ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

Groundwater, Surface Water, Soil and Sediment Data Evaluation

COROZAL WELL SITE
COROZAL, PUERTO RICO
EPA FACILITY ID: PRN000206452

MAY 14, 2014

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

JUNE 16, 2014

THE ATSDR 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 our 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 best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i) (6) within a limited time frame. 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. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. This revised document has now been released for a 30-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 will conclude 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.

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PUBLIC HEALTH ASSESSMENT

Groundwater, Surface Water, Soil and Sediment Data Evaluation

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Prepared by:

Eastern Branch
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry

Summary

Introduction

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

This well supplies drinking water to about 240 people in and around Corozal and Naranjito. Manufactured chemicals called volatile organic compounds (VOCs) were detected at low levels in the Corozal well November 2010. An alternate water source for the affected residents was provided through coordinated efforts among the Government of Puerto Rico and other agencies until the installation of a granular-activated-carbon (GAC) treatment system. Chlorination byproducts such as Trihalomethanes (THMs) were detected at low levels in the potable hauled-water.

The purpose of this Public Health Assessment (PHA) was to determine whether the community was harmed by exposure to VOCs in Corozal well water and what public health actions needed to be taken to reduce harmful exposures. Because of limited available data, ATSDR focused its evaluation on exposure to VOCs in Corozal well water. Other potential exposure pathways may be evaluated in detail in the future as more data are collected from the site.

Conclusions

ATSDR reached three important conclusions in the PHA:

Conclusion 1

Today, no exposures to VOCs (including PCE and Total Trihalomethanes) in drinking water from the Corozal Well site are occurring.

Basis for Conclusion

The Puerto Rico Department of Health (PRDOH) closed the well in November 2010. The well was reopened for service after installation of a granular-activated-carbon (GAC) treatment system in March 2011 which reduced exposures to below levels of concern.

Conclusion 2

Past exposures to VOCs (including PCE and TTHMs) from drinking or using water from the Corozal well were unlikely to cause harm to human health.

Basis for Conclusion

Because no sampling data are available before 2010, ATSDR estimated past exposure doses for PCE in Corozal water. For the time period between 1977 and 2010, we assumed people were exposed daily to the actual contaminant levels recorded since 2010. Based on these estimates, exposure to levels of PCE in Corozal water were below levels of health concern. Because contaminant concentrations can change over time, the levels since 2010 may not be representative of the time period of interest and therefore may underestimate or overestimate exposures. The Total THMs exposure duration was short (only for 4 months) and below levels of health concern, so it is unlikely to result in any adverse health effects.

Conclusion 3

Incidental exposure to surface water is a completed exposure pathway; however, exposures are not expected to harm people's health.

Basis for Conclusion

The available sampling information indicated low PCE concentrations (ranging from non-detect to 17µg/L). Additionally, the surface water exposures were infrequent and short in duration.

Next Steps

- The US Environmental Protection Agency (EPA) and/or the Puerto Rico Environmental Quality Board (EQB) continue efforts to identify the source, characterize the extent of the contamination, and implement remedial measures to address and prevent groundwater contamination.
- EPA continues the operation and maintenance of the GAC treatment system until the Corozal well groundwater source is free of any chemical (e.g., VOCs) contamination. EPA monitoring and reporting protocols include a notification to the PRDOH as well as the community in the event of a detection of any contaminant.
- PRDOH continue oversight of the Corozal well operation, maintenance and routine water monitoring conducted by the local water system operator per the Safe Drinking Water Act requirements.
- ATSDR will evaluate additional data collected by EPA and update the findings of this PHA, if necessary.

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 "Corozal Groundwater Contamination Site." If you have concerns about your health, you contact your health care provider.

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List of Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CREG	Cancer Risk Evaluation Guide
CV	Comparison Value
EPA	U.S. Environmental Protection Agency
EQB	Puerto Rico Environmental Quality Board
GAC	Granular-activated-carbon
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Assessment System
MCL	Maximum Contaminant Level
mg/L	Milligram per liter
MLE	Maximum Likelihood Mean
MRL	Minimal Risk Level
NCEH	National Center for Environmental Heath
NPL	National Priorities List
PCE	Tetrachloroethylene (or Perchloroethylene)
PHA	Public Health Assessment
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRDOH	Puerto Rico Department of Health
RfD	Reference Dose
RMEG	Reference Media Evaluation Guide
ROS	Regression on Order Statistics
TCE	Trichloroethylene (or Trichloroethene)
µg/L	Microgram per liter
UCL	95% Upper Confidence Level
VOC	Volatile Organic Compound

Purpose and Health Issues

The Corozal Groundwater Contamination site was proposed for the National Priorities List (NPL) in September 2011 and listed in March 2012. The Agency for Toxic Substances and Disease Registry (ATSDR) is required by Congress to conduct public health activities on all sites proposed for the NPL. This public health assessment evaluates the public health significance of the Corozal Groundwater Contamination site. ATSDR reviewed available environmental data, potential exposure scenarios, and community health concerns to determine whether adverse health effects are possible. Because of limited data, the evaluation focuses on potential community exposures to volatile organic compounds (VOCs) in the public drinking water supply. We also evaluated the possibility of any adverse health effects that may result from other types of exposure as well as make recommendations for further sampling that would allow evaluation of such exposures.

Background

Site Description and History

The Corozal Well site (the site) is located in north-central Puerto Rico off Carretera 811 Km 3.0 Interior Barrio Palos Blanco, Corozal. The well (also called Comunidad Santana well, with system ID number of PR0724147) was in service from 1977 to 2010 and provided drinking water to approximately 240 persons in the communities of Palo Blanco, Corozal and Cedro Abajo Naranjito [EPA 2011a].

In November 2010, the Puerto Rico Aqueduct and Sewer Authority (PRASA), on behalf of Puerto Rico Department of Health (PRDOH), sampled the well water and discovered that concentrations of tetracholorethylene (PCE) exceeded the Maximum Contaminant Level (MCL) of 5 microgram per liter (μg/L) established by the US Environmental Protection Agency (EPA).

In response to the discovery of the groundwater contamination, PRDOH closed the well on November 18, 2010. An alternate water source for the affected residents was provided through coordinated efforts among the Government of Puerto Rico and other agencies.

PRDOH also requested that the National Center for Environmental Heath (NCEH) of the Centers for Disease Control and Prevention (CDC) conduct a community health evaluation. In December 2010, NCEH’s Division of Laboratory Science (DLS) Epi-Aid assistance team completed an evaluation which included a survey, measurements for height and weight, as well as blood and urine collection, to assess health status and potential exposure to PCE among community members [CDC 2010].

In March 2011, EPA installed a granular-activated-carbon (GAC) treatment system at the site and treated water was provided to the community water distribution system. EPA proposed the site for inclusion on the National Priorities List (NPL) on September 2011 and the listing was finalized in March 2012. EPA began the process of investigating possible source areas, but has not yet identified the source of the groundwater contamination as of February 2013.

Since discovery of the groundwater contamination, Puerto Rico Environmental Quality Board (PREQB), PRASA, EPA, and NCEH collected numerous environmental samples including groundwater, surface water, and soil/sediment at the site, as well as blood and urine samples from nearby community members. As part of the public health assessment process, in April 2012, the ATSDR site team along with personnel from PRDOH, EPA and members of the community, conducted a site visit. ATSDR visited the contaminated well, water treatment facility, storage tank, and surrounding areas.

This public health assessment focuses on evaluating past exposure to contaminants in drinking water. ATSDR also evaluated potential exposures to other environmental media such as surface water, soil, and biota.

