ATSDR
Public Health Assessment

Evaluation of Volatile Organic Compounds (VOCs) in Public Drinking Water

Dorado, Puerto Rico

USEPA Facility ID: PRN000201872

Final Release

June 22, 2026

Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Office of Community Health Hazard Assessment

Atlanta, GA 30341

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Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
CV	Comparison value
DBP	Disinfection by-product
DNER	Puerto Rico Department of Natural and Environmental Resources
EPA	United States Environmental Protection Agency
HAA	Haloacetic Acids
IARC	International Agency for Research on Cancer
LOAEL	Lowest observed adverse effect level
IRIS	Integrated Risk Assessment System
MCL	Maximum contaminant level
mg/L	Milligram per liter
MLE	Maximum likelihood estimation
MRDLG	Maximum residual disinfectant level goal
MRL	Minimal risk level
NCEH	National Center for Environmental Health
NPL	National Priorities List
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethylene (or perchloroethylene)
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDOH	Puerto Rico Department of Health
PWS	Public Water System
RfD	Reference dose
RMEG	Reference media evaluation guide
PREQB	Puerto Rico Environmental Quality Board
SVOC	Semi-volatile organic compounds
TCE	Trichloroethylene (or trichloroethene)
µg/L	Microgram per liter
VOC	Volatile Organic Compound

A Public Health Assessment: A Note of Explanation

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's fulfilment of statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame based on currently available information. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. The revised document was released for a 45-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment 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.

You may contact ATSDR toll free at 1-800-CDC-INFO

or

visit our home page at: https://www.atsdr.cdc.gov

About ATSDR

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency of the U.S. Department of Health and Human Services (HHS). ATSDR works with other agencies and tribal, state, and local governments to study possible health risks in communities where people could come in contact with dangerous chemicals.

1. Summary

1.1. Introduction

The Agency for Toxic Substances and Disease Registry's (ATSDR) top priority at this site is to ensure that the people living in Dorado, Puerto Rico, have the best information possible to safeguard their health.

The U.S. Environmental Protection Agency (EPA) listed the Dorado Groundwater Contamination site on the National Priorities List (NPL) on April 7, 2016. The Agency for Toxic Substances and Disease Registry (ATSDR) is responsible for conducting public health activities at NPL sites.

The Dorado drinking water supply systems that contribute to the public drinking water supply provide drinking water to more than 67,000 people in Dorado and nearby municipalities. Dorado has four drinking water supply systems that were registered with EPA under the Public Water Supply System (PWS). The drinking water supply system is made up of two active groundwater supply systems, one active well system, and the Super Aqueduct system (surface water) that blends groundwater to provide drinking. Some volatile organic compounds (VOCs), primarily tetrachloroethylene (PCE) and trichloroethylene (TCE), have been detected at low levels in the Dorado drinking water systems (Figure 1) since the 1980s. Disinfectants and disinfection by products (DBPs) such as trihalomethanes (THMs) were also detected at low levels.

The purpose of this Public Health Assessment (PHA) was to determine whether the community was harmed by exposure to VOCs in the Dorado drinking water systems that contributed to the public drinking water supply in the Dorado area and what public health actions needed to be taken to reduce harmful exposures. Because of limited available data, ATSDR focused its evaluation only on exposure to VOCs from the Dorado drinking water supply systems that contribute to the public drinking water supply in the Dorado area. ATSDR found that some VOCs found in groundwater were **site-related**, whereas other VOCs were **not site-related** and originated from a connecting water source that had disinfection-by-products contamination from the use of disinfectants in the water. Other potential exposure pathways may be evaluated in detail in the future as more data are collected from the site.

ATSDR made every attempt to obtain critical environmental data for the site; however, there are significant data limitations. Without historical data or knowledge about the source of contamination, there are significant uncertainties in estimating the potential for harmful health effects at this site. ATSDR used conservative assumptions to be protective of the community's health. Therefore, actual exposures may be different from those described in this document.

ATSDR reached the following conclusions in this PHA:

Conclusion 1

People using the public drinking water supply for drinking, cooking, and bathing in the Dorado area from 1984 (when contamination was first discovered) to the present day are not likely to have harmful health effects from the low levels of chemicals in the water.

Basis for Conclusion

ATSDR found some chemicals in the public drinking water supply related to the groundwater contamination (site-related) and other chemicals related to the addition of disinfectants to kill germs in the water (not-site-related).

Site-Related Chemicals (Groundwater Contamination)

Trichloroethylene (TCE)

- **Few samples contained TCE above drinking water standards**. Only three of the more than 200 samples tested had TCE levels above 5.0 parts per billion (ppb), EPA's drinking water standard.
- **Wells with higher levels were closed.** TCE levels ranged from non-detected to 6.4 ppb. Half of the samples had TCE levels below the detection limit of 0.5 ppb. The highest level (6.4 ppb) was recorded in February 2006 from the Maguayo III well, which was removed from service in 2011 [PRASA 2017].
- **Estimated doses were lower than dose levels showing health problems.** ATSDR estimated exposure doses using the maximum concentration of TCE of 6.4 ppb, which resulted in estimated total doses for TCE exposures ranging from 0.0005 to 0.0022 milligrams per kilogram per day (mg/kg/day) for different age groups. These doses are well below the effect level (0.37 mg/kg/day) from available scientific studies that showed decreased thymus weights and developmental immunotoxicity. Therefore, TCE levels in the public drinking water supply are not likely to harm people's health [ATSDR 2013, 2014].
- **Estimated cancer risk was low.** ATSDR estimated lifetime increased cancer risks for long-term exposures to the maximum concentration of 6.4 ppb TCE. The estimated risks, less than 2 and 6 extra cases of cancer for every 100,000 exposed adults or children, respectively, are considered low.

PCE

- **Few samples contained PCE above drinking water standards.** PCE levels ranged from non-detected to 15 ppb. From 2008 to 2015, about 10 percent of the samples had PCE levels above 5.0 ppb. The highest level (15 ppb) was recorded in 2019 from the Maguayo IV well [USEPA 2020].
- **Estimated doses were lower than dose levels showing health problems.** ATSDR estimated exposure doses using the maximum concentration of PCE of 15 ppb, which resulted in estimated doses ranging from 0.0015 to 0.0064 mg/kg/day based on age

group. This estimated dose range is lower than EPA's and ATSDR's health-based guidance values (health guideline) of 0.006 mg/kg/day and 0.008 mg/kg/day for non-cancer effects, respectively and, therefore, not likely to harm people's health.

- **Estimated cancer risk was low.** ATSDR estimated lifetime increased cancer risk for long-term exposures to the maximum concentration of 15 ppb PCE. The estimated risks, less than 2 for every 100,000 exposed adults or children, are considered very low.

Disinfection-Related Chemicals (Not Site-Related)

- **Disinfection-related chemicals did not exceed drinking water standards.** All maximum concentrations of disinfection-related chemicals did not go above EPA's safe drinking water standards and ATSDR non-cancer comparison values. Therefore, they would not likely be associated with harmful non-cancer health effects such as skin irritation, liver, or kidney injury. Additionally, the average concentrations of those chemicals in the public drinking water supply would likely be lower than the maximum value since the water is mixed before reaching residential taps.

- **Cancer risk cannot be calculated.** ATSDR cannot conclude whether exposures to the levels of disinfectants and disinfection-by-products (DBPs) in the public drinking water supply could result in increased cancer risk. The reason for this is because there are significant data limitations (lack of complete mixing percentage contribution and the lack of tap water sampling data for the site for DBPs, and no cancer slope factors for some of the detected disinfectants and DBPs) to estimate increases in cancer risk. The benefits of using disinfecting chemicals to kill germs that could cause sudden and severe life- threatening illness far outweigh their potential low increased risk of cancer.

Conclusion 2

ATSDR does not have enough information to determine whether harmful exposures from soil or vapor intrusion may be occurring.

Basis for Conclusion

The source of groundwater contamination remains unknown. Source areas may have higher levels of contamination. ATSDR cannot tell if anyone is coming in contact with soil or air within buildings that may be contaminated at source areas. Contaminant levels at or near the source(s) of contamination could be very different from the sampled locations. We don't have enough information to conclude whether chemicals in soil or the air inside buildings could harm people's health. We are working with the state and EPA to gather this information and to identify the source of contamination.

- **EPA has not found the source of contamination.** EPA conducted Preliminary Assessment/Site Inspections (PA/SI) at 21 facilities near the groundwater contamination to identify potential contaminant sources

- EPA collected 279 soil samples, and 50 groundwater samples. There were very limited surface soil (3 samples) and soil gas samples (2 samples).

- EPA reported results from a screening level analysis of potential vapor intrusion in tested areas. Detected contaminant concentrations were compared to EPA's vapor intrusion screening levels (VISLs), and all were below the screening levels (VISLs) used for residential buildings. More details can be found in the EPA Human Health Risk Assessment (HHRA).

Next Steps

EPA and/or Puerto Rico Department of Natural and Environmental Resources (DNER):

- Continue efforts to identify the source, collect additional samples to characterize the extent of the contamination, and implement remedial measures to address and prevent groundwater contamination.

Puerto Rico Department of Health (PRDOH):

- Continue to conduct routine water monitoring per the Safe Drinking Water Act requirements, with the assistance of EPA.

Agency for Toxic Substances and Disease Registry (ATSDR):

- Evaluate additional data collected by EPA and PRDOH and update the findings of this report, if requested.

For More Information

For further information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the "Dorado Groundwater Contamination Site." If you have concerns about your health, please contact your health care provider.

2. Purpose

The U.S. Environmental Protection Agency (EPA) listed the Dorado Groundwater Contamination Site (the site) on the National Priorities List (NPL) on April 7, 2016. The Agency for Toxic Substances and Disease Registry (ATSDR) is responsible for conducting public health activities at NPL sites. This public health assessment evaluates the public health significance of the site.

3. Background

3.1. Site Description and History

The site is located in a mixed residential, commercial, and industrial area in north-central Puerto Rico, within the municipality of Dorado. The site's groundwater has been contaminated with organic based solvents. The source of the contamination is still under investigation and EPA has evaluated some locations for possible responsible parties.

Dorado has four drinking water supply systems that were registered with EPA under the Public Water Supply System (PWS): two active groundwater well supply systems (Maguayo (31,061 people) and Dorado Urbano (36,630 people); one inactive well system (Vivoni) located south (upgradient) of the other wells; and the Super Aqueduct system (surface water from the northwest coast of the island used to supplement the water supply since 2001). The blended groundwater and surface water systems provide drinking water to more than 67,000 people [WESTON 2015]. The Puerto Rico Aqueduct and Sewer Authority (PRASA) operates the Dorado water systems.

Figure 1 below shows the locations of the wells' waterlines. Appendix C Table 13 shows a summary of the Dorado well systems.

3.1.1. Maguayo System (PWSID PR0005597)

The active Maguayo system withdraws water from the upper aquifer of the North Coast Limestone Aquifer System. This aquifer is the principal source of fresh water for Dorado and is historically the principal source for public and industrial water use in the northern region. The system has six wells (Maguayo II- Maguayo VII that were constructed from 1968 through 1988. Historically, the Maguayo system wells were periodically deactivated and then reactivated.

