacobs Engineering, for lack of protective equipment and leaving them exposed to the coal ash that may have caused their illnesses (Bourne 2019). Thirty-six of the workers that cleaned up the site have died from brain cancer, lung cancer, leukemia, and other diseases associated with inhalation exposure to the chemicals in coal ash (Bourne 2019). The coal ash spill at TVA caused a situation in which so much focus was placed on public reassurance of both safety and environmental restoration, that this approach may have tragically affected the health of the workers responsible for cleaning the site.

In contrast, the Town of Pines spill received minimal media attention and experienced a seemingly slow-moving clean-up effort. Though this analysis indicates the levels of contaminants have decreased, the concentrations are still above recommended threshold levels. As the spill occurred into the groundwater (and therefore was not as visible as the surface water TVA spill) and it occurred in a sparsely inhabited area, far fewer people were potentially affected. The attributes of the spill did not make for a 'sensational' media story, and despite its official status as a Superfund site, the media attention has always been very minimal. The site has now been in progress for almost 20 years, with the last update of the on-going clean-up

progress documented four years ago in March of 2016. Though progress is slow, and media attention is negligible, those that were affected by the contaminated groundwater were ‘taken care of’ via provision of a new water source, either being connected to city water or provided bottled water, to ensure any human health risks from consumption of contaminated ground water are eliminated (EPA 2016).

Regulatory Changes Related to Coal Ash

In 2009, the EPA began inspecting coal ash surface impoundments under the coal ash disposal rule to ensure safe disposal, as well as structural stability, of coal ash impoundments. The coal ash rule regulates the disposal of coal combustion residuals as solid waste (EPA 2015). However, there have been recent proposals to loosen the strictness of this rule (EPA 2019), by reducing the amount of surface impoundments examined by the EPA to those only near sensitive areas. Proposed changes to this rule, and ultimately coal ash surface impoundments policies, may lead to substandard maintenance of coal ash ponds and impact water quality.

Following the catalyst that was the TVA spill, the EPA identified that improperly constructed or managed coal ash disposal sites have been linked to cases of human health concerns derived from exposure to contaminants in surface or ground water (McCoy 2020). As a result, the EPA began to evaluate the condition and safety of coal ash ponds across the country in the form of the CCR Assessment Program (McCoy 2020). This program assessed the structural integrity of over 500 impoundments, with a total of 152 areas being rated as poor. Subsequently, the EPA added new requirements for coal ash ponds and coal ash landfills. On June 21, 2010 the EPA officially proposed the “Disposal of Coal Combustion Residuals from Electric Utilities” rule. The EPA conducted a public consultation process to gauge feedback on whether CCR’s should be regulated as hazardous waste or non-hazardous solid waste, the outcome of which

would impact enforcement mechanisms adopted. It was determined that CCR's would be regulated as non-hazardous solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA), thereby restricting the EPA's enforcement authority (McCoy 2020). The rule's primary enforcement mechanism, effective from 2015, requires citizens to bring legal action against individuals who are not acting in compliance with the rule (McCoy 2020).

Under the Obama Administration, a final provision to the rule – allowing states and the federal government to directly enforce the EPA's regulations, due to the EPA's authority being restricted – was enacted via the Water Infrastructure for Improvements to the Nation (WIIN) Act in 2016 (McCoy 2020). This provision allowed states and the federal government to directly enforce the EPA's regulations due to the EPA's authority being restricted. However, under the Trump Administration, this provision was tabled for reconsideration, and in 2017 the EPA filed a motion to remand the last six provisions to the final rule. The effects of these regulatory changes led to delayed closure deadlines, existing coal ash ponds continued receipt of more coal ash loads, and suspension of groundwater monitoring if a state determines there is no potential for the hazardous material to contaminate groundwater (McCoy 2020). In October 2018, a coalition of environmental groups filed a petition for review of the EPA's latest changes to the coal ash rule. Throughout 2019, the EPA released several proposed changes to the coal ash rule, such as requiring companies to prove that a deposit of coal ash above a certain size would not harm the environment, as well as extending the deadlines for electricity producers to close or retrofit unlined coal ash storage ponds (McCoy 2020).

Recently, the EPA weakened restrictions by recommending they should only examine coal ash ponds near sensitive locations such as floodplains, seismic zones, and unstable areas. In 2020, the EPA proposed a rule that would allow facilities to demonstrate that their unlined coal

ash impoundments are ‘as safe’ as lined impoundments, so that the facilities can continue operating (McCoy 2020). Key amendments in this regulation include: soil or clay lined impoundments now categorized as “unlined”, requiring impoundments to stop receiving waste as of April 2021, granting facilities extra time to find storage solutions, adding a requirement of an executive summary to the annual groundwater monitoring and corrective action reports, and, amending requirements for the type of information companies must put online about coal ash ponds in their possession. Overall, the proposed rule would make the currently regulatory state less effective than the current rule in place.