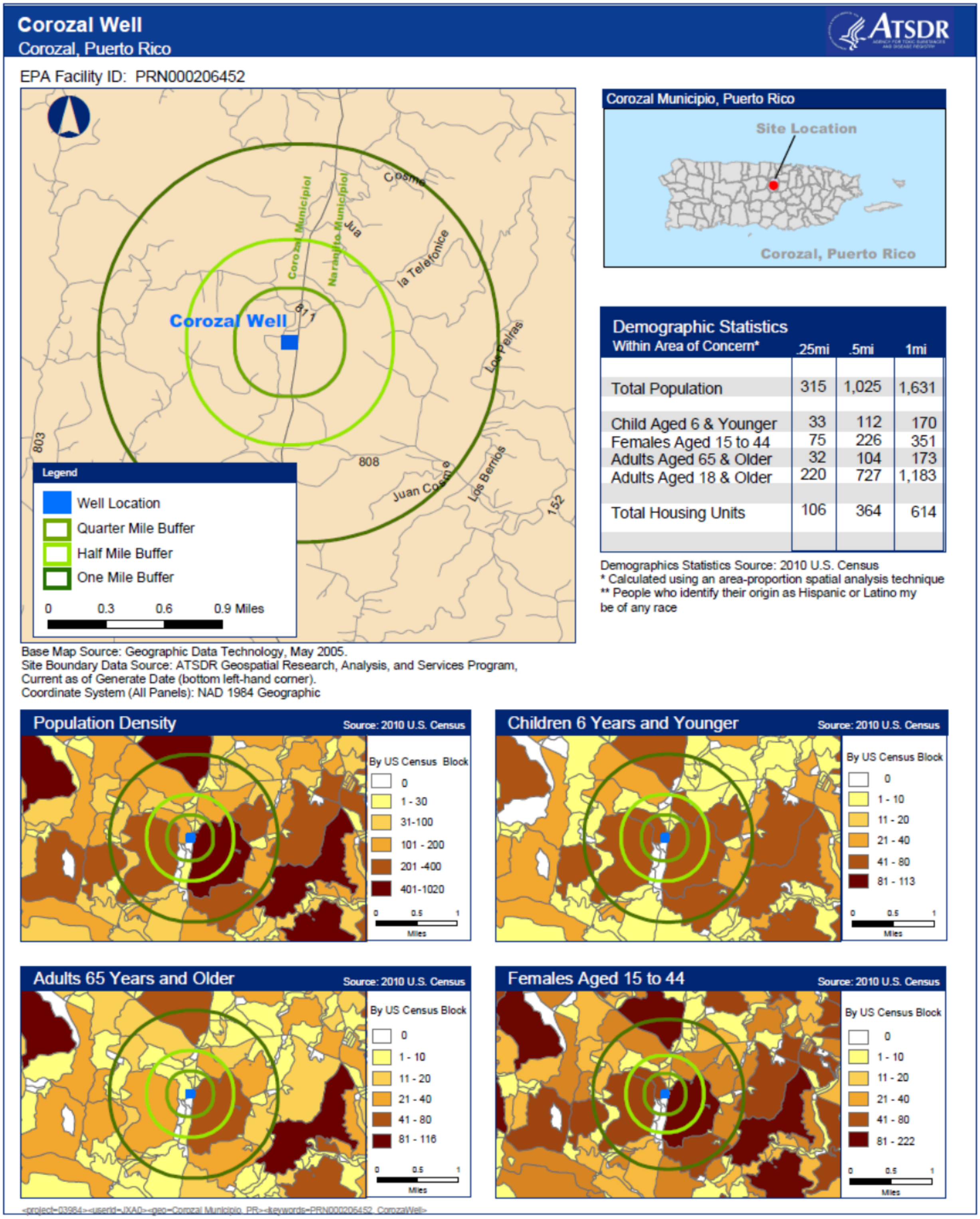
Demographics

The area surrounding the well is a well-maintained rural neighborhood. Figure 1 shows demographic information for the affected drinking water well from a quarter-mile to one-mile radius. According to the 2010 U.S. Census data, the total population living within a one-mile radius of the well is 1,631. However, the well only serves a population less than 300 in a quarter-mile radius. The majority of the population is of Hispanic or Latino origin. Although the well is located in the Corozal municipality, the majority of families served by the well live in the Naranjito municipality. For example, in the December 2010 CDC Epi-Aid survey, approximately 95 percent of participants (173) were from the Naranjito community. The 2010 U.S. Census demographics statistics also show that the population living around the well includes the following potentially sensitive groups: approximately10% children aged 6 and younger, 24% women of childbearing age, and t 10% adults aged 65 and older [US 2010 census].

Land and Natural Resource Use

The site is a rural residential area with limited commercial and industrial activities. The well is located near an unnamed creek downhill from the majority of the residential properties. The Corozal well has been in operation since 1977 and it is the sole source of the drinking water for the communities of Palo Blanco, Corozal and Cedro Abajo Naranjito [EPA 2011a]. There are no other wells or surface water intakes contributing to the system. The well is privately owned and operated by a local entity, and is not part of the PRASA public water system [EPA 2011a]. The Corozal well is 159 feet deep. The well typically operates 16 hours per day and has a pump capacity of 36 gallons per minute. There is a 30,000 gallon storage tank associated with the Corozal well system, and the groundwater is treated by chlorination prior to distribution as drinking water [EPA 2011a].

Figure 1. Site Map and Demographic Information for the Corozal Well Groundwater Contamination Site



Demographic Statistics Within Area of Concern*	.25mi	.5mi	1mi
Total Population	315	1,025	1,631
Child Aged 6 & Younger	33	112	170
Females Aged 15 to 44	75	226	351
Adults Aged 65 & Older	32	104	173
Adults Aged 18 & Older	220	727	1,183
Total Housing Units	106	364	614

<project=03984><userid=JXA0><geo=Corozal Municipio, PR><keywords=PRN000206452_CorozalWell>

Discussion

Data Used

ATSDR evaluated the available environmental sampling information for potential exposure to groundwater contaminants at the site. The following is a summary of all data used in this evaluation:

- EPA Hazard Ranking System package. EPA [2011a] - EPA Region 2 provided the references listed in the package. Among 32 available reference documents, ATSDR identified relevant environmental sampling data from 10 documents. Environmental samples (groundwater, surface water, soil and sediment) collected by EPA, PRASA, and PREQB from November 2010 through March 2011 were available for this review.
- PRDOH package. During the April 2012 site visit, ATSDR obtained additional groundwater sampling data from PRDOH. These data were collected from November 2010 through February 2012 [PRDOH 2012].
- Additional EPA Data. On August 2012, ATSDR received additional data from EPA Region 2 for groundwater and surface water samples collected from April 2011 through April 2012 [EPA 2012a].

ATSDR also reviewed information on Quality Assurance (QA)/Quality Control (QC) specifications for field data quality 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 appropriate. This evaluation included all valid results.

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 accepted comparison values (CV), and 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 to result from exposure to site contaminants is described briefly in this section. See Appendix A and B for more detailed descriptions 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, now, 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 Corozal well.
2. Transport through an environmental *medium*: groundwater is the medium that transported the VOC contamination.

3. An *exposure point*: Prior to the Corozal well being taken out of service, residents obtained drinking water from the contaminated well.
4. An *exposure route*: Prior to the Corozal well being taken out of service, residents drank and bathed in the water and may have breathed in contaminant vapors from the water.
5. An *exposed population*: Prior to the Corozal well being taken out of service, a total of approximately 240 people were served by the well.