PRASA records indicated that the Maguayo ll, Maguayo VI, and Maguayo VII wells were active in 2015. Maguayo III and IV wells have been out of operation since 2011 and the Maguayo V well has been out of operation since 2010. Groundwater is treated by chlorination and mixed with potable surface water from the Super Aqueduct system prior to being distributed to the community [USEPA 2016].

3.1.2. Dorado Urbano System (PWSID PR0005607)

The blended Dorado Urbano system also withdraws water from the upper aquifer of the North Coast Limestone Aquifer System. There are eight wells in this system. Two active wells, Santa Rosa and Nevarez, were constructed in 1998 and 2011, respectively. Some of the wells in the system have been closed temporarily and others permanently due to contamination. For example, the San Antonio 2 and Higuillar wells have been out of operation since 2005. San Antonio 1, San Antonio 3, Dorado Dairy 1, and Dorado Dairy 2 wells have been out of operation since 2006.

3.1.3. Vivoni Well System (PWSID PR0005517)

The Vivoni well system has only one well, located south of the other well systems. The Vivoni well has been inactive since 2012.

3.1.4. North Coast Super Aqueduct System (PWSID PR000)

The North Coast Super Aqueduct System is the largest water transmission project built in Puerto Rico. The system consists of pipelines, pumping stations, filtration plants, treated water storage tanks, and system accessories to control and distribute potable water through the San Juan Metropolitan area, including Dorado. The system takes surface water from the Rio Grande de Arecibo, which is fed principally from the Lagos Dos Bocas, a lake in Utuado. The Super Aqueduct System was connected to the Dorado groundwater systems in 2001 in order to supplement the water supply already in existence.

Since the 1980s, water samples collected by PRASA and the Puerto Rico Department of Health (PRDOH) have shown that the two active groundwater systems (Maguayo and Dorado) have had detections of volatile organic compounds (VOCs), primarily tetrachloroethylene (PCE) and trichloroethylene (TCE). In addition, Puerto Rico's Environmental Quality Board (PREQB) and EPA collected numerous environmental samples, including groundwater and soil, at the site.

4. Site Visit

As part of the public health assessment process, in August 2016, ATSDR staff met with local officials from PRDOH, EPA's Caribbean Environmental Protection Division (CEPD), and PRASA to conduct a site visit. ATSDR visited the municipality of Dorado's public drinking water distribution system, groundwater wells, and surrounding areas. ATSDR contacted CEPD to receive further updates about the site. In 2019, CEPD conducted a remedial investigation and feasibility study (RI/FS), which also included a baseline human health risk assessment and a screening-level ecological risk assessment. During this event, environmental sampling of groundwater from public and private wells and surface water and sediments from the Rio de la Plata was performed. ATSDR does not have the full environmental sampling data from this event; however, preliminary screening of the data in the documents support the conclusions and recommendations based on the drinking water data evaluated for the site [USEPA 2020]. For example, we used the maximum concentration of PCE (15 µg/L) detected in the RI/FS event.

5. Demographics

The site is located in the city of Dorado. According to the U.S. Census data from 2010, the total population living within Dorado city limits was 38,165. The majority of the population is of Hispanic or Latino origin (98%). The 2010 U.S. Census demographics statistics also show that the population living around the well systems includes the following potentially sensitive groups: approximately 9.5% children aged 6 and younger, 21% women of childbearing age, and 12% adults aged 65 and older [US Census 2010].

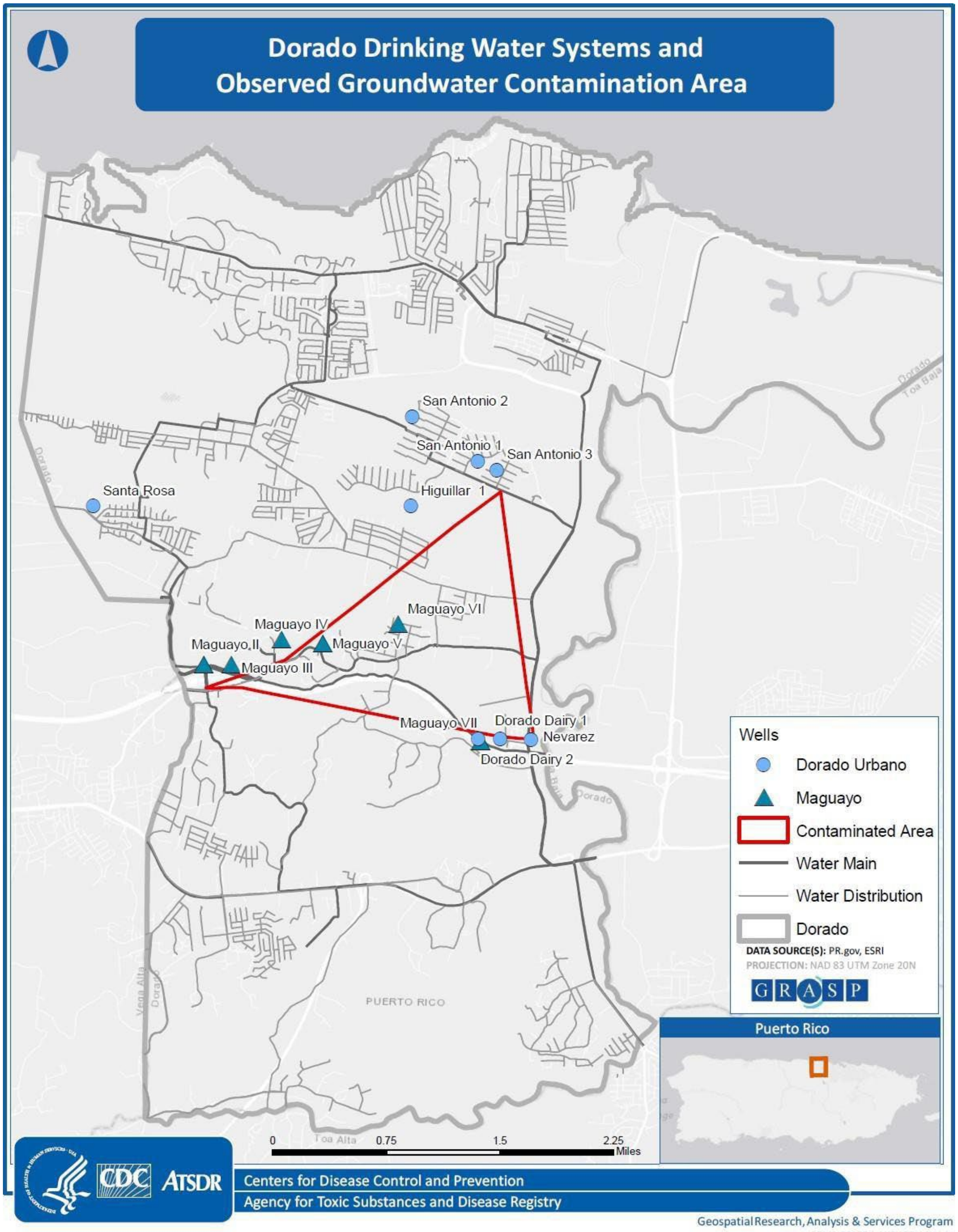

Figure 1. Dorado Water Lines and Well Locations, Dorado, Puerto Rico

6. Discussion

6.1. Data Used

Environmental sampling data are critical to the public health evaluation process. ATSDR evaluated the available environmental data for potential exposure to groundwater contaminants at the site.

EPA Region 2 provided the Hazard Ranking System (HRS) package with documentation records and references listed in the package. Among the 53 available reference documents, ATSDR identified relevant environmental sampling data from the documents. In addition, environmental samples (groundwater and soil) collected by EPA and PRASA (under the request of PREQB) from 2002 through 2015 were available for this review. We also considered the 2019 RI/FS groundwater sampling by EPA in this document.

Chronological Order of Sampling Events and Data Source

EPA 2008 data: In 2008, during the Maguayo Site Discovery Initiative sampling event EPA collected groundwater samples (6) from 4 Maguayo wells (Maguayo III, V, VI, and VII and the Vivoni well [WESTON 2008].

EPA 2009 data: In 2009, during the second phase of the Maguayo Site Discovery Initiative sampling event, EPA collected additional groundwater samples (7) from 3 Maguayo wells (Maguayo II, VI, and VII, one Dorado Urbano well (Santa Rosa), and the Vivoni well [WESTON 2010].

EPA 2011 and 2013 data: EPA conducted Preliminary Assessment/Site Inspections (PA/SI) and Site Reassessment (SR) at 21 facilities in order to identify potential contaminant sources. During the PA/SI event, EPA collected a total of 279 soil samples and 50 groundwater samples. During the SR events, EPA collected limited surface soil (3 samples) and soil gas samples (2 samples), subsurface samples (370 samples), and groundwater samples (62 samples). [WESTON 2011a-j, 2012, 2014a-e]. See Appendix C Table 2 for a summary of the samples.

EPA 2015 data: In September 2015, EPA collected 19 groundwater samples from both active and inactive water supply wells. The five active wells sampled were Nevarez, Santa Rosa, Maguayo wells II, VI, and VII. Inactive wells sampled were San Antonio 2, San Antonio 3, Higuillar, Dorado Dairy 2, Nevarez, Vivoni and Maguayo III-V [USEPA 2015].

PRASA data 2002-2015: PRASA provided available sampling data from 2002-2015 for the wells in the Dorado systems [WESTON 2015a-b]. See Appendix C Table 3 for a summary of the samples.

North Coast Super Aqueduct System data: PRASA provided a data set that included quarterly test results for the past 15 years. The detected chemicals are all chlorination-by-products; TCE/PCE were not detected [PRASA 2017].

EPA 2019 data: As part of a remedial investigation/feasibility study (RI/FS), EPA's contractor conducted a Human Health Risk Assessment (HHRA). The investigations extended through 19 wells in Dorado during April-May (Round 1) and August 2019 (Round 2) [USEPA 2020].

ATSDR also reviewed information on Quality Assurance (QA)/Quality Control (QC) specifications for field and laboratory data quality to verify the acceptability and adequacy of data including Chain of Custody sheets, project narratives, and laboratory certifications. The laboratory analysis methods and the QA/QC procedures were deemed appropriate. This evaluation included all validated results.

7. Evaluation Process

ATSDR provides site-specific public health recommendations based on an evaluation of the toxicological literature, levels of environmental contaminants detected at a site compared with health-based comparison values (CV), the characteristics of the exposed population, and the frequency and duration of exposure. The typical process by which ATSDR evaluates the potential for adverse health effects resulting from exposure to site contaminants is described briefly in this section. See Appendix A and B for a more detailed description and terminology.