Challenges to Access Superfund Site Data

The ability to access Superfund site data can prove very challenging. The reality of these challenges became apparent in conducting this analysis. Similar to the role that public awareness received by media attention may play in the speediness of a cleanup, it is interesting to consider whether public awareness also impacts the availability and accessibility to important environmental data. The availability of each Superfund sites’ information *seems* to be connected to the extent of media coverage the site has received. Obtaining articles and general information on TVA was significantly easier than for the Town of Pines. Although this was not surprising, this stood out particularly in efforts to access specific EPA data for both sites. The data are contained in various databases, and in both online and in physical repositories. The ability to obtain ‘baseline’ data for environmental concentrations proved challenging. Each Superfund site has an information repository “*where current information, technical reports, and reference materials regarding a Superfund site is stored*” (EPA 1992). These are not necessarily online but are typically established in a public library or municipal office, in the community in which the site is located, to provide the public with easily accessible information. Although this

‘public’ accessibility of the information might sound sensible ‘in theory’, the reality is that it creates a very challenging course for the public to navigate to indeed learn more about that particular site. Due to the first-hand experience I gained of this process through my study, and given the general lack of awareness of the details of many Superfund sites by nearby residents, this factor represents an additional factor that the ‘lack of’ public awareness may have on mitigating environmental and human health risks from Superfund sites.

Coal Ash Inhalation Hazards

Surviving workers from the TVA spill recently won a lawsuit with the verdict affirming the company failed to protect them, and that the exposure to the coal ash at the TVA spill could have caused their illnesses (Adkisson et al v. Jacobs Engineering Group, Inc). The Town of Pines Superfund site has also not recorded adverse health effects to the residents within the town. The cancer risk to residents at Town of Pines has been estimated at a 1 in 10,000 chance (EPA 2016). This rate incorporates the risk of developing cancer due to all lifelong exposures, not only from drinking contaminated groundwater in the Town of Pines (EPA 2016). As the Town of Pines Superfund site contamination occurred within the groundwater, there was no risk of inhalation exposure to the clean-up workers.

Moving Forward: Cleaner Coal Ash, Reuse Purposes

The capacity for the coal industry to adopt cleaner practices can assist in the challenges faced as a result of the ‘war on coal’ (Morris 2016). The economic impact to coal workers and the communities, particularly when spills like TVA and Town of Pines occur, can be devastating. The environmental stewardship of the entire life cycle of coal and its by-products, is also receiving significant attention. Some of these steps include lowering the amount of coal ash

produced by increased cleaning mechanisms, known as “scrubbers”, in the plant itself (Duke Energy 2019). More importantly there are steps that can be taken to reuse coal ash after it is formed, instead of simply putting it in impoundments. The results from an AECOM, a consulting and engineering firm, study (Bradley 2012) determined that coal ash may be reused and repurposed for concrete, road base, and structural fill, as the exposure to constituents in those mediums would not pose human health exposure risks.

Reusing coal ash is the key to getting coal ash out of impoundments and minimizing the accidental pollution of groundwater and surface water. Overall, approximately 40% of coal ash is beneficially reused, with the rest being disposed into impoundments and landfills (EPA 2018). Reusing this abundant waste product can help conserve natural resources and minerals (Federal Highway Association). Coal ash is considered an extremely effective additive to concrete to increase its durability and crack-resistance (Drexel University 2019). In 2010 alone, 11 million tons of greenhouse gas emissions were avoided due to enhancing cement with coal ash (Bradley 2012). Notable projects that have used coal ash enhanced concrete are the Burj Khalifa, the Metropolitan Museum of Art, the Hoover Dam Bypass, and the Royal Ontario Museum (ACAA). Other forms of building and construction materials that reuse coal ash are coal ash bricks, coal ash-based ceramic, coal ash-based polymer products, and coal ash in road construction (Ahmad 2012).

Coal ash is also a suitable plant growth media supplement (Bilski et al. 2011). Due to each blend of coal having different chemical make-ups, the particular coal ash mix is selected to assist the ability of soil to help crop growth for barley and Sudan grass. Studies have shown that plants do not accumulate toxic amounts of heavy metals, despite being grown on soil that is comprised of 100% coal ash (Bilski et al. 2011). Similar to using coal ash as a growth

supplement, coal ash can also be used as a mine reclamation amendment. Essentially, this process takes coal ash and returns it to the site the initial coal was retrieved from. This process helps raise the pH of the coal refuse, lower its hydraulic conductivity, and lower the rate of gas exchange with the atmosphere (Stewart 1996). The numerous opportunities for coal ash reuse are considered environmentally beneficial, posing negligible risks to human health.