This analysis indicates that a completed groundwater exposure pathway existed in the past for those using water from the Corozal well. Currently, there are no completed exposure pathways for the Corozal well given that the well has been taken out of service. The past exposure pathways were evaluated further by ATSDR to determine whether any potential health effects were 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 *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 evaluation. In general, to select CVs, the hierarchy described in the ATSDR Public Health Guidance manual was used. In some cases professional judgment was used to select the most appropriate CVs for the specific site conditions [ATSDR 2005].
- The next step of evaluation focuses on identifying which chemicals and exposure situations could be 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 "worst case" type assumptions to obtain the highest dose that could be expected. Each calculated exposure dose is compared against the corresponding *health guideline*, typically an ATSDR minimal risk level (MRL) or EPA Reference Dose (RfD), for that chemical. 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 actual exposures that occurred or are occurring at the site. The exposure dose is then compared with known health effect levels (for both cancer and noncancer effects) identified in ATSDR's toxicological profiles or EPA's Integrated Risk Information System (IRIS). *These comparisons are the basis for stating whether the exposure presents a health hazard.*

Table 1 summarizes the groundwater monitoring data for the Corozal well along with corresponding CVs as discussed above. The available data indicate that PCE exceeded its CVs and warrants further evaluation in this PHA.

Table 1. VOCs Detected in Corozal Well Groundwater

Contaminant	Highest Concentration Detected in Groundwater Sample, μg/L	Non-cancer CV in μg/L	Cancer CV in μg/L; Cancer Class	Selected for Further Evaluation?
			17 – CREG; Probable carcinogen	
Trichloroethylene	0.34	5 – MCL	0.76 – CREG Probable carcinogen	No
			18 – CREG; Probable carcinogen	
T-butyl alcohol	3.1	3,000 – RMEG	N/A	No
			N/A	
1,2,3-Trichlorobenzene	0.17	40 – LTHA	N/A	No
2-Butanone	4.6	6000 – RMEG	N/A	No
Toluene	48	200 – EMEG	N/A	No

Please see Appendix A for definitions and additional information about CVs.

CV = comparison value
μg/L = micrograms of contaminant per liter of water
MCL = maximum contaminant level
RMEG = reference media evaluation guide
CREG = cancer risk evaluation guide
EMEG = environmental media evaluation guide
LTHA = lifetime health advisory

Data sources: as summarized in "Data Used" section.
N/A = not applicable (insufficient evidence to classify contaminant as oral human carcinogen)

Evaluation of Completed Exposure Pathways

<u>PCE exposure from Corozal Well Water</u>

Tetrachloroethylene (PCE) is also known as perchloroethylene. It is a widely used industrial solvent for degreasing, dry cleaning, and other, similar uses [ATSDR 1997].

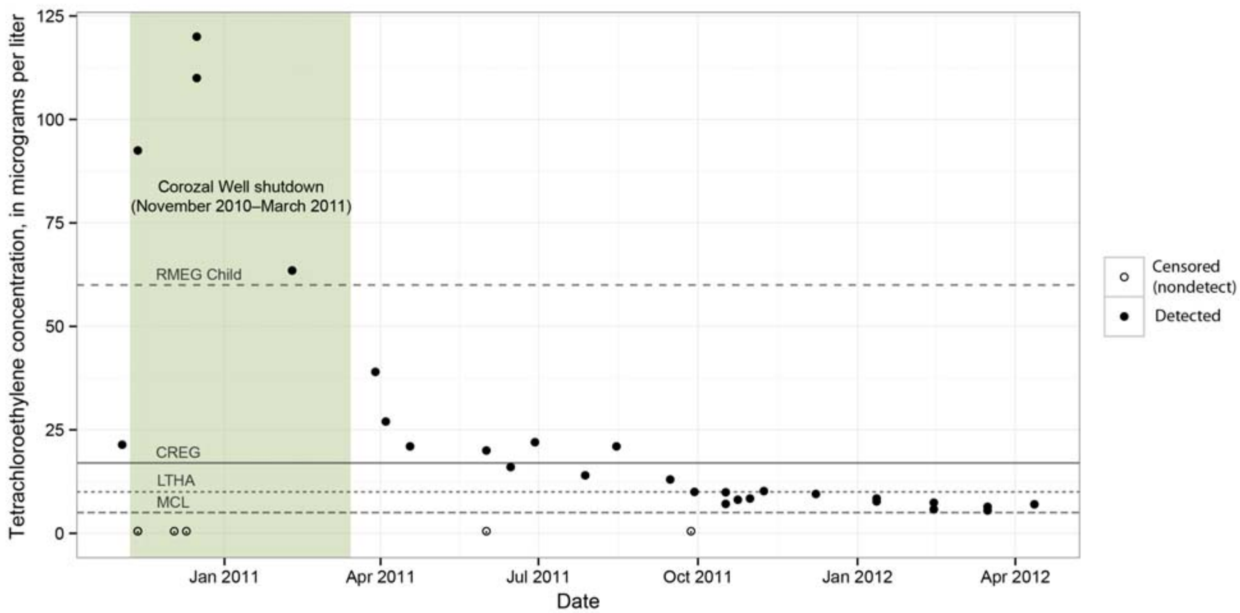
Exposure pathway analysis performed for the site indicates that a completed groundwater exposure pathway existed in the past for those using water from the Corozal well. People could have been exposed to these compounds in several ways:

- *Ingestion:* People could have drunk the water or eaten food prepared using the water.
- *Inhalation:* People could have breathed in VOCs that volatilized (moved into the air) from well water during showering, bathing, or other household use.
- *Dermal Exposure:* People could have absorbed VOCs through their skin during showering, bathing, or other use.

Often, ingestion exposure is the most significant source of exposure to hazardous substances from a site. In the case of VOC contamination, however, inhalation and dermal exposures can make a significant contribution to the total exposure dose (that is, the total amount of contaminant that enters a person's body). A common estimation is that noningestion exposures yield a contaminant dose comparable to the ingestion dose [ATSDR 2005]. This estimation may underestimate exposures to people who may be exposed to PCE from shower water for periods of 30 minutes or more per day. For the general purposes of this evaluation, however, we doubled the estimated ingestion exposure doses using measured water PCE concentrations and default assumptions for the amount of water consumed per day and other exposure parameters to account for additional exposure from inhalation and dermal exposures.

From November 2010 to April 2012, a total of 40 groundwater samples were collected from the well and analyzed for PCE. PCE concentrations ranged from nondetect to 120 μg/L. Initial groundwater sample results indicated higher levels of PCE in late 2010 and early 2011. But samples collected later indicated significantly lower PCE concentrations. Figure 2 shows the PCE results for the well. The highest concentrations of PCE were recorded during the time the well was shut down (November 2010–March 2011). Several nondetects were also recorded during this time. No VOC sampling data were available before November 2010. Factors that could account for varying levels of PCE in the well over time include the location and nature of the contaminant source and the subsurface characteristics and groundwater flow in the area. A number of factors also may have influenced whether the available PCE sample results are representative of PCE levels in the well over time, including whether the well was in normal operation prior to sample collection, how long the well may have operated prior to sample collection, and how the well was purged (pumped) prior to sample collection during well shutdown.

Figure 2. Corozal Well Tetrachloroethylene (PCE) Monitoring Results*



**Note: Corozal well was ordered shut by PRDOH in November 2010. The well was back to service in March 2011 after installation of a granular activated carbon unit. Only untreated groundwater data is included in above figure.*
CREG = cancer risk evaluation guide
LTHA = lifetime health advisory
MCL = maximum contaminant level
RMEG = reference media evaluation guide

No VOC sampling data are available before November 2010. Therefore, the duration of exposure is unknown. Because no testing at residential taps was performed, we also do not know the exact levels of PCE to which people were exposed. To be conservative, for our dose calculations we made the following assumptions:

- We assumed people could have been exposed to PCE for about 34 years, from 1977, when the well was first in operation, until November, 18th 2010, when the well was taken out of service. Currently, because of the installation of the granular-activated-carbon (GAC) treatment system, no completed exposure pathways for the Corozal well remain. Routine treated water tests indicate no PCE detection.
- We assumed that the contaminant levels were similar to those in the groundwater data collected since 2010 because the contamination source is unknown and we have no historical data. This is a data limitation and this assumption may not represent the PCE levels for the time period of interest and therefore may underestimate or overestimate exposures.

- ATSDR used the regression on order statistics (ROS) method to estimate basic statistical parameters of the PCE data. We used 35 µg/L as the exposure point concentration for dose calculation. This value is the 95% upper confidence level (UCL) concentration of the maximum likelihood mean (MLE) of the PCE data. See Appendix C for more details.
- We used the most current body weights and ingestion rates recommended by the EPA for children and adults (see Table 2) [EPA 2011b].
- We doubled estimated ingestion exposure doses, using 35 µg/L as the exposure point concentration. This estimate accounts for additional exposure from inhalation and dermal exposures. Tables 2 and 3 show the results of the dose calculations.

Table 2: Water Ingestion Rates[a] and Estimated PCE Ingestion Doses Based on 35 µg/L PCE

Age Range	Body Weight (kg)	Mean Water Ingestion (mL/day)	Mean PCE Ingestion Dose (mg/kg/day)	95th Percentile Water Ingestion (mL/day)	95th Percentile Ingestion Dose (mg/kg/day)
Birth to <1 year	7.8 [b]	504[b]	0.0023	1,113	0.0050
1 to <2 years	11.4	308	0.0009	893	0.0027
2 to <6 years	17.4 [b]	402	0.0008	1,052	0.0021
6 to <11 years	31.8	480	0.0005	1,251	0.0014
11 to <21 years	64.2 [b]	753	0.0004	2,042	0.0011
21 to <65 years	80	1,183	0.0005	2,848	0.0013
65+ years	76	1,242	0.0006	2,604	0.0012

[a]Ingestion rates for combined direct and indirect water from community water supply (US EPA 2011b), [b] Values are the time weighted ingestion rates within the age range from the age-specific ingestion rates recommended by the EPA for children and adults (US EPA 2011b).

Table 3: Total Estimated PCE Exposure (Ingestion, inhalation, and Dermal) Doses[a] Based on 35 µg/L PCE

Age Range	Mean Ingestion Total Dose (mg/kg/day)	95th Percentile Total Dose (mg/kg/day)	Exceeded RfD of 0.006 mg/kg/day (yes/no)
Birth to <1 year	0.0046	0.0100	Yes
1 to <2 years	0.0018	0.0054	No
2 to <6 years	0.0016	0.0042	No

6 to <11 years	0.0010	0.0028	No
11 to <21 years	0.0008	0.0022	No
21 to <65 years	0.0010	0.0026	No
65+ years	0.0012	0.0024	No

Total doses for most age groups are lower than EPA's oral RfD of 0.006 mg/kg/day for PCE except for one age group (birth to <1 year) with high water intake rate (95th percentile water ingestion rate).The PCE 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 [EPA 2012b]. ATSDR considers that noncancer effects would not be expected for this exposure because (1) Conservative exposure assumptions were used for dose estimation, (2) the oral ingestion estimated dose of 0.0100 for the age group is only slightly above the RfD, and (3) the oral ingestion estimated dose is much lower (260 to 970 times) than the doses that resulted in adverse health effects in studies.

Regarding cancer effects, the Department of Health and Human Services, National Toxicology Program classifies PCE as a reasonably anticipated human carcinogen, and the International Agency for Research on Cancer (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, CEPA 2001]. 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 [EPA 2012b].

EPA released its updated PCE health risk assessment in February 2012. The oral cancer slope factor was determined to be 0.0021 $(mg/kg/day)^{-1}$. Using this value, and assuming children and adults drank water containing 35 µg/L of PCE detected in the well every day for 34 years, we calculated an estimated cancer risk of 1 in 100,000, which means out of 100,000 persons exposed, one additional cancer might occur. The cancer risk calculation indicated that there would be an extremely low estimated increased risk of cancer predicted for this exposure. Please see Appendix A for details of the cancer risk calculation.

The following is a summary of the cancer risk calculations for all exposures routes:

Table 4: Cancer Risk Calculations

	Total Cancer Risk (RME [a])	**Total Cancer Risk (CTE [b])**
Child Cancer Risk (birth to<21 years	9.2E-07	3.6E-07
Adult Cancer Risk (21 to 78 years)	1.5E-06	6.6E-07
Life time Cancer Risk (Children + Adult)	2.5E-06	1.0E-06

[a] RME = Reasonable Maximum Exposure. Refers to people who are at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but are still within a realistic range of exposure
[b] CTE = Central Tendency Exposure . Refers to individuals who have average or typical water intake rate.

Total Trihalomethanes (TTHMs) Exposure from Potable Hauled-Water

From the shutdown of the Corozal well in November 2010 to its reopening in March 2011, residents received potable hauled-water delivered by PRASA, the National Guard and EPA. This hauled-water was transferred into a water storage tank where the hauled-water was distributed to residences through the existing distribution system. Between January 24 and 27, 2011, Weston Solutions, Inc. conducted a sampling event under a contract with EPA. Hauled water samples were collected from 72 residential taps for target compound list (TCL) VOC analysis. ATSDR contacted EPA and PRDOH for the sampling result report; however, only three samples were available for this review. Therefore, ATSDR evaluation and conclusions were based on the available sampling results. Five chemicals (bromodichloromethane, bromoform, chloroform, dibromochloromethane, and methylene chloride) were detected among 52 analytes. The levels of methylene chloride were below its respective CV. Therefore, no further discussion is needed. The other 4 chemicals are called trihalomethanes (THMs) as a group. Table 2 is a summary of the detected THMs in the potable hauled-water.

Table 5. THMs Detected in Corozal Potable Hauled Water

Contaminant	Tap water Sample #1, µg/L	Tap water Sample #2, µg/L	Tap water Sample #3, µg/L	Selected for Further Evaluation? †
Bromoform	ND(0.5)	0.96	ND(0.5)	**Yes**
Dibromochloromethane	9.9	9.5	10	**Yes**

µg/L = micrograms of contaminant per liter of water
Data sources: as summarized in "Data Used" section beginning on page 4.
ND = not detected. Numbers in parenthesis are detection limits.
† Contaminants exceeding the lowest comparison values were selected for further evaluation.

Chlorination is a process that proven to reduce most bacteria and viruses in water and prevent the occurrence of diarrheal disease. THMs are chlorination byproducts formed when chlorine reacts with organic matter such as bacteria in water. Animals and humans exposed to THMs may have potential effects such as adverse pregnancy outcomes and increased cancer risks [Chowdhury S et al. 2011; Levallois P et al 2012; Windham G and Fenster L 2008]. EPA has established an MCL of 80 µg/L for total THMs (TTHMs) in public drinking water [EPA 1998]. ATSDR has established the following CVs to screen the concentrations of THMs found in drinking water:

Table 6. ATSDR THMs Comparison Values

Contaminant	Chronic EMEG Child (μg/L)	Chronic EMEG adult (μg/L)	CREG (μg/L)
Bromodichloromethane	200	700	0.56
Bromoform	200	700	4.4
Chloroform	100	350	NA
Dibromochloromethane	900	3200	0.42

μg/L = micrograms of contaminant per liter of water
NA= not available.
EMEG = environmental media evaluation guide
CREG = cancer risk evaluation guide

At the Corozal well site, concentrations of THMs were below their respective ATSDR noncancer CVs. Two potable hauled-water samples (sample #2 and #3) had TTHMs concentration above 80 μg/L (90.46 and 88 μg/L, respectively).

Bromodichloromethane and dibromochloromethane have concentrations that exceeded their respective CREGs. Further evaluation focused on exposure situations indicating that

- Residents were exposed to the potable hauled-water for about 4 months from November 2010 to March 2011.
- THMs were not detected in any of the available groundwater (non-hauled-water) samples taken from December 2010 through March 2012.
- Although no sampling data were available for TTHMs before December 2010, ATSDR learned that chlorination was not performed for Corozal well water before 2007.
- The EPA MCL and ATSDR CREGs are set for long-term exposures. The MCL is the level of a contaminant in drinking water below which there is no known or expected risk to health. CREGs are based on a one-in-a-million excess cancer risk for an adult exposed to contaminated drinking water every day for 70 years.

A review of the above discussion leads ATSDR to conclude that the short term exposure (about 4 months) to TTHMS in potable hauled-water is unlikely to result in any adverse health effects at the Corozal well site. The ATSDR evaluation and conclusions were based on limited sampling results.

Incidental Exposure to Surface water

EPA's Expanded Site Inspection (ESI) efforts indicate that PCE was present in the surface water samples taken in the immediate vicinity of the Corozal well. Surface water samples were taken from an unnamed stream that flows past the Corozal well. Interviews with local residents revealed that people may occasionally go to the creek to harvest crawfish and wild root vegetables (2–3 times per month in summer months). Therefore, ATSDR considers surface water exposure to be a completed exposure pathway. However, the available sampling information indicated that the PCE concentrations was low (ranging from nondetect to 17μg/L), and incidental ingestion of surface water was infrequent. Therefore it is unlikely that the exposures would pose a hazard to people exposed.

Evaluation of Potential Exposure Pathways

ATSDR investigated the possibilities of other potential exposure pathways at the site as described below:

Incidental Exposure to Soil/sediment

During the site visit, ATSDR observed that residents may work in the fields, play on their property and the nearby unnamed creek, and therefore contact surface soil and sediment. EPA sampled soil/sediment uphill of the well and along the stream, and soils at two close industrial facilities. Analytical results indicated that PCE was not detected in any of the soil samples. Therefore, the soil exposure pathway is considered incomplete at the sampled areas of the site. ATSDR will continue to evaluate the potential for exposure to contaminated soil, surface water, or other identified substances as this information becomes available throughout the remedial investigation process.

Biota Exposure

Biota, or the plants and animals in an environment, can be sources of food, clothing, or medicines for people. If people consume contaminated biota, they can be exposed to chemicals in them. During the April 2012 site visit, local officials informed ATSDR team members that residents may consume locally grown produce such as yucca, banana, pineapple, and breadfruit. Consumption of wild-caught crawfish and root vegetables is also possible. Available soil and sediment samples indicated, however, that the contamination is currently isolated to the groundwater and no PCE was detected in any of the soil/sediment samples. We have no biota sampling information; however, using the soil/sediment sampling results, we find that local biota contamination is unlikely. PCE was not detected in any of the soil samples taken from the nearby unnamed creek and two close industrial facilities. Therefore, the biota exposure pathway is not a completed pathway at the tested areas. However, the contamination source has not been determined for the site; contamination levels could be higher near the source. ATSDR will evaluate additional data collected by EPA and PRDOH and update the findings of this PHA, if necessary.

Vapor Intrusion

Vapor intrusion is the migration of VOCs from the subsurface-contaminated groundwater and soil through the pore spaces of soil into buildings above. The air within the pore spaces of soil is called subsurface vapor, in some cases also called soil gas or soil vapor [ATSDR 2001; EPA 2002; EPA 2003]. Subsurface vapors can enter residences and other buildings through foundation cracks and gaps, mechanical ventilation systems, and leakage areas (for example, utility entry points, construction joints, and drainage systems). When groundwater is shallow (fewer than 100 feet below ground surface) and VOC levels are high enough in the groundwater, VOCs can move into the buildings above and build up inside. For the Corozal well site, the well is located more than 150 feet below ground surface, which is deeper than the 100-foot depth recommended by EPA for potential vapor intrusion concerns. In addition, all residential buildings are located up in higher elevations, a distance above the well area. Finally the levels of VOCs that were present in the municipal wells were too low to cause a concern for vapor intrusion. The contamination source, however, has not been determined for the site. Contamination levels could be much higher near the source. ATSDR will work with EPA and EQB to ensure that proper characterization of groundwater and soil gas contaminant levels is conducted so that evaluation of this potential exposure pathway can occur.

Physical Hazards

No unusual physical hazards were identified in the vicinity of the affected wells. People would not be able to access the well pump houses or associated equipment because the area in which they're located is fenced with locked gates.

Children's Health Considerations

ATSDR recognizes that infants and children might be more vulnerable than adults to exposures in communities with contaminated air, water, soil, or food. This potential vulnerability results from the following factors: 1) children are more likely to play outdoors and bring food into contaminated areas; 2) children participate in activities and movement that make them more likely to be in contact with dust and soil; 3) children's small size results in higher doses of chemical exposure per kg of body weight; and 4) developing body systems can sustain permanent damage if toxic exposures occur during critical growth stages. Because children depend completely on adults for risk identification and management decisions, ATSDR is committed to evaluating their special interests at the site.

At the Corozal well site, children were potentially exposed to contaminated well water before the well was taken out of service. ATSDR estimated their exposures conservatively. ATSDR estimated exposure doses for 6 age groups including small children who would have a higher exposure dose than an adult. (See Section on PCE exposure evaluation for details).

Health Outcome Data

Health outcome data can give a more thorough evaluation of the public health implications of a given exposure. Health outcome data can include mortality information (e.g., the number of people dying from a certain disease) or morbidity information (e.g., the number of people in an area getting a certain disease or illness). The review is most informative when (1) a completed human exposure pathway exists, (2) potential contaminant exposures are high enough to result in measurable health effects, (3) there has been sufficient time since exposure occurred for the disease to have developed, (4) enough people are affected for the health effect to be measured, and (5) a database is available to identify rates of diseases plausibly associated with the exposure for populations of concern.

Although a comprehensive review of health outcome data was not performed for this site, the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health (NCEH) conducted a community health evaluation. In December 2010, NCEH's Division of Laboratory Science (DLS) Epi-Aid assistance team completed their evaluation with individual exposure questionnaire, measurements for height and weight, as well as blood and urine collection to assess the health status and potential exposure of community members to PCE. A total of 194 community members representing 64 of the 84 families served by the Corozal well, participated in the health evaluation. Participants' ages ranged from 5 to 84 years with a mean of 36.5 years. DLS collected 179 blood and urine samples for VOC analysis including PCE. The results of laboratory tests and the survey are summarized below [CDC 2010]:

- PCE or PCE metabolites were not detected in urine, and PCE levels in blood are similar to those of the general U.S. population.
- The Corozal well was the main source of water for drinking, cooking, and bathing. Most of the participants used the water directly without any treatment.
- Some participants reported using chemicals that contained PCE (e.g., degreasers, lubricants, paint removers, etc.) in the past 30 days.
- More than 78% of the adult participants were overweight or obese based on the body mass index (BMI).
- Approximately half of the adult participants consumed at least one alcoholic drink in the past 30 days, and they consumed an average of 7.1 drinks on days they drank.
- Approximately10 % of the adult participants are current smokers.
- Some participants reported a range of symptoms and diagnosed health conditions. However, those symptoms and health conditions were not specific to PCE exposure and, based on the low levels of PCE found in the well, unlikely related to any PCE exposure.
- Limitations of this health evaluation include unknown exposure duration, inability to provide information about past and future health effects associated with the PCE exposure, and lack of specific symptoms/diagnoses /laboratory results associated with PCE exposures.
- Recommendations include physician education, Safe Drinking Water Act compliance, and individual follow-up with primary care physicians for any abnormal findings.

Community Health Concerns

As part of the public health assessment process to investigate exposure to contamination, ATSDR and DLS staff participated in public meetings, reviewed site documents, and conducted in-person interviews to understand community members' concerns regarding the contamination, investigation, and remediation of the site. ATSDR also communicated with EPA, EQB, PRDOH, and PRASA officials about issues that they may have heard from the community. Community environmental health concerns related to groundwater contamination include the following:

- How the well water (groundwater) would be cleaned up
- How long the GAC treatment system will be in place

To clean up the well water, EPA is working on identifying the contamination source(s), and developing an appropriate clean-up or remedy. The current approach to provide residents with clean drinking water by the use of the GAC treatment system is effective. ATSDR recommends that EPA continue the operation and maintenance of the GAC treatment system until the groundwater is free of any contamination, and notify the community and the PRDOH in the event of detection of any contamination in future sampling events.

Conclusions and Recommendations

ATSDR reached the following conclusions in the PHA:

- Currently, no exposures to VOCs (including PCE and TTHMs) in drinking water from the Corozal well at the Corozal Well Groundwater Contamination site are occurring. The Puerto Rico Department of Health (PRDOH) closed the well on November 2010. The well was reopened for service after installation of a granular-activated-carbon (GAC) treatment system in March 2011 which reduced exposures to below levels of concern.
- Past exposures for PCE measured in drinking water were unlikely to cause harm. Because no sampling data are available before 2010, ATSDR estimated past exposure doses for PCE in Corozal water. For the time period between 1977 and 2010, we assumed people were exposed daily to the actual contaminant levels recorded since 2010. Based on these estimates, exposure to levels of PCE in Corozal water were below levels of health concern. Because contaminant concentrations can change over time, the levels since 2010 may not be representative of the time period of interest and therefore may underestimate or overestimate exposures.
- Past exposure to TTHMS in potable hauled-water is not expected to harm people's health at the Corozal well site because the exposure duration was short (4 months only) based on limited sampling results.
- Incidental exposure to surface water is a completed exposure pathway. But it is unlikely that any exposures would harm people's health. The available sampling information indicated low PCE concentrations (ranging from nondetect to 17µg/L). Plus the surface water exposures are infrequent and short in duration.
- More information is needed to assess other potential exposure pathways including soil/sediment, biota, vapor intrusion, and exposure nearer to the source of contamination once determined.

ATSDR recommends:

1. EPA and/or EQB continue efforts to identify the source, characterize the extent of the contamination, and implement remedial measures to address and prevent groundwater contamination.
2. EPA continues the operation and maintenance of the GAC treatment system until the Corozal well groundwater source is free of any chemical (e.g., VOCs) contamination.

EPA monitoring and reporting protocols include a notification to the PRDOH as well as the community in the event of a detection of any contaminant.

Public Health Action Plan:

1. PRDOH continue oversight of the Corozal well operation, maintenance and routine water monitoring conducted by the local water system operator per the Safe Drinking Water Act requirements.
2. ATSDR will evaluate additional data collected by EPA and PRDOH and update the findings of this PHA, if necessary. For example, ATSDR will reevaluate the site exposure scenarios when the contamination source is identified.

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Appendix A. Explanation of Evaluation Process

Screening Process

In evaluating environmental data for the Corozal well site, ATSDR used comparison values (CVs) to determine which chemicals to examine more closely. CVs are health-based contaminant concentrations found in a specific media (air, soil, or water) and are used to screen contaminants for further evaluation. CVs incorporate assumptions of daily exposure to the chemical and a standard amount of air, water, and soil that someone might inhale or ingest each day.

CVs are set at a concentration below which no known or anticipated adverse human health effects are expected to occur. Different CVs are developed for cancer and noncancer health effects. Noncancer levels are based on valid toxicological studies for a chemical, with appropriate safety factors included, and the assumption that small children and adults are exposed every day. Cancer levels are based on a one-in-a-million excess cancer risk for an adult exposed to contaminated soil or contaminated drinking water every day for 70 years. For chemicals for which both cancer and noncancer CVs exist, we use the lower level to be protective. Exceeding a CV does not mean that health effects will occur, just that more evaluation is needed.

CVs used in preparing this document are listed below:

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one additional excess cancer in one million persons exposed over a lifetime. CREGs are calculated from U.S. Environmental Protection Agency (EPA) cancer slope factors (CSFs).

Reference Media Evaluation Guides (RMEGs) are estimated contaminant concentrations in a media where noncancer health effects are unlikely. RMEGs are derived from EPA's reference dose (RfD). RfDs can be found at http://www.epa.gov/iris.

Environmental Media Evaluation Guides (EMEGs) are concentrations of contaminants in water, soil, or air unlikely to produce any appreciable risk of adverse, non-cancer effects over a specified duration of exposure. EMEGs are derived from ATSDR minimal risk levels by factoring in default body weights and ingestion rates. ATSDR computes separate EMEGs for acute (≤14 days), intermediate (15–364 days), and chronic (>365 days) exposures.

Maximum Contaminant Levels (MCLs) are enforceable standards set by EPA for the highest level of a contaminant allowed in drinking water. MCLs are set as close to MCL goals (MCLGs, the level of a contaminant in drinking water below which there is no known or expected risk to health) as feasible using the best available treatment technology and taking cost into consideration.

Determination of Exposure Pathways

ATSDR identifies human exposure pathways by examining environmental and human components that might lead to contact with contaminants of concern (COCs). A pathway analysis considers five principal elements: a source of contamination, transport through an environmental medium, a point of exposure, a route of human exposure, and an exposed population. Completed exposure pathways are those for which the five elements are evident, and indicate that exposure to a contaminant has occurred in the past, is now occurring, or will occur in the future. Potential exposure pathways are those for which exposure seems possible, but one or more of the elements is not clearly defined. Potential pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring now, or could occur in the future. The identification of an exposure pathway does not imply that health effects will occur. Exposures might be, or might not be, substantive. Therefore, even if exposure has occurred, is now occurring, or is likely to occur in the future, human health effects might not result.

ATSDR reviewed site history, information on site activities, and the available sampling data. On the basis of this review, ATSDR identified household use of Corozal well water as the main pathway of concern at the site.

Evaluation of Public Health Implications

The next step is to take those contaminants present at levels above the CVs and further evaluate whether those chemicals may be a health hazard given the specific exposure situations at this site. Child and adult exposure doses are calculated for the site-specific exposure scenario, using our assumptions of who goes on the site and how often they contact the site contaminants. The exposure dose is the amount of a contaminant that gets into a person's body. Following is a brief explanation of how we calculated the estimated exposure doses for the site.

Ingestion and other uses of Groundwater

The overall exposure dose of PCE was estimated for all age groups including young children – considered the most sensitive to environmental toxins in many situations. To be conservative, ATSDR made the following assumptions for our dose calculations:

- We assume people could have been exposed to PCE for about 34 years – from 1977, when the well was first in operation, until late-2010, when use of the well stopped. The exposure to PCE from the Corozal well stopped in November 2010 when the well was shut down. Currently, there are no completed exposure pathways for the Corozal well because of the installation of the granular-activated-carbon (GAC) treatment system. Treated water tests indicated that no PCE was detected.
- We assumed that the contaminant levels were similar to those in the groundwater data collected since 2010. This is a data limitation and this assumption may not represent the PCE levels for the time period of interest and therefore may underestimate or overestimate exposures.
- ATSDR used the regression on order statistics (ROS) method to estimate basic statistical parameters of the PCE data. We used 35 μg/L as the exposure point concentration for dose calculation. This value is the 95% upper confidence level (UCL) concentration of the maximum likelihood mean (MLE) of the PCE data. See Appendix C for more details.
- We used the most current body weights and ingestion rates recommended by the EPA for children and adults (see Table 2) [EPA 2011b].
- We doubled ingestion exposure doses estimated using 35 μg/L as the exposure point concentration to account for additional exposure from inhalation and dermal exposures.
- Tables below are the results of the dose calculations.

Water Ingestion Rates[a] and Ingestion Doses

Age Range	Body Weight (kg)	Mean (mL/day	Ingestion Dose (mg/kg/day)	95th Percentile (mL/day)	Ingestion Dose (mg/kg/day)
Birth to <1 year	7.8 [b]	504[b]	0.0023	1,113	0.0050
1 to <2 year	11.4	308	0.0009	893	0.0027
2 to <6 year	17.4 [b]	402	0.0008	1,052	0.0021
6 to <11 year	31.8	480	0.0005	1,251	0.0014
11 to <21 year	64.2 [b]	753	0.0004	2,042	0.0011
21 to <65 year	80	1,183	0.0005	2,848	0.0013
65+ year	76	1,242	0.0006	2,604	0.0012

[a]Ingestion rates for combined direct and indirect water from community water supply (USEPA 2011b), [b] Values are the time weighted ingestion rates within the age range from the age-specific ingestion rates recommended by the EPA for children and adults (USEPA 2011b).

Total PCE Exposure (Ingestion, inhalation, and Dermal) Doses

Age Range	Total Mean Ingestion Dose (mg/kg/day)	Total 95th Percentile Dose (mg/kg/day)
Birth to <1 year	0.0046	0.0100
1 to <2 year	0.0018	0.0054
2 to <6 year	0.0016	0.0042
6 to <11 year	0.0010	0.0028
11 to <21 year	0.0008	0.0022
21 to <65 year	0.0010	0.0026
65+ year	0.0012	0.0024

Estimated doses were calculated use the formula below:

$$D = \frac{C * IR * EF}{BW}$$

where,

D = exposure dose (mg/kg-day)
C = contaminant concentration (mg/L)
IR = ingestion rate of contaminated water (L/day)
EF = exposure factor (unitless)
BW = body weight (kg)

For example, for children 1-2 years old, using the body weight of 11.4 kg, mean ingestion rate of 308 mL/day (0.308 L/day), and EF of 1, the exposure dose (D) = 35 µg/L× 0.308 L/day×1/11.4 kg= 0.0009 mg/kg/day.

Noncancer Health Effects

The calculated exposure doses are then compared to an appropriate health guideline for that chemical. Health guideline values are considered safe doses; that is, health effects are unlikely below this level. The health guideline value is based on valid toxicological studies for a chemical, with appropriate safety factors built in to account for human variation, animal-to-human differences, and/or the use of the lowest study doses that resulted in harmful health effects (rather than the highest dose that did not result in harmful health effects). For noncancer health effects, ATSDR used health guideline values of RMEG and RfD for PCE.

If the estimated exposure dose for a chemical is less than the health guideline value, then the exposure is unlikely to cause a noncancer health effect in that specific situation. If the exposure dose for a chemical is greater than the health guideline, then the exposure dose is compared to known toxicological values for that chemical and is discussed in more detail in the public health assessment (see Discussion section). These toxicological values are doses derived from human and animal studies that are summarized in the ATSDR Toxicological Profiles. A direct comparison of site-specific exposure and doses to study-derived exposures and doses that cause adverse health effects is the basis for deciding whether health effects are likely or not.

Total doses for all age groups are lower than ATSDR's MRL and EPA's RfD for oral exposure to PCE. Therefore, no non-cancer effects would be expected for this exposure.

Cancer Health Effects

The estimated 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 (CSF for PCE is 0.0021$(mg/kg\text{-}day)^{-1}$). EPA CSFs can be found at http://www.epa.gov/iris. The results estimate the maximum increase in risk of developing cancer after 70 years of exposure to the contaminant. For this site, we assumed 34 years as conservative worst-case exposure duration, because PCE was not tested until late 2010 and the well was in service since 1977. Formula used for cancer risk calculation:

Excess Cancer Risk = (C x CSF x IR x ED)/BW x AT where

C (mg/L) = contaminant concentration in water

CSF (mg/kg/day) = cancer slope factor

IR (L/day) = water ingestion rate

ED (years) = Exposure duration

BW (kg) = body weight

AT (lifetime in years) = 78 years

For example, for children 1-2 years old, using the body weight of 11.4 kg, mean ingestion rate of 308 mL/day (0.308 L/day), and ED of 1 year, AT of 78 years, the excess cancer risk is:

Excess Cancer Risk = 35 mg/L x 0.0021 $(mg/kg\text{-}day)^{-1}$) x 0.308 L/day x 1year/11.4 kg x 78 year = 7.4E-08

The following is a summary of the cancer risk calculation for all exposures routes:

Age group	RME [a] ingestion rate L/day	Body Wt. kg	Age group duration year	Site -specific Age group duration year	Duration adjustment (34 / 78 year)	Lifetime Excess Cancer Risk
Birth to <1 year	1.113	7.8	1	1	0.0128	1.3E-07
1 to <2 year	0.893	11.4	1	1	0.0128	7.4E-08
2 to <6 year	1.052	17.4	4	4	0.0513	2.3E-07
6 to <11 year	1.251	31.8	5	5	0.0641	1.9E-07
11 to <21 year	2.042	64.2	10	10	0.1282	3.0E-07
21 to <65 year	2.848	80.0	44	34	0.4359	1.1E-06
65 to <78 year	2.604	76.0	13	13	0.1667	4.2E-07
					Total risk:	2.4E-06

Age group	**CTE [b] ingestion rate L/day**	**Body Wt kg.**	**Age group duration year**	**Site - specific Age group duration year**	**Duration adjustment (34 / 78 year)**	**Lifetime Excess Cancer Risk**
Birth to <1 year	0.504	7.8	1	1	0.0128	6.1E-08
1 to <2 year	0.308	11.4	1	1	0.0128	2.5E-08
2 to <6 year	0.402	17.4	4	4	0.0513	8.7E-08
6 to <11 year	0.48	31.8	5	5	0.0641	7.1E-08
11 to <21 year	0.753	64.2	10	10	0.1282	1.1E-07
21 to <65 year	1.183	80.0	44	34	0.4359	4.7E-07
65 to <78 year	1.242	76.0	13	13	0.1667	2.0E-07
					Total risk:	1.0E-06

Total Cancer risks (the two previous tables above are combined and summarized):

	Total Cancer Risk (RME [a])	**Total Cancer Risk (CTE [b])**
Child Cancer Risk (birth to<21 years	9.2E-07	3.6E-07
Adult Cancer Risk (21 to 78 years)	1.5E-06	6.6E-07
Life time Cancer Risk (Children + Adult)	2.5E-06	1.0E-06

[a] *RME = Reasonable Maximum Exposure. Refers to people who are at the high end of the exposure distribution (approximately the 95th percentile). The RME scenario is intended to assess exposures that are higher than average, but are still within a realistic range of exposure*

[b] *CTE = Central Tendency Exposure . Refers to individuals who have average or typical water intake rate.*

The actual increased risk of cancer is probably lower than the calculated number, which gives a worst-case excess cancer risk estimate. The methods used to calculate cancer slope factors assume that high-dose animal data can be used to estimate the risk for low dose exposures in humans. The methods also assume that no safe level exists for exposure. Little experimental evidence exists to confirm or refute those two assumptions. Lastly, most methods compute the upper 95th percent confidence limit for the risk. The actual cancer risk can be lower, perhaps by several orders of magnitude [EPA 1989].

Because of uncertainties involved in estimating cancer risk, ATSDR employs a weight-of-evidence approach in evaluating all relevant data [ATSDR 1993]. Therefore, the increased risk of cancer is described in words (qualitatively) rather than giving a numerical risk estimate only. Numerical risk estimates must be considered in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions. The actual parameters of environmental exposures must be given careful consideration in evaluating the assumptions and variables relating to both toxicity and exposure.

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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 got 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 is 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 (http://www.epa.gov/OCEPAterms/) National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

Appendix C. Corozal Well Site Environmental Data Analysis Procedures

Since 2010, the United States Environmental Protection Agency (EPA) and the Puerto Rico Department of Health (PRDOH) conducted several environmental investigations and collected numerous groundwater, surface water, and soil/sediment samples at the site. For this public health assessment (PHA), ATSDR evaluated available environmental sampling information for the Corozal well site for potential exposure to groundwater contaminants at the site.

ATSDR received the above data in different formats such as Excel files, PDF files, and photocopies of specific sheets within chemical analysis reports. The Agency's Division of Community Health Investigations (DCHI)\Science Support Branch (SSB) provided the data import and statistical analysis services for the site. The following summarizes their analytical approach, statistical results, and conclusions/recommendations.

Environmental Data

A summary of the environmental data examined for the site is listed in Table C1. Only the groundwater data analysis is presented in detail for the purposes of this PHA. The focus of the analysis was the groundwater samples that came directly from Corozal well (i.e., untreated groundwater samples). Sample results from various points in the groundwater treatment process, including intermediate and final effluent samples collected from the granular activated carbon (GAC) filter installed in March 2011, were reviewed and summarized for internal exploratory and verification purposes. Groundwater samples that were collected and labeled as influent to the GAC filter were included in the analysis with the untreated groundwater samples.

Table C1. Summary of available environmental data by medium for the Corozal well site

Medium	Number of Samples	Number of Analytes	Number of Analytes Detected
Groundwater	108	237	39
Sediment	3	159	3
Surface Soil	16	159	4
Subsurface Soil	33	52	4
Surface Water	11	160	7

Data Analysis Methodology

ATSDR data analysts assembled and cleaned the available environmental data and analyzed it using R statistical software, version 2.15.1 (R Development Core Team 2012).

Analytical results that are below detection limits for a given analyte are typically reported as "nondetects". Nondetects are also often referred to as censored data. Historically, censored environmental data either have been omitted from data analysis or replaced by various substitute values such as the zero, ½ the detection limit, or the detection limit itself. However, censored data contain valuable information that can be used to develop descriptive statistics for a data set (Helsel 2012). Censored data were included in this data analysis in accordance with recommendations outlined in Helsel 2012. Maximum likelihood estimation (MLE) and regression on order statistics (ROS) were used to incorporate nondetect data and develop summary descriptive statistics for each analyte as applicable. The MLE and ROS statistics were generated using the R package NADA: Nondetects And Data Analysis for environmental data (Lee 2012).

Results: Descriptive Statistics

A summary of detections as well as maximum and minimum reported concentrations for selected results for untreated groundwater samples collected from the Corozal well are included in Table C2. Only chemicals with at least one detection are included in Table C2. Table C3 provides additional descriptive statistics, including the mean and 95% confidence levels on the mean, for trichloroethylene (TCE) and perchloroethylene (PCE). Note that PCE is the primary contaminant of concern in this PHA.

References

Helsel D. 2012. Statistics for censored environmental data using Minitab and R. 2nd ed. Hoboken, NJ: John Wiley Sons, Inc.

Lee L. 2012. NADA: Nondetects And Data Analysis for environmental data. R package version 1.5-4. Available at http://cran.r-project.org/web/packages/NADA/.

R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. Available at http://cran.r-project.org/.

Table C2. Descriptive Summary of Chemicals Detected in Untreated Groundwater Samples from Corozal Well

[µg/L, micrograms per liter; CREG, cancer risk evaluation guide; CEMEG, child environmental media evaluation guide; RMEG, reference media evaluation guide; LTHA, lifetime health advisory; NA, not available]

Media Type: Untreated Groundwater

Location: Corozal well (i.e., Comunidad Santana)

Chemical Name	Number of samples	Number of censored results	Number of detected results	Detection rate	Minimum censored concentration (µg/L)	Maximum censored concentration (µg/L)	Minimum detected concentration (in µg/L)	Maximum detected concentration, (µg/L)	Comparison Value(µg/L)
METHYLENE CHLORIDE	34	32	2	0.06	0.11	5	5	5	18 – CREG
TETRACHLOROETHYLENE	34	6	28	0.82	0.5	0.5	5.5	120	17 – CREG
TRICHLOROBENZENE; 1,2,4-	34	33	1	0.03	0.11	5	0.12	0.12	1,000 – CEMEG
TRICHLOROETHYLENE	34	27	7	0.21	0.25	5	0.13	0.34	0.76 – CREG
ALCOHOL; T-BUTYL	16	15	1	0.06	1.6	5	3.1	3.1	3,000 – RMEG
CARBON DISULFIDE	25	24	1	0.04	0.08	5	0.49	0.49	1,000 – RMEG
TRICHLOROBENZENE; 1,2,3-	20	19	1	0.05	0.16	5	0.17	0.17	40 – LTHA
BARIUM	2	1	1	0.5	200	200	28	28	2,000 – RMEG
CALCIUM	1	0	1	1	NA	NA	33600	33600	NA
CHLORIDE	1	0	1	1	NA	NA	20500	20500	NA
DIOXANE; 1,4-	3	2	1	0.333	100	100	100	100	0.35 – CREG
IRON	1	0	1	1	NA	NA	20	20	NA
MAGNESIUM	1	0	1	1	NA	NA	24700	24700	NA
NITRATE	6	0	6	1	NA	NA	1740	2320	16,000 – RMEG
NITRATE AND NITRITE	1	0	1	1	NA	NA	2160	2160	10,000– MCL
PHOSPHATE	2	0	2	1	NA	NA	74	80	NA
PHTHALATE; DI(2-ETHYLHEXYL)	4	2	2	0.5	0.02	1	5	5	2.5 – CREG
PHTHALATE; DIMETHYL	2	0	2	1	NA	NA	5	5	1,000 – RMEG
POTASSIUM	1	0	1	1	NA	NA	1530	1530	NA

SODIUM	1	0	1	1	NA	NA	11900	11900	NA
SULFATE	3	0	3	1	NA	NA	14100	16700	NA
VANADIUM	1	0	1	1	NA	NA	5	5	100– RMEG

Table C3. Descriptive Statistics for Selected Chemicals Detected in Untreated Groundwater Samples from Corozal Well

[ROS, regression on order statistics; MLE, maximum likelihood estimation; CREG, cancer risk evaluation guide]

Media Type: Untreated Groundwater

Location: Corozal well (i.e., Comunidad Santana)

Chemical Name	Number of samples	Detection rate	Mean calculated using MLE	Arithmetic mean of detections only	Median calculated using ROS	Geometric standard deviation	Standard error	95% lower confidence level on the MLE mean	95% upper confidenc e level on the MLE mean	Comparison Value(µg/L)
TETRACHLOROETHYLENE	34	0.82	21.2	21.3	9.7	1.15	5.14	12.8	35	17 – CREG
TRICHLOROETHYLENE	34	0.21	0.182	0.182	0.18	0.255	0.0126	0.161	0.205	0.76 – CREG