ATSDR evaluates ways that people may come into contact with contaminated media that may lead to people being exposed to the contaminants (exposure pathways). Exposure pathways consist of five elements that must all be present for exposure to occur—whether that exposure is in the past, current, or in the future. The five elements and their relationship to the site are listed below:

1. A contamination source: The source of contamination for the site has not yet been identified, but it is presumed because of the contamination present in groundwater at the site.
2. Transport through an environmental medium: Drinking water is the medium that transported the VOC contamination.
3. An exposure point: Dorado residents obtained drinking water from the public drinking water supply. This supply included water from contaminated wells.
4. An exposure route: Dorado residents drank and bathed in the water and may have breathed in contaminant vapors from the water.
5. An exposed population: Approximately 67,000 people were served by the public drinking water supply comprised of several Dorado drinking water systems, some with contaminated wells.
6. The exposure pathway analysis (Table 1) indicates that a completed groundwater exposure pathway (for past and current) existed for those using the public drinking water supply from the site.

Table 1. Exposure Pathways for Dorado Groundwater Contamination Site, Dorado, Puerto Rico

Exposure Pathway	Sources of Contamination	Fate and Transport	Point of Exposure	Exposed Population	Route of Exposure	Pathway Classification
Public drinking water supply	Releases from unknown operations around the site	Infiltration of contaminants to municipal wells; infiltration of contaminants in ground through broken water pipes	Residential faucet/tap	Residents in the area who use the public drinking water supply	Dermal Ingestion Inhalation	Past (Completed) Current (Completed) Future (Completed)
Groundwater from Dorado drinking water systems; Private Groundwater Wells	Releases from unknown operations around the site	Migration of contaminated groundwater into areas with private wells	Residential tap water; other potable water taps	People who use private wells	Dermal Ingestion Inhalation	Past (Eliminated) Current (Eliminated) Future (Potential)
Vapor Intrusion	Releases from unknown operations around the site	Migration of subsurface vapors into indoor air	Enclosed structures over contaminated soil or groundwater	People living or working in homes or buildings built over contaminated subsurface	Inhalation	Past (Potential) Current (Potential) Future (Potential)
Surface soils	Releases from unknown operations around the site	Improper chemical disposal or spillage onto ground	On-site property and nearby residences	Facility workers, residents/property owners	Ingestion Dermal Inhalation	Past (Potential) Current (Potential) Future (Potential)
Subsurface soils	Release from unknown operations around the site	Subsurface soil transported or released from site	Areas of ground excavation; above –ground seeps	People who contact contaminated subsurface soils	Ingestion Dermal Inhalation	Past (Potential) Present (Potential) Future (Potential)
Surface Water	Release from unknown operations around the site	Migration of contaminated groundwater and soil into the La Plata River	La Plata River	People who contact contaminated surface water	Ingestion Dermal Inhalation	Past (Potential) Present (Potential) Future (Potential)

Chemicals contaminating groundwater and soil might also off-gas and migrate into the air of homes and commercial buildings. The migration of vapor-forming chemicals and gases from any subsurface source into indoor air is known as vapor intrusion. ATSDR cannot evaluate the vapor intrusion and surface soil pathways further because the contamination sources are not identified, and there are limited surface soil and soil vapor samples. The sources of the contamination are still under investigation by EPA. During the PA/SI and SR events, EPA collected hundreds of soil samples and groundwater samples. But there were very limited surface soil (3 samples) and soil gas samples (2 samples). In addition, contaminant concentrations at or near sources could be very different from the sampled locations. Therefore, ATSDR cannot evaluate the health implications of past, current, or future vapor intrusion and surface soil exposure.

ATSDR evaluated the completed exposure pathway for the public drinking water supply in the Dorado area further to determine whether any potential health effects may be associated with exposure to contaminated water:

- When presented with results of comprehensive environmental sampling for chemicals, ATSDR reduces the number of contaminants that need to be evaluated by screening the results for each chemical against health-based comparison values (CVs)- concentrations of chemicals in the environment (air, water, or soil) below which no adverse human health effects would be expected to occur. If a contaminant is present at a level higher than the corresponding CV that does not mean adverse health effects will occur; the contaminant is merely retained for the next step of the evaluation. We followed the ATSDR Public Health Guidance Manual to select CVs [ATSDR 2005a]. In some cases, professional judgment was used to select the most appropriate CVs for the specific site conditions.
- The next step of the evaluation focuses on identifying which chemicals and exposure situations could be considered a health hazard. We calculate exposure doses- estimated amounts of a contaminant that people come in contact with and get into their bodies on an equivalent body weight basis—under specified exposure situations, typically starting with the "worst-case" type assumptions which result in the highest dose expected. Each calculated exposure dose is compared against the corresponding health- based guidance value (health guideline), typically an ATSDR minimal risk level (MRL) or EPA Reference Dose (RfD), for that chemical if available. Health guidelines are considered safe doses; that is, if the calculated dose is at or below the health guideline, no adverse health effects would be expected.
- If the "worst-case" exposure dose for a chemical is greater than the health guideline, then the exposure dose may be refined to reflect

more closely the actual exposures that occurred or are occurring at the site. The refined exposure dose is then compared with known health effect levels for non-cancer effects and used to estimate cancer risks as identified in ATSDR's toxicological profiles or EPA's Integrated Risk Information System (IRIS). These comparisons are the basis for determining whether the exposure presents a health hazard.

8. Environmental Data Evaluation

For the completed public drinking water supply exposure pathway, ATSDR reviewed about 1,500 samples. ATSDR screened environmental data for about 150 chemicals including dioxins/furans, metals, pesticides, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), and semi volatile organic compounds (SVOCs). Contaminant levels that did not exceed a CV were not evaluated further because these concentrations were too low to cause adverse health effects. Six chemicals found in the groundwater wells and eight chemicals found in the Super Aqueduct system exceeded their respective CVs. Table 2 below is a summary of the chemicals.

Table 2. Summary of Chemicals Above Comparison Values for the Public Drinking Water Supply Comprised of Groundwater Wells and a Super Aqueduct

Chemicals	Highest Concentration Detected in Groundwater Sample, µg/L	Highest Concentration Detected in Super Aqueduct Sample, µg/L	ATSDR CV in µg/L	Further Evaluation Needed (Yes/No)	Number of Detects
PCE	15	Not detected	12 – CREG	Yes*	173
TCE	6.4	Not detected	0.43 – CREG	Yes	144
1,2-dichloroethane	0.5	Not detected	0.27 – CREG	No	1
Benzene	0.5	Not detected	0.44 – CREG	No	1
Vinyl Chloride	0.9	Not detected	0.017 – CREG	No	1
Bromodichloromethane	8.4	15.8	0.39 – CREG	Yes	67
Chlorine Dioxide	Not Tested	3,500	210 – RMEG	No	2
Di(2-ethylhexyl)phthalate	5	4.8	1.7– CREG	No	1
Dichloramine	Not Tested	1,320	700**	Yes	12
Trichloroacetic Acid	Not Tested	24.7	0.35 – CREG	Yes	61
Dichloroacetic Acid	Not Tested	22	0.49 – CREG	Yes	61
Monochloramine	Not Tested	980	700 – RMEG	Yes	21
Dibromochloromethane	1.8	6.4	0.29 – CREG	Yes	40

Please see Appendix A for definitions and additional information about CVs. CV = comparison value of water; µg/L = micrograms of contaminant per liter of water; RMEG = reference media evaluation; CREG = cancer risk evaluation guide; EMEG = environmental media evaluation guide; Data sources: as summarized in "Data Used" section.

* Maximum contaminant level (MCL) for Tetrachloroethene is 5 µg/L

** Monochloramine's RMEG used as a proxy for dichloramine

Five chemicals (i.e., 1,2-dichloroethane, benzene, chlorine dioxide, di(2-ethylhexy) phthalate, and vinyl chloride) that have only 1 or 2 detects are not discussed further because of limited data and generally low concentrations. ATSDR retained eight chemicals for further evaluations. PCE and TCE were detected in groundwater only. Disinfectants (dichloramine and monochloramine), and DBPs (bromodichloromethane, dibromochloromethane, dichloroacetic acid, and trichloroacetic acid) were mostly detected in the surface water from the Super Aqueduct system. The disinfectants and DBPs are not related to the groundwater contamination. ATSDR evaluated PCE, TCE, disinfectants, and DBPs further in this document.

9. Public Health Implications

For chemicals that exceed comparison values, ATSDR calculates estimated exposure doses (the amount of chemical to which a person is exposed) and determines the potential for noncancer and cancer health effects. To estimate exposure doses, ATSDR made several assumptions.

Assumptions are based on default values from ATSDR's Public Health Guidance Manual [ATSDR 2005a], ATSDR's Exposure Dose Guidance [ATSDR 2016 a-d], EPA's Exposure Assessment Handbook [USEPA 2011a], and Child-Specific Exposure Factors Handbook [USEPA 2008], and professional judgment. Each calculated exposure dose is compared against the corresponding health-based guidance value (health guideline). See Appendix A for a detailed discussion of ATSDR's evaluation process, dose calculation assumptions, and results.

Often, ingestion is the most significant source of exposure to chemicals in drinking water at a site. However, in the case of VOC contamination, inhalation and dermal exposures can make a significant contribution to the total exposure dose. In Dorado, people could have been exposed to these chemicals in several ways:

- Ingestion: People could drink the water or eat food prepared using the water.
- Inhalation: People could breathe in VOCs that volatilized (moved into the air) from water during showering, bathing, or other household uses. Showering is considered a major contributor to overall exposure because VOCs evaporate quickly from hot water into the air. Showering is typically done in a small, enclosed space where VOC concentrations might build up. About 50% to 90% of VOCs in water may volatize during showering, laundering, and other activities [Moya et. al. 1999; Giardino and Andelman 1996].
- Dermal Exposure: In addition to breathing in the VOCs from the air, people can absorb chemicals through their skin. People could have absorbed VOCs through their skin during showering, bathing, or other activities.

ATSDR used the Shower and Household Water-use Exposure (SHOWER) Model, a three-compartment model to evaluate residential exposure to PCE and TCE volatilizing from indoor water use. The SHOWER model accounts for inhalation and dermal exposures from most common indoor water uses, including showering, bathing, clothes washers, and dishwashers. The model predicts exposures for the entire day and for households of up to four persons [ATSDR 2018].

Because PCE and TCE have the same toxic endpoints via the oral and inhalation routes, results from this shower model were added to our estimates of ingestion exposure for a combined total estimated exposure dose.

ATSDR compared the effect levels in key scientific studies to the estimated exposure doses (from ingestion, inhalation, and dermal exposures) for children and adults in order to evaluate the potential for health effects.

As mentioned earlier in this document, Dorado has four drinking water systems that blend groundwater and surface water to provide the public drinking water supply to the Dorado area. For the reasons listed below, ATSDR used the maximum values (worst-case scenario assumption) of detected chemicals to estimate exposure doses for the Dorado population:

(1) Groundwater wells are deactivated and reactivated periodically. However, a complete schedule (e.g., annual percentage contribution of operating wells) for the use of wells were not available. The only available information was for the year 2015 as listed in Appendix C Table 13.
(2) The Super Aqueduct water is mixed with groundwater for distribution. It has been connected to the Dorado groundwater system since 2001. We only have information for the percentage contribution from the system for the year 2015. We assumed the percentage contribution is the same from 2001 to 2016. Mixing groundwater and surface water will change the concentration of contaminants present in the systems.
(3) VOCs were first detected in the groundwater wells in 1984. However, we do not have historical well data from 1984-2001. Complete data are not available for every well when they were active. For example, Maguayo II was constructed in 1968 and is still active currently, but we are missing data from 1984 through 2001. We only have data for PCE and TCE in years 2002 and 2003. Data were missing from 2004, 2005, 2006, and 2008. Data were also missing for other wells as indicated in Appendix C Table 15. We assumed the exposure started in 1984 and the contamination levels from 1984 to 2001 were similar to the years for which we have data; however, the levels could have been higher or lower.

Trichloroethylene (TCE) Exposure

TCE is a colorless and volatile liquid used as a solvent for cleaning metal parts. Liquid TCE evaporates quickly into the air. It is nonflammable and has a sweet odor. TCE is only slightly soluble in water, but there is evidence that dissolved TCE remains in groundwater for long periods. When present in groundwater, free-phase TCE tends to settle into a layer at the bottom of the aquifer and then continuously dissolves into the groundwater [ATSDR 2014].

Potential Non-Cancer Health Effects from TCE Exposure in Water

Adverse non-cancer health effects associated with chronic oral TCE exposure include decreased body weight, liver and kidney effects, and neurological, immunological, reproductive, and developmental effects evidenced in animal and human studies. Previous epidemiological studies of women living in areas where the drinking water was contaminated with TCE, as well as other VOCs, have suggested an increased risk of several types of birth defects. Studies in Arizona and New Jersey suggested an association between TCE contamination in public drinking water wells and cardiac defects, and the New Jersey study also found an increased risk of oral clefts and neural tube defects [Bove *et. al*., 1995, Goldberg *et. al*, 1990]. Studies of women exposed to TCE-contaminated drinking water have shown some evidence of increased risks of low or very low birth weight, term low birth weight, and small for gestational age. In laboratory animals, exposure to high levels of TCE has damaged the central nervous system, immune system, liver and kidneys, and adversely affected reproduction and development of offspring [ATSDR 2014]. ATSDR adopted EPA's RfD of 0.0005 mg/kg/day as its chronic oral MRL in January 2013 [ATSDR 2013].

Dorado groundwater TCE data were available from 2002 to 2015 for eight wells. TCE concentrations ranged from non-detected to 6.4 µg/L among more than 200 samples. Half of the samples have TCE concentrations below the detection limit of 0.5 µg/L. Only three samples from Maguayo wells III and VI have levels above the EPA MCL of 5.0 µg/L. The highest concentration of 6.4 µg/L was recorded in February 2006 from Maguayo well III.

Using the highest measured TCE concentration (6.4 µg/L) results in estimated total doses ranging from 0.0007 to 0.003 mg/kg/day (Table 3). This is the "worst-case" assumption that would result in the highest dose expected. In addition to using the maximum TCE concentration, we used the reasonable maximum exposure (RME)- that is the maximum exposure reasonably expected for a population. For example, we used the highest exposed person in the SHOWER model scenario; that is, we assumed that the individual lives in a 4-person household and showers after four consecutive morning showers with no ventilation fan and stays in the house all day. Generally, the estimated doses are higher for young children (1-6 years) than for older children (6 to <21 years) and adults (21+ years). ATSDR compared the estimated exposure doses to ATSDR's MRL of 0.0005 mg/kg/day. All of the exposure doses for children and adults exceed the MRL (Table 4); therefore, ATSDR compared the estimated exposure doses with effect levels from available studies. The most sensitive observed adverse effects, which were used as the primary basis for the RfD and MRL, were based on the co-critical effects of heart malformations (rats), adult immunological effects (mice), and developmental immunotoxicity (mice), all from oral studies. The lowest dose shown in scientific studies to have a decreased thymus weight and developmental immunotoxicity is 0.37 mg/kg/day. Low to very low levels of evidence indicate the potential for developmental cardiotoxicity in children of mothers exposed during pregnancy, but the studies available are not of sufficient quality to provide an exposure dose or air concentration at which developmental cardiotoxicity, if any, may occur [ATSDR 2025]. EPA selected 0.0005 mg/kg/day as the chronic RfD because it was the midpoint of the candidate RfDs following rounding to one significant figure. ATSDR used the same methodology in determining the ATSDR chronic-duration oral MRL for TCE. Regarding the weight of evidence for, and human relevance of, fetal cardiac malformations observed in rats, the reader is referred to the updated conclusions reported in the Targeted Systemic Evidence Map (SEM) and Rapid Systematic Review for Trichloroethylene and Developmental Cardiotoxicity (ATSDR

2025). All estimated doses for Dorado residents are many times lower than the lowest doses of observed adverse effects.

Table 3. Estimated Total TCE Exposure Doses from Exposure to the Public Drinking Water Supply in the Dorado area

Age Group (years)	Ingestion Dose (mg/kg/day)	Inhalation Dose (mg/kg/day)	Dermal Absorption Dose (mg/kg/day)	Total Dose (mg/kg/day)	Above ATSDR chronic-duration oral MRL of 0.0005 mg/kg/day (Yes/No)
0 - <1	0.0009	0.00098	0.000036	0.0010	Yes
1 - <2	0.0005	0.0025	0.000024	0.0030	Yes
2 - <6	0.0004	0.0017	0.000021	0.0021	Yes
6 - <11	0.0003	0.00096	0.000017	0.0013	Yes
11 - <16	0.0002	0.00065	0.000014	0.0009	Yes
16 - <21	0.0002	0.00051	0.000013	0.0007	Yes
>21	0.0002	0.00045	0.000012	0.0007	Yes
Pregnant women (16-45)	0.0002	0.0006	0.000013	0.0008	Yes

MRL- Minimal Risk Level

Potential Cancer Health Effects from TCE Exposure in Drinking Water

TCE exposures can cause cancer, with increased susceptibility for early-life exposures. The occupational studies of relatively high TCE exposures have shown increased risks for several types of cancer. The most consistent evidence has been for kidney, liver, and esophageal cancers and non-Hodgkin's lymphoma [ATSDR 2014]. Additional evidence from occupational studies points to possible relationships between TCE exposure and increased risk of Hodgkin's lymphoma, cervical cancer, multiple myeloma, bladder cancer, female breast cancer, and prostate cancer [Krishnadasan et al. 2007; Sung et al. 2007; Siegel Scott and Chiu 2006; Zhao et al. 2005; Hansen et al. 2001; Wartenberg et al. 2000; ATSDR 2014]. Many of these studies have strong limitations including unknown exposure levels and small sample sizes. In addition, many of these studies were unable to adequately separate the effects of TCE from other solvents present in the workplace.

The Department of Health and Human Services (DHHS) National Toxicology Program (NTP) classifies TCE as reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity from studies in humans, sufficient evidence of carcinogenicity from studies in experimental animals, and information from studies on mechanisms of carcinogenesis [NTP 2016]. The human studies were epidemiological studies that showed increased rates of liver cancer and non-Hodgkin's lymphoma, primarily in workers who were exposed to TCE on the job. The animal studies showed increased numbers of liver, kidney, testicular, and lung tumors by two different routes of exposure.

The International Agency for Research on Cancer (IARC) has determined that TCE is a known human carcinogen. Evidence for cancer is based on kidney cancer, limited evidence for non-Hodgkin lymphoma and liver cancer as well as various tumors in animals [IARC 2012].

EPA characterizes TCE as “carcinogenic to humans” by all routes of exposure [USEPA 2011b]. This conclusion is based on human epidemiology studies showing associations between human exposure to TCE and kidney cancer, non-Hodgkin’s lymphoma, and liver cancer. EPA published an oral cancer slope factor for TCE of 0.046 per milligram per kilogram of body weight per day and an inhalation unit risk of 0.0000041 per microgram per cubic meter of air reflecting total incidence of kidney, non-Hodgkin’s lymphoma, and liver cancers [USEPA 2011b]. EPA used a PBPK model-based route-to-route extrapolation of the inhalation unit risk estimate for kidney cancer, with a factor of 5 applied to include non-Hodgkin’s lymphoma and liver cancer risks, to obtain an oral slope factor for combined cancer risk of 0.046 per milligram per kilogram of body weight per day, or 0.046 per milligram per kilogram of body weight per day. The combined cancer slope factor can be split into individual component slope factors as follows: for kidney cancer, the oral slope factor is 0.00933 per milligram per kilogram of body weight per day; for non-Hodgkin’s lymphoma, the oral cancer slope factor is 0.0216 per milligram per kilogram of body weight per day; and for liver cancer, the oral cancer slope factor is 0.0155 per milligram per kilogram of body weight per day.

EPA also concluded, by weight of evidence evaluation, that TCE is carcinogenic by a mutagenic mode of action for induction of kidney tumors. As a result, increased early-life susceptibility is assumed for kidney cancer, and age-dependent adjustments factors (ADAFs) should be used for the kidney cancer component of the total cancer risk when estimating age-specific cancer risks. The ADAFs are factors by which cancer risk is multiplied to account for increased susceptibility to mutagenic compounds early in life. Standard ADAFs are 10 (for ages below 2 years old), three (for ages 2 up to 16 years old), and 1 (for ages greater than 16).

For a given age group, the estimated increased risk of developing cancer resulting from exposure to the contaminants was calculated by multiplying the site-specific estimated exposure dose, by an appropriate cancer slope factor. EPA values can be found at http://www.epa.gov/iris, the appropriate ADAF, and the fraction of a 78-year lifetime under consideration. Using the above factors, ATSDR calculated the lifetime excess cancer risk from exposure to the maximum concentrations of TCE in well water. The excess cancer risk is the number of increased cases of cancer in a population over a lifetime above background that may result from exposure to a particular contaminant under the assumed exposure conditions. For example, an estimated cancer risk of one in a million (0.000001) represents a possible one excess case of cancer in a population of one million people. Because of the uncertainties and conservatism inherent in deriving the cancer slope factors, this is only an estimate of risk; the true risk is unknown. ATSDR calculated the excess cancer risk for people exposed to 6.4 µg/L TCE in water using the total exposure doses in Table 4. We assumed that children were exposed for 21 years (from birth to >21 years of age) and that adults were exposed for a total of 33 years.

Table 4. Estimated Increased Risk of Cancer from Exposure to TCE in Contaminated Drinking Water at the Dorado Site

Age Group	Estimated Cancer Risk for 6.4 µg/L
Children: birth to <21 years (21 years exposure)	6 additional cases per 100,000 exposed individuals
Adults: +21 years (33 years exposure)	1 additional case per 100,000 exposed individuals

Based on the calculated cancer risk for long-term exposure, children and adults exposed to the maximum (6.4 µg/L) level of TCE in drinking water would have a low increased risk for cancer health effects. Stated another way, exposure to 6.4 µg/L TCE in drinking water would result in 1 and 6 extra cases of cancer for every 100,000 exposed adults and children, respectively. Cancer is a common disease, and the lifetime risk of being diagnosed with any form of cancer is about 38.5%—about 38,500 out of every 100,000 people [Howlader et. Al 2017]. This is considered a low increased risk of cancer. Please note this is a theoretical estimate of cancer risk that is used by ATSDR as a tool for deciding whether public health actions are needed to protect health — it is not an actual estimate of cancer cases in a community.

Tetrachloroethylene (PCE) exposure

PCE is also known as perchloroethylene. It is a widely used industrial solvent for degreasing, dry cleaning, and other, similar uses [ATSDR 2019]. People who are exposed for long periods to low levels of PCE may have changes in mood, memory, attention, reaction time, or vision. Studies in animals exposed to PCE have shown liver and kidney effects and changes in brain chemistry.

Potential Non-Cancer Health Effects from PCE Exposure in Drinking Water

From February 2002 to May 2015, more than 200 groundwater samples were collected from the wells and analyzed for PCE. In 2019, EPA sampled 19 groundwater wells in the Dorado drinking water systems contributing to the public drinking water supply during April-May (Round 1) and August 2019 (Round 2) as part of the remedial investigation/feasibility study (RI/FS) and Human Health Risk Assessment (HHRA). PCE concentrations ranged from non-detect to 15 µg/L. The highest concentration (15 µg/L) was recorded in 2019 from the Maguayo IV well [USEPA 2020].

ATSDR's MRL for chronic-duration oral PCE exposure is 0.008 mg/kg/day. The MRL is based on a lowest-observed-adverse-effect level of 2.3 mg/kg/day for color-vision loss with uncertainty factors applied. EPA has established an RfD of 0.006 mg/kg/day for PCE. The RfD is based on neurologic effects in adults exposed to PCE in air at work; effects were estimated to occur at doses ranging from 2.6 - 9.7 mg/kg/day. Uncertainty factors were applied to these points of departure to obtain RfDs ranging from 0.0026-0.0097 mg/kg/day [USEPA 2012b].

To calculate the estimated exposure doses, we used the maximum PCE concentration of 15 µg/L and the exposure assumptions also used for TCE. Table 6 shows the estimated exposure doses. Total PCE doses for all age groups are lower than both EPA's oral RfD and ATSDR's chronic-duration oral MRL. ATSDR concludes non-cancer effects are not expected for this exposure to PCE because: (1) conservative exposure assumptions ("worst-case" exposure assumptions) were used for dose estimation; and (2) the total estimated doses for all age groups were below the RfD and MRL.

Table 5. Estimated Total PCE Exposure Doses from Exposure to the Public Drinking Water Supply in the Dorado area

Age Group (year)	Ingestion Dose (mg/kg/day)	Inhalation Dose (mg/kg/day)	Dermal Absorption Dose (mg/kg/day)	Total Dose (mg/kg/day)	Above ATSDR chronic-duration oral MRL of 0.008 mg/kg/day (Yes/No)
0 - <1	0.0021	0.0039	0.0003	0.0064	No
1 - <2	0.0012	0.0049	0.0002	0.0062	No
2 - <6	0.0009	0.0031	0.0002	0.0042	No
6 - <11	0.0006	0.0017	0.0002	0.0025	No
11 - <16	0.0005	0.0012	0.0001	0.0018	No
16 - <21	0.0005	0.0009	0.0001	0.0015	No
>21	0.0005	0.0008	0.0001	0.0015	No
Pregnant Women (16-45)	0.0006	0.0011	0.0001	0.0018	No

MRL- Minimal Risk Level

Potential Cancer Health Effects from PCE Exposure in Water

Regarding cancer effects, studies in humans suggest that exposure to PCE might lead to a higher risk of getting bladder cancer, multiple myeloma, or non-Hodgkin's lymphoma. In animals, PCE has been shown to cause cancers of the liver, kidney, and blood system. The DHHS NTP classifies PCE as a reasonably anticipated human carcinogen, and the IARC has determined that PCE is a probable human carcinogen. These determinations are based on limited human epidemiological studies suggesting elevated risks for esophageal cancer, non-Hodgkin's lymphoma, cervical cancer, and sufficient animal studies showing PCE-induced leukemia in rats and liver cancers in mice [NTP 2011, IARC 1995]. EPA considers PCE a likely human carcinogen based on epidemiological evidence showing associations between PCE and bladder cancer, non-Hodgkin's lymphoma, and multiple myeloma [USEPA 2012b]. Many of these studies have strong limitations including no measured exposure levels, small sample sizes, and inability to adequately separate the effects of PCE from other solvents present in the workplace.

EPA's oral cancer slope factor is 0.0021 per milligram per kilogram of body weight per day [USEPA 2012b]. Using this value, and assuming children and adults drank water containing 15 µg/L of PCE every day for up to 21 years and 33 years, respectively we calculated an estimated cancer risk for people who use the contaminated public drinking water supply at the site.

Appendix A provides details of the cancer risk calculation.

Table 6. Estimated Increased Risk of Cancer from Exposure to PCE in the Public Drinking Water Supply coming from the Dorado Drinking Water Systems

Age Group	Estimated Cancer Risk for 15 µg/L
Children: birth to <21 years (21 years exposure)	less than 2 additional cases per 100,000 exposed individuals
Adults: +21 years (33 years exposure)	1 additional case per 1,000,000 exposed individuals

Based on the cancer risk for long-term exposure, children and adults exposed to the maximum (15 µg/L) levels of PCE in drinking water are not at increased risk for cancer health effects. Cancer is a common disease, and the lifetime risk of being diagnosed with any form of cancer is about 38.5%—about 38,500 individuals out of every 100,000 people [Howlader et. Al 2017]. Exposure to 15 µg/L PCE in drinking water would be estimated to result in less than two additional cases of cancer for every 100,000 exposed adults and children. This is considered a very low increased risk of cancer. Please note this is a theoretical estimate of cancer risk that is used by ATSDR as a tool for deciding whether public health actions are needed to protect health — it is not an actual estimate of cancer cases in a community.

Disinfectants and Disinfection Byproducts (DBPs) Exposures

Some disinfectants and DBPs were detected in the Dorado drinking water systems. The majority of those were found in the Super Aqueduct system. ATSDR reviewed the Super Aqueduct quarterly test results provided by PRASA for the past 15 years. Six chemicals exceeded their respective health-based CVs and are discussed below including disinfectants (dichloramine and monochloramine) and DBPs (bromodichloromethane, dibromochloromethane, dichloroacetic acid, and trichloroacetic acid).

Disinfectants

Dichloramine and monochloramine are chloramines that form during a reaction between chlorine and ammonia. Chloramines (also known as secondary disinfection) are disinfectants used to treat drinking water. When chloramines are used as a disinfectant, ammonia is added to chlorine treated water. Chloramines are as effective as chlorine for the deactivation of bacteria and other microorganisms, and they are used to maintain residual disinfection activity in the drinking water distribution system to provide longer-lasting disinfection as the water moves through pipes to consumers. Chloramines have been used by water utilities in the United States since the 1930s [USEPA 2017].

Potential Non-Cancer Health Effects from Monochloramine and Dichloramine Exposure in Drinking Water

EPA established an oral RfD of 0.1 mg/kg/day for monochloramine based on the assumption that a threshold exists for toxic effects like cellular necrosis. The main toxicological study used to establish the RfD examined effects in rats and mice that drank chlorinated drinking water for

103-104 weeks. No clinical changes due to chlorinated drinking water consumption, and no non-neoplastic lesions after the 2-year treatment were found. They established a no-observed-adverse-effect-level (NOAEL) of 200 milligrams per liter (mg/L) or 9.5 mg chloramine/kg/day for mice. An uncertainty factor of 100 was used to reflect 10 for interspecies extrapolation and 10 for the protection of sensitive human subpopulations when developing the RfD [NTP 1992].

ATSDR established an RMEG of 0.7 mg/L for monochloramine and dichloramine using EPA's RfD and default exposure assumptions.

For public drinking water systems, EPA's Maximum Residual Disinfectant Level Goal (MRDLG) for chloramine is 4 mg/L [which is 4,000 µg/L or 4 parts per million]. Concentrations below this level are considered safe, and no harmful health effects are likely to occur. Potential health effects from long-term exposure above the MRDLG are eye/nose irritation, stomach discomfort, and anemia. Dichloramine has been linked to skin, eye, and respiratory problems in relation to indoor swimming pools and hot tubs. [USEPA 1998]

Current studies indicate that using water with small amounts of monochloramine does not cause harmful health effects and provides relative protection from exposure to waterborne microorganisms of health concern.

Studies report that drinking water with chloramine levels less than 50 mg/L (50,000 µg/L) produces no observed health effects. Normal levels found in disinfection can range from 1 to 4mg/L [CDC 2018].

At the Dorado site, most detected levels of monochloramine and dichloramine were below the RMEG (Figure 2 and Figure 3). Although the maximum levels of monochloramine and dichloramine were detected above the RMEG, the levels were well below the MRDLG of 4 mg/L, the CDC's reporting level of 50 mg/L, and the NOAEL of 200 mg/L. Therefore, based on the "worst-case" exposure assumptions, non-cancer health effects are not expected for this exposure to monochloramine and dichloramine.

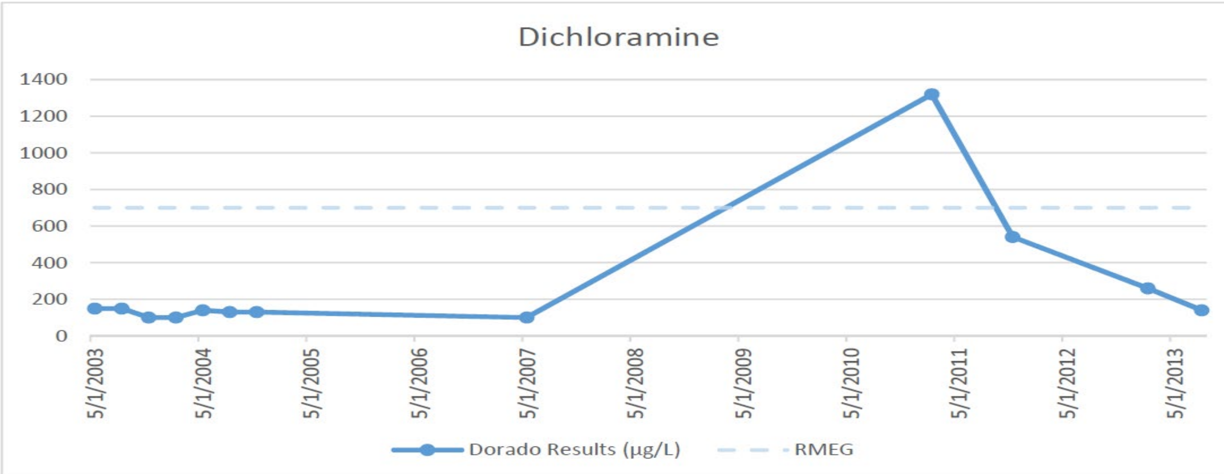

Figure 2. Dichloramine Concentrations Over Time in Super Aqueduct System, Dorado, Puerto Rico

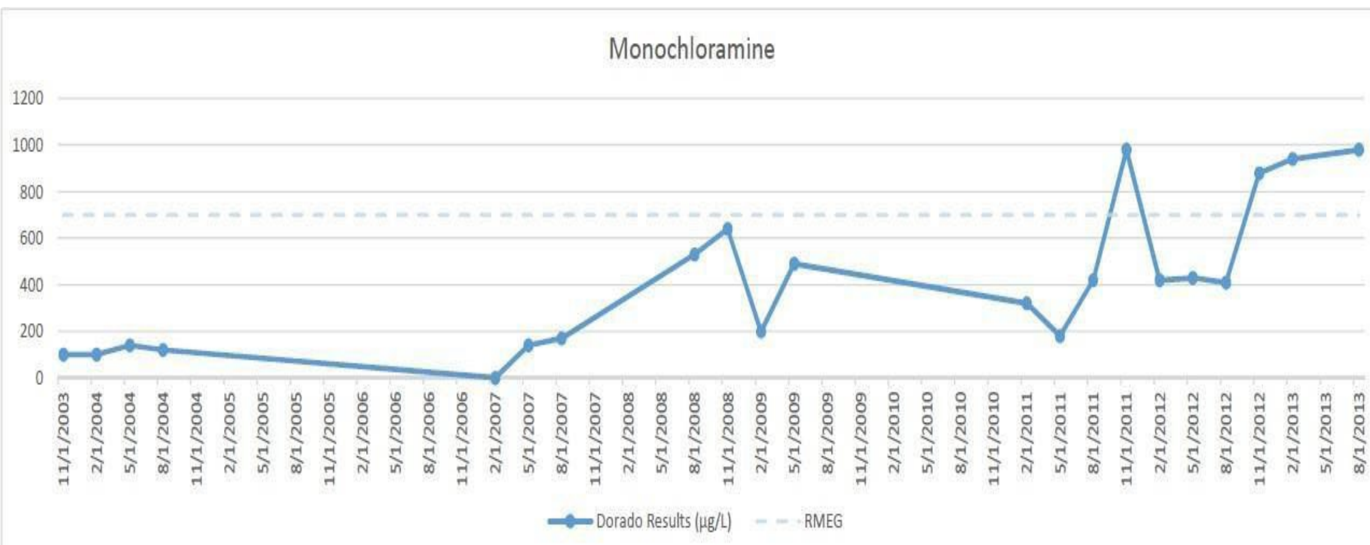

Figure 3. Monochloramine Concentrations Over Time in Super Aqueduct System, Dorado, Puerto Rico

Potential Cancer Health Effects from Monochloramine and Dichloramine Exposure in Drinking Water

EPA considers monochloramine not classifiable as a human carcinogen based on inadequate human data and equivocal evidence of carcinogenicity from animal bioassays [USEPA 2005]. A 2-year bioassay showed a marginal increase in mononuclear cell leukemia in female F344/N rats. No evidence of carcinogenic activity was reported in male rats or in male or female B6C3F1 mice. Genotoxicity studies, both in vitro and in vivo, yielded no evidence of genotoxicity. There are no epidemiological studies of monochloramine by itself. It has been mostly studied in conjunction with other DBPs or water quality. EPA has not established an oral cancer slope factor (CSF) for chloramines [USEPA 2005].

It should be noted that animal studies used very high concentrations of chloramines to induce cancer activities and the evidence of carcinogenicity from animal studies are inconsistent.

Without a CSF for a cancer risk calculation, plus data limitations as described in the "Environmental Data Evaluation" section, ATSDR cannot conclude whether exposures to the levels of monochloramine and dichloramine in the public drinking water supply at the Dorado site could result in increased risk for cancer.

Disinfection-by-products (DBPs)

When chlorine is used to kill microorganisms of health concern, such as many types of viruses and bacteria in the drinking water, it reacts with the microbes and naturally occurring organic material to form chlorination byproducts called trihalomethanes (THMs). THMs include chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

When chlorine or other disinfectants are used in drinking water systems, a group of chemicals called halo acetic acids (HAAs) are formed along with other DBPs. HAAs include monochloroacetic acid, dichloroacetic acid (DCA), trichloroacetic acid (TCA), monobromoacetic acid, and dibromoacetic acid.

At the Dorado site, four DBPs (bromodichloromethane, dibromochloromethane, DCA, and TCA) were detected above their respective CVs and evaluated further (Table 2).

Potential Non-Cancer Health Effects from DBP Exposure in Water

The effects of DBPs on people's health depend largely on the amount a person takes into their body and the duration of exposure. For example, the main effect of swallowing or breathing large amounts of bromoform is slowing of normal brain activities, which results in sleepiness or sedation occurring quickly after the chemicals enter the body. Exposures capable of producing these effects include swallowing 1-4 drops of liquid bromoform, an amount much greater than is usually found in a glass of drinking water. In animal studies, animals exposed to high doses of bromoform or dibromochloromethane may also develop liver and kidney injury within a short period. Exposure to low levels of bromoform or dibromochloromethane does not appear to seriously affect the brain, liver, or kidneys. Other animal studies suggest that typical bromoform or dibromochloromethane exposures do not pose a high risk of affecting the chance of becoming pregnant or harming an unborn baby. Bromodichloromethane is not known to cause adverse health effects in people, but animal studies show that high concentrations can damage the liver and kidneys and affect the brain [USEPA 2005].

Adverse health effects of HAAs include skin irritation, loss of skin, inflammation and degeneration of the structural protein collagen, and increase in the risk of birth defects. Those effects are caused by exposure to high concentrations (from LOAEL of 12.5 mg/kg/day for DCA and 7.6 mg/kg/day for TCA) [USEPA 2003, 2011c].

At the Dorado site, all concentrations of the detected DBPs were below levels that would cause any non-cancer adverse health effects. In addition, the Super Aqueduct water is mixed with groundwater that would change (likely reduce) the HAA concentrations in the drinking water. Therefore, based on the "worst-case" exposure assumptions, ATSDR concludes non-cancer effects are not expected for exposure to DBPs.

Potential Cancer Health Effects from DBP Exposure in Drinking Water

Although the concentrations of DBPs in the public drinking water supply are low, people are exposed to them daily and for long periods. Carcinogenic activities of DBPs were only shown in laboratory studies of animals exposed to high concentrations. The IARC concluded that dibromochloromethane is not classifiable as a human carcinogen [IARC 1991]. The EPA classified dibromochloromethane and bromodichloromethane as possible human carcinogens based on animal studies for liver, kidney, and intestinal cancers. Those increased cancers in animals occurred in high doses. For example, intestinal tumors occurred at high doses above 100 mg/kg/day [USEPA 2003 and 2011c].

The EPA has classified HAAs as a class of probable human carcinogen. However, this classification is based on studies performed on animals, and the evidence to support its carcinogenicity in humans is limited. Experiments on mice exposed to varying levels (up to 5 g/L) of trichloroacetic acid in drinking water for 60 weeks showed an increase in the development of liver tumors and liver cancer [USEPA 2003, 2011c].

At the Dorado site, the majority of DBPs were found in the Super Aqueduct system. As mentioned before, the Super Aqueduct water is mixed with groundwater that would change (likely dilute) the HAA concentrations in the drinking water. However, ATSDR does not have a complete schedule (e.g., annual percentage contribution of operating wells in the public drinking water system) of the activities for this evaluation. In addition, lack of data from point of exposure (tap water) increases the uncertainty of accurately assessing the potential impact of exposures.

Therefore, ATSDR cannot conclude whether exposures to the levels of DBPs in drinking water at the Dorado site could result in an increased risk for cancer. The benefits of using disinfecting chemicals to kill germs that could cause sudden and severe life-threatening illness such as cholera, typhoid, and dysentery far outweigh their potential low increased risk of cancer.

10. Community Health Concerns

There are no known community groups established in relation to this site. During the site visit in 2016, ATSDR staff met with the Mayor of Dorado and his staff. There was no formal concern or complaint expressed from the mayor's office, nor the community, at the time of the meeting. The mayor's environmental office members, the Caribbean Environmental Protection Division (EPA CEPD) community coordinators, PREQB, PRDOH, and PRASA officials were made aware of the public health assessment process and were requested to convey any community concerns that may arise.

In September 2017, Hurricanes Irma and Maria made landfall in Puerto Rico and caused widespread flooding and devastation. The site drinking water infrastructure was not functional and mostly out of service due to lack of electric power and major infrastructure damage. On October 14, 2017, CNN news reported that Puerto Rican citizens were drinking water from a hazardous waste site located in Dorado [Sutter, 2017]. Some of these wells are approved for consumption by the PRDOH and PRASA (e.g., Santa Rosa and Nevarez well). These wells were being used to provide water tankers with potable water for distribution. The other wells that had been accessed by the public, Maguayo II and VI, did not have TCE/PCE above their MCLs. Citizens were also seen filling up cisterns at Maguayo IV. EPA and PRASA secured the fencing around the wells mentioned and conducted sampling of well locations throughout the site. Sampling results were discussed in an EPA news release that stated that EPA water sample results show there are no exceedances of drinking water standards at the Dorado Groundwater Superfund site in Puerto Rico [EPA 2017]. ATSDR did not receive community concerns regarding the drinking water contamination at this site following the hurricanes.

11. Data Limitations and Uncertainties

The purpose of our evaluation is to assess the potential impact that the environmental contamination may have on the community's health, but there are limitations in the environmental data available. Specifically, ATSDR was unable to obtain critical environmental data for the site. The major limitations are:

- The Dorado site has a very complex water system. Groundwater from different wells and surface water from the Super Aqueduct are mixed before distribution. The wells are taken off-line and reactivated periodically. ATSDR does not have a complete schedule (e.g., annual percentage contribution of operating wells in the drinking water system) of the activities for this evaluation. Such information is only available for one year (2015).
- Historical documents indicated that VOCs have been detected in the water systems since 1984 [USGS 1986]. Historical data from 1984-2001 were not available for this review. From 2002 to 2016, we have a large amount of data, but it is incomplete. The Super Aqueduct system did not have any VOCs above detection limits in the available data. However, DBPs were encountered in the Super Aqueduct system and not found in available well data. See Appendix C Table 15 for missing data information.
- Lack of tap water data: Most samples were collected from groundwater wells and the Super Aqueduct before the water was mixed and delivered to the tap of individual residences. Therefore, the levels of contaminants were likely much lower at the point of exposure (tap water).
- Because no cancer slope factors exist for some of the detected disinfectants and DBPs, plus the data limitations listed above, ATSDR cannot conclude whether exposures to the levels of disinfectants and DBPs in the public drinking water supply could result in increased risk for cancer. Due to the relatively low detections of these compounds, ATSDR believes the

benefits of using disinfecting chemicals to kill germs that could cause sudden and severe life-threatening illness far outweigh their potential low increased risk of cancer.

When limitations existed, ATSDR chose to be more conservative in an effort to be protective of the community's health. Therefore, actual exposures may have been different from those described in this document.

12. Conclusions and Recommendations

ATSDR reached the following conclusions in this PHA:

Conclusion 1

People using the public drinking water supply for drinking, cooking, and bathing in the Dorado area from 1984 (when contamination was first discovered) to the present day are not likely to have harmful health effects from the low levels of chemicals in the water.

Basis for Conclusion

ATSDR found some chemicals in the public drinking water supply related to the groundwater contamination (site-related) and other chemicals related to the addition of disinfectants to kill germs in the water (not-site-related).

Site-Related Chemicals (Groundwater Contamination)

Trichloroethylene (TCE)

- **Few samples contained TCE above drinking water standards**. Only three of the more than 200 samples tested had TCE levels above 5.0 parts per billion (ppb), EPA's drinking water standard.
- **Wells with higher levels were closed.** TCE levels ranged from non-detected to 6.4 ppb. Half of the samples had TCE levels below the detection limit of 0.5 ppb. The highest level (6.4 ppb) was recorded in February 2006 from the Maguayo III well, which was removed from service in 2011 [PRASA 2017].
- **Estimated doses were lower than dose levels showing health problems.** ATSDR estimated exposure doses using the maximum concentration of TCE of 6.4 ppb, which resulted in estimated total doses for TCE exposures ranging from 0.0005 to 0.0022 milligrams per kilogram per day (mg/kg/day) for different age groups. These doses are well below the effect level (0.37 mg/kg/day) from available scientific studies that showed decreased thymus weights and developmental immunotoxicity. Therefore, TCE levels in the public drinking water supply are not likely to harm people's health [ATSDR 2013, 2014].
- **Estimated cancer risk was low.** ATSDR estimated lifetime increased cancer risks for long-term exposures to the maximum concentration of 6.4 ppb TCE. The estimated risks, less

than 2 and 6 extra cases of cancer for every 100,000 exposed adults or children, respectively, are considered low.

PCE

- **Few samples contained PCE above drinking water standards.** PCE levels ranged from non-detected to 15 ppb. From 2008 to 2015, about 10 percent of the samples had PCE levels above 5.0 ppb. The highest level (15 ppb) was recorded in 2019 from the Maguayo IV well [USEPA 2020].
- **Estimated doses were lower than dose levels showing health problems.** ATSDR estimated exposure doses using the maximum concentration of PCE of 15 ppb, which resulted in estimated doses ranging from 0.0015 to 0.0064 mg/kg/day based on age group. This estimated dose range is lower than EPA's and ATSDR's health-based guidance values (health guideline) of 0.006 mg/kg/day and 0.008 mg/kg/day for non-cancer effects, respectively and, therefore, not likely to harm people's health.
- **Estimated cancer risk was low.** ATSDR estimated lifetime increased cancer risk for long-term exposures to the maximum concentration of 15 ppb PCE. The estimated risks, less than 2 for every 100,000 exposed adults or children, are considered very low.

Disinfection-Related Chemicals (Not Site-Related)

- **Disinfection-related chemicals did not exceed drinking water standards.** All maximum concentrations of disinfection-related chemicals did not go above EPA's safe drinking water standards and ATSDR non-cancer comparison values. Therefore, they would not likely be associated with harmful non-cancer health effects such as skin irritation, liver, or kidney injury. Additionally, the average concentrations of those chemicals in the public drinking water supply would likely be lower than the maximum value since the water is mixed before reaching residential taps.
- **Cancer risk cannot be calculated.** ATSDR cannot conclude whether exposures to the levels of disinfectants and disinfection-by-products (DBPs) in the public drinking water supply could result in increased cancer risk. The reason for this is because there are significant data limitations (lack of complete mixing percentage contribution and the lack of tap water sampling data for the site for DBPs, and no cancer slope factors for some of the detected disinfectants and DBPs) to estimate increases in cancer risk. The benefits of using disinfecting chemicals to kill germs that could cause sudden and severe life- threatening illness far outweigh their potential low increased risk of cancer.

Conclusion 2

ATSDR does not have enough information to determine whether harmful exposures from soil or vapor intrusion may be occurring.

Basis for Conclusion

The source of groundwater contamination remains unknown. Source areas may have higher levels of contamination. ATSDR cannot tell if anyone is coming in contact with soil or air within buildings that may be contaminated at source areas. Contaminant levels at or near the source(s) of contamination could be very different from the sampled locations. We don't have enough information to conclude whether chemicals in soil or the air inside buildings could harm people's health. We are working with the state and EPA to gather this information and to identify the source of contamination.

- **EPA has not found the source of contamination.** EPA conducted Preliminary Assessment/Site Inspections (PA/SI) at 21 facilities near the groundwater contamination to identify potential contaminant sources. EPA collected 279 soil samples, and 50 groundwater samples. There were very limited surface soil (3 samples) and soil gas samples (2 samples).
- EPA reported results from a screening level analysis of potential vapor intrusion in tested areas. Detected contaminant concentrations were compared to EPA's vapor intrusion screening levels (VISLs), and all were below the screening levels (VISLs) used for residential buildings. More details can be found in the EPA Human Health Risk Assessment (HHRA).

Next Steps

EPA and/or Puerto Rico Department of Natural and Environmental Resources (DNER) will:

- Continue efforts to identify the source, collect additional samples to characterize the extent of the contamination, and implement remedial measures to address and prevent groundwater contamination.

Puerto Rico Department of Health (PRDOH) will:

- Continue to conduct routine water monitoring per the Safe Drinking Water Act requirements, with the assistance of EPA.

Agency for Toxic Substances and Disease Registry (ATSDR) will:

- Evaluate additional data collected by EPA and PRDOH and update the findings of this report, if requested.

For More Information

For further information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the "Dorado Groundwater Contamination Site." If you have concerns about your health, please contact your health care provider.

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Appendix A: Exposure Dose Calculations

An exposure dose (usually expressed as milligrams of chemical per kilogram of body weight per day, or "mg/kg/day") is an estimate of how much of a substance a person may contact based on their actions and habits. Estimating an exposure dose requires identifying how much, how often, and how long a person or population may come in contact with a concentration of a substance in a specific medium.

To estimate exposure doses at this site, ATSDR used default exposure assumptions about weight and other body characteristics of children and adults exposed, how they may have been exposed, and how often they may have been exposed. The following section details the exposure assumptions and calculation of exposure doses for the drinking water, inhalation, and dermal contact pathways evaluated in this document.

Drinking water ingestion

Ingestion of contaminated water is one of the most significant exposure pathways at this site. ATSDR used the following equation and assumptions to estimate exposure to TCE and PCE from the ingestion of contaminated well water:

$$\textit{Exposure dose}\left(\frac{\frac{mg}{kg}}{day}\right) = \textit{chemical concentration}\left(\frac{mg}{L}\right) \times \textit{ingestion rate}\left(\frac{L}{day}\right) \div \textit{bodyweight}\,(kg) \qquad \textbf{Equation 1}$$

Table 7. Assumptions for Ingestion of Contaminated Water

Age Group (year)	Body Weight (kg)	RME Intake Rate (L/day)
Birth to <1	7.8	1.113
1 to <2	11.4	0.893
2 to <6	17.4	0.977
6 to <11	31.8	1.404
11 to <16	56.8	1.976
16 to <21	71.6	2.444
21+	80	3.1
Pregnant Women (16 to 45)	73	2.589

[ATSDR 2014b]. Agency for Toxic Substances and Disease Registry. 2014. Exposure Dose Guidance for Water Ingestion. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. November 2014.

RME = the maximum exposure reasonably expected for a population

EXAMPLE INGESTION CALCULATION

Using the equation above and values in Table 7 to calculate the amount of TCE ingested from drinking water containing the maximum TCE concentration (6.4 μg/L) for an adult (21+ years old):

Ingestion Exposure Dose

$$\frac{\mathbf{0.0064}\frac{mg}{L}\times\mathbf{3.1}\frac{L}{day}}{\mathbf{80}kg}=\frac{\mathbf{0.00025}\frac{mg}{kg}}{d}$$ **Equation 2**

Inhalation and Dermal (skin contact)

Besides drinking, the contaminated water was used for household purposes, including showering. Volatile organic compounds (VOCs) such as TCE and PCE can escape, or volatilize, from water used in the home. Breathing in (inhaling) the VOC vapors in air that occur when using contaminated water for showering can be a significant source of exposure. Dermal (skin contact) absorption of contaminants in water occurs during showering, bathing, or other household uses. ATSDR used Shower and Household Water-use Exposure (SHOWER) Model, a three- compartment model to evaluate residential exposure to PCE and TCE volatilizing from indoor water use.

The SHOWER model accounts for inhalation and dermal exposures from most common indoor water uses, including showering, bathing, clothes washers, and dishwashers. The model predicts exposures for the entire day and for households up to four persons [ATSDR 2018].

The SHOWER model outputs dermal and inhalation doses for each exposure group based on the maximum water concentration of TCE and PCE of 6.4 and 15 μg/L, respectively. The doses modeled are based on many assumptions in the SHOWER model. See Table 8 for some of the assumptions used to calculate ingestion, dermal, and inhalation doses for TCE and PCE exposure through usage of water through drinking, showering, washing hands, and other indoor appliance usage.

Table 8. Assumptions for Inhalation and Dermal Contact of Contaminated Water

Exposure Group (Year)	Body Weight (kg)	Daily Breathing Rate (L/min)	Shower and Bathroom Breathing Rate (L/min)	Total Skin Surface Area (cm²)	Hand Surface Area (cm²)
Birth to < 1	7.8	3.75	7.60	3.992	211
1 to < 2	11.4	5.56	12.00	5,300	300
2 to < 6	17.4	6.81	11.25	7,225	348
6 to < 11	31.8	8.33	11.00	10,800	510
11 to < 16	56.8	10.56	13.00	15,900	720
16 to < 21	71.6	11.32	12.00	18,400	830
Adult	80.0	10.53	12.35	19,810	980
Pregnant women	73.0	15.50	15.50	18,610	980

ATSDR used a conservative approach to calculate the inhalation and dermal doses by selecting the highest exposed person in the modeled scenario. This scenario included a person showering after four consecutive morning showers in a four-person household with no ventilation fan and assumed that the person is home all day. Each household member takes an eight-minute shower with a five-minute stay in the bathroom.

Total TCE/PCE intake from drinking water

ATSDR combined the drinking (oral), inhalation, and dermal exposures to derive a total exposure dose because TCE and PCE have the same toxic endpoints via the oral and inhalation routes. Low to very low levels of evidence indicate the potential for developmental cardiotoxicity in children of mothers exposed during pregnancy, but the studies available are not of sufficient quality to provide an exposure dose or air concentration at which developmental cardiotoxicity, if any, may occur [ATSDR 2025].

To estimate the total intake of TCE, ATSDR summed the ingestion, inhalation and skin intakes:
Total exposure dose= ingestion dose + inhalation dose + dermal dose

Table 9 and Table 10 below are results of the dose calculations.