CONCLUSION

“Coal has always been both a creative and a destructive force. It is the tension between the two that makes the story of coal so compelling.” -Barbara Freese (2016)

At TVA, immediate remediation action was taken, resulting in the clean-up finalized within approximately one year (with a majority of the ash being removed within two weeks of the initial incident). There is an argument that this was due primarily to the severity of the spill, and the intensity of media coverage it created. However, importantly and ironically, the TVA site has produced the most short-term harm to human health via exposure to coal ash contaminants because of inhalation by clean-up workers. It has been suggested that the intense media coverage may have led the company to adopt an ill-thought out, swift clean-up response (including lack of personal protective equipment for workers) to calm public fears.

In contrast, the Town of Pines site, where media coverage was almost non-existent, experienced a much slower remediation response rate. In the almost 20-year period that this site has been a concern, the levels of one contaminant have been reduced, but the overall clean-up of the site is still not complete. The lack of media attention and overall lack of information provided to the public may be the cause for slow progress by management. However, it is noted that the EPA was quick to solve the problem of contaminated drinking wells, by providing externally sourced clean water.

A number of important outcomes and recommendations were evident from this analysis of data, and the broader literature review undertaken in relation to this topic. There is clearly

inconsistency in the approach to information sharing with communities nearby Superfund sites. Large media coverage may ensure that the community becomes familiar with the nature of the event, while the formation of community advisory groups will give the community the information and voice required to advocate for their public and environmental health interests. As discussed above, the availability and access to Superfund site information is also challenging. Given the potential environmental justice issues at play regarding access and interpretation of scientific data, this item requires further attention. Community advisory groups seem to assist and hasten the process of remediation and help community members' interests to be represented in decision-making processes.

The ability of those involved in the Superfund sites to communicate the key risks associated with those contaminating events is also an important factor. The TVA and Town of Pines examples highlight that the most harmful human health effects were in fact experienced by the inhalation of coal ash by the unprotected workers who cleaned up the TVA. The role of the 'messaging' promoted by those controlling the release of Superfund related information (i.e. the companies involved, community groups, or the government) and the ability for it to be manipulated, is another important factor in Superfund site mitigation and management. The importance of those managing Superfund sites, at both the outset of the contamination and ongoing, to clearly communicate accurate and comprehensible information to community members is paramount.

APPENDIX

As discussed above, the human health risk from consumption of manganese contaminated groundwater was calculated, based on the sampling data from 2015 at the Town of Pines. The values used in calculating the risk are included in Table 5 below, and the outcomes of the risk calculations, outcomes are reported on page 34 at Table 6:

Table 5: Town of Pines - Manganese Known Values and Conversions.

Known Values	<i>Original Value</i>
<i>Acceptable Daily Intake</i>	0.05 mg/L
<i>Acceptable Daily Intake with Amount Consumed</i>	0.185 mg
<i>Amount Consumed</i>	15.5 cups (3.7L)
<i>Body Weight (Adult Male)</i>	70 kg

Table 6: Town of Pines - Manganese Calculations for the Second Date of 5/06/2015.

Site Identifier	5/06/2015 Manganese Level (Residue) mg/L	Dietary Exposure (Residue) mg/L /day	RQ Level of Concern (LOC) ¹ mg/L /day	Dietary Risk Quotient (Residue)	Dietary Risk Quotient (RQ = 1)	Ingested Dose per kg BW (Residue) mg/L /day /kg	Ingested Dose per kg BW (RQ = 1) mg/L /day /kg	Dietary Risk expressed as % of ADI ² (Residue)	RQ Level of Concern expressed as % of ADI ²
MW101	0.43	1.6	0.05	8.5	1	0.023	0.00071	45.0	1.4
MW102	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW103	1.8	6.7	0.05	36	1	0.095	0.00071	190.3	1.4
MW104	1.4	5.2	0.05	28	1	0.074	0.00071	148	1.4
MW105	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW106	1.6	5.9	0.05	32	1	0.085	0.00071	169.1	1.4
MW107	2.8	10.4	0.05	56	1	0.15	0.00071	296	1.4
MW108	0.70	2.6	0.05	14	1	0.037	0.00071	73.9	1.4
MW109	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW109	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW110	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW111	34	125	0.05	680	1	1.80	0.00071	3594.3	1.4
MW113	0.69	2.6	0.05	13.9	1	0.037	0.00071	73.3	1.4
MW114	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW114	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW115	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW116	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW116	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW117	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW119	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW120	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW121	0.6	2.2	0.05	12	1	0.032	0.00071	63.4	1.4
MW121	0.56	2.1	0.05	11.1	1	0.029	0.00071	58.8	1.4
MW122	4.1	15.7	0.05	82	1	0.22	0.00071	433.4	1.4
MW123	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4
MW124	1.0	3.7	0.05	20	1	0.053	0.00071	105.7	1.4

¹ Risk Quotient Level of Concern² Acceptable Daily Intake

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