Health Consultation

Benzene Contamination in the
Transient Non-Community Drinking Water System of
Warm Springs Christian Center
13478 HWY 251

WARM SPRINGS, RANDOLPH COUNTY, ARKANSAS 72478

Arkansas Facility Identification Number: 61-01003

APRIL 17, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

Arkansas Department of Health and