Table 9. Estimated Total TCE Exposure Doses for Dorado Groundwater Contamination Site

Age Group (year)	Ingestion Dose (mg/kg/day)	Inhalation Dose (mg/kg/day)	Dermal Absorption Dose (mg/kg/day)	Total Dose (mg/kg/day)
0_<1	0.0009	0.00098	0.000036	0.0010
1-<2	0.0005	0.0025	0.000024	0.0030
2-<6	0.0004	0.0017	0.000021	0.0021
6-<11	0.0003	0.00096	0.000017	0.0013
11-<16	0.0002	0.00065	0.000014	0.0009
16-<21	0.0002	0.00051	0.000013	0.0007
>21	0.0002	0.00045	0.000012	0.0007
Pregnant women (16-45)	0.0002	0.0006	0.000013	0.0008

Table 10. Estimated Total PCE Exposure Doses for Dorado Groundwater Contamination Site

Age Group (year)	Ingestion Dose (mg/kg/day)	Inhalation Dose (mg/kg/day)	Dermal absorption Dose (mg/kg/day)	Total Dose (mg/kg/day)
0-<1	0.0021	0.0039	0.0003	0.0064
1-<2	0.0012	0.0049	0.0002	0.0062
2-<6	0.0009	0.0031	0.0002	0.0042
6-<11	0.0006	0.0017	0.0002	0.0025
11-<16	0.0005	0.0012	0.0001	0.0018
16-<21	0.0005	0.0009	0.0001	0.0015
>21	0.0005	0.0008	0.0001	0.0015
Pregnant Women (16-45)	0.0006	0.0011	0.0001	0.0018

Estimated Cancer Risks

The estimated risk of developing cancer resulting from exposure to the contaminants from the groundwater was calculated by multiplying the site-specific estimated exposure dose by an appropriate EPA cancer slope factor (CSF). The lifetime excess cancer risk indicates the cancer potential of contaminants. The cancer estimates are usually expressed in terms of excess cancer cases in an exposed population in addition to the background rate of cancer.

To calculate the lifetime excess cancer risk, ATSDR multiplied the oral cancer slope factor by the daily exposure dose (combined oral, inhalation, and dermal), the appropriate ADAF for TCE, and the fraction corresponding to the fraction of a 78-year lifetime under consideration.

CANCER RISK CALCULATIONS:

Table 11. Calculation of Excess Cancer Risk for Residents Exposed to TCE in Well Water via Drinking, Inhalation, and Dermal Contact – at 6.4 µg/L - Dorado Drinking Water Systems

Age Group (Year)	Estimated Total Exposure Dose (mg/kg/day)	Duration (years)	Fraction of Lifetime	ADAF	Total Cancer Risk: (Adjusted for Kidney and Unadjusted for NHL and Liver)
0 to <1	0.0010	1	1/78	10	0.0000059
1 to <2	0.0030	1	1/78	10	0.000018
2 to <6	0.0021	4	4/78	3	0.000015
6 to <11	0.0001	5	5/78	3	0.000012
11 to <16	0.0009	5	5/78	3	0.000008
16 to <21	0.0009	5	5/78	1	0.0000021
Total Years - Children		21	21/78		0.000006
Adult 21+	0.0007	33	33/78		0.000014

NHL – Non-Hodgkins Lymphoma

Table 12. Calculation of Excess Cancer Risk for Residents Exposed to PCE in Well Water via Drinking, Inhalation, and Dermal Contact – at 15 µg/L – Dorado Drinking Water Systems

Age Group (Year)	Estimated Total Exposure Dose (mg/kg/day)	Duration (years)	Fraction of Lifetime	Lifetime Cancer Slope Factor (per mg/kg/day)	Cancer Risk
0 to <1	0.0064	1	1/78	0.0021	0.00000017
1 to <2	0.0062	1	1/78	0.0021	0.0000017
2 to <6	0.0042	4	4/78	0.0021	0.00000045
6 to <11	0.0025	5	5/78	0.0021	0.00000034
11 to <16	0.0018	5	5/78	0.0021	0.00000024
16 to <21 years	0.0015	5	5/78	0.0021	0.00000024
Total Years - Children	-	21	-	-	0.00000016
Adult 21+ years	0.0015	33	33/78	0.0021	0.00000098

Appendix B Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency in Atlanta, Georgia, with 10 regional offices in the United States. ATSDR serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases from toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. For additional questions or comments, call 1-800-CDC-INFO.

Acute

Occurring over a short time [compare with chronic].

Acute exposure

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

Adverse health effect

A change in body function or cell structure that might lead to disease or health problems.

Cancer

Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk

A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen

A substance that causes cancer.

Central nervous system

The part of the nervous system that consists of the brain and the spinal cord.

Chronic

Occurring over a long time [compare with acute].

Chronic exposure

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

Comparison value (CV)

Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway

[see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. The Superfund Amendments and Reauthorization Act (SARA) later amended this law.

Concentration

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

Contaminant

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

Dermal

Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact

Contact with (touching) the skin [see route of exposure].

Detection limit

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

Dose

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose" is the amount of a substance that actually gets into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental media

Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Epidemiologic study

A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Epidemiology

The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure

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

Exposure pathway

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

Groundwater

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

Health outcome data

Information from private and public institutions on the health status of populations. Health outcome data can include morbidity and mortality statistics, birth statistics, tumor and disease registries, or public health surveillance data.

Ingestion

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

Inhalation

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

Intermediate duration exposure

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

Metabolism

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

Metabolic byproduct

Any product of metabolism.

Minimal risk level (MRL)

An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects.

MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs are not used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity

State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality

Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)

EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

Point of exposure

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

Population

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

Prevention

Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public health assessment (PHA)

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

Public health surveillance

The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Reference dose (RfD)

An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Risk

The probability that something will cause injury or harm.

Route of exposure

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

Sample

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

Sample size

The number of units chosen from a population or an environment.

Source of contamination

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

Substance

A chemical.

Superfund

[see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)

In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Toxicological profile

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

Toxicology

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

Transport mechanism

Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Volatile organic compounds (VOCs)

Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:

Environmental Protection Agency-
https://sor.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do

National Library of medicine (NIH) - (https://medlineplus.gov/appendixb.html)

Appendix C: Tables

Table 13. Summary of Drinking Water Systems Contributing to the Public Drinking Water Supply in the Dorado Area

System Name	Well Name and Super Aqueduct	PWSID*	Construction Date	Percent Contribution (2015)	Population Served (2015)	Status/Notes
Dorado	San Antonio 1	5607	Not available	0	0	Out of operation (2006)
Dorado	San Antonio 2	5607	1961	0	0	Well not operating (2005)
Dorado	San Antonio 3	5607	1978	0	0	Out of operation (2006)
Dorado	Higuillar	5607	1942	0	0	Out of operation (2005)
Dorado	Dorado Dairy 1	5607	Not available	0	0	Out of operation (2006)
Dorado	Dorado Dairy 2	5607	1994	0	0	Out of operation (2006)
Dorado	Santa Rosa	5607	1995	14.95	4,644	Operating
Dorado	Nevarez	5607	1996	14.61	4,538	Operating
Dorado	Super aqueduct	n/a	2001	70.44	21,897	Operating
Maguayo	Maguayo II	5597	1968	17.15	9,158	Out of operation (2019)
Maguayo	Maguayo III	5597	1988	0	0	Out of operation (2011)
Maguayo	Maguayo IV	5597	1979	0	0	Out of operation (2011)
Maguayo	Maguayo V	5597	Not available	0	0	Out of operation (2010)
Maguayo	Maguayo VI	5597	1988	14.23	9,158	Out of operation (2019)
Maguayo	Maguayo VII	5597	1988	30.52	9,158	Out of operation (2019)
Super aqueduct	Super aqueduct	n/a	Not available	38.1	9,158	Operating

*PWSID: Public Water System Identification Number

Table 14. PRASA Data Summary

System	Well #	Data Available (Years)
Dorado (PWSID 5607)	San Antonio 1	None
Dorado (PWSID 5607)	San Antonio 2	2009, 2015
Dorado (PWSID 5607)	San Antonio 3	2015
Dorado (PWSID 5607)	Higuillar	2015
Dorado (PWSID 5607)	Dorado Dairy 1	None
Dorado (PWSID 5607)	Dorado Dairy 2	2015
Dorado (PWSID 5607)	Santa Rosa	2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015
Dorado (PWSID 5607)	Nevarez	2011, 2012, 2013, 2014, 2015
Vivoni (PWSID 5616)	Vivoni	2007, 2008, 2009, 2010
Maguayo (PWSID 5597)	Maguayo II	2002 (PCE/TCE only), 2003 (PCE/TCE only), 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015
Maguayo (PWSID 5597)	Maguayo III	2002 (PCE/TCE only), 2003 (PCE/TCE only), 2004 (PCE/TCE only), 2005 (PCE/TCE only), 2006 (PCE/TCE only), 2007, 2008, 2009, 2010, 2011, 2012, 2013
Maguayo (PWSID 5597)	Maguayo IV	2007, 2009, 2010, 2011
Maguayo (PWSID 5597)	Maguayo V	2002 (PCE/TCE only), 2007, 2008, 2009, 2010, 2011, 2012, 2013

System	Well #	Data Available (Years)
Maguayo (PWSID 5597)	Maguayo VI	2002 (PCE/TCE only), 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015
Maguayo (PWSID 5597)	Maguayo VII	2002 (PCE/TCE only), 2010, 2011, 2012, 2013, 2014, 2015

Table 15. Facilities for Preliminary Assessment/Site Inspections from 2011-2013 and Facilities for Site Reassessment in 2015

Location	Number of Ground water Samples	Number of Soil Samples (Depth)	Number of Soil Gas Samples	Sample Year
Higuillar Dry Cleaner	2	15 (0.3-31.3’)	0	2015
Green Point Sign and Screen Printing	2	19 (0.5-31.5’)	0	2013
PRIDCO Building No: L-439-0-97	0	41 (1-39.9’)	0	2015
Adriel Auto	6	19 (1-28.5’)	0	2013
Metal Machining CO.	0	16 (1-47.5’)	0	2013
Narvaez Cleaner and Tailoring	0	16 (1-37.5’)	2	2013
Laundry Espinosa	3	15 (0.6-31.8’)	0	2015
PRIDCO Building No: L\T-0320-0-56	5	15 (1.5-26.7’)	0	2011
PRIDCO Building No: S-0050-0-51	5	16 (1.4-37’)	0	2011
Former Narvaez Cleaner and Tailoring	3	23 (0.5-50’)	0	2013
Edward’s Dry Cleaners	3	14 (0.5-16’	0	2015
PRIDCO Building No: L-107-2-64-16/18/19	3	16 (1.5-48’)	0	2011
PRIDCO Building Nos: T-1125-0-73 and T-1125-1-79	2	10 (1.2-46.7’)	0	2011
PRIDCO Block No: S- 0745-0-66	1	16 (1.5-46.7’)	0	2011
PRIDCO Building No: S-1166-0-74	2	19 (1.5-41.7’)	0	2011
PRIDCO Block No: T- 1322-088	3	19 (1.5-36.7’)	0	2011

Location	Number of Ground water Samples	Number of Soil Samples (Depth)	Number of Soil Gas Samples	Sample Year
PRIDCO Building No: T-0638-0-66	4	19 (1.5-20.7')	0	2.15
PRIDCO Block No: T- 0957-1-71	6	26 (1.6-46.7')	0	2011
PRIDCO Building No: S-0838-0-67	6	25 (1.5-32.5')	0	2011
PRIDCO Building No: T-0868-0-67	6	13 (1.5-31.7')	0	2011
Total	62	373	2	null

Note: PRIDCO = Puerto Rico Industrial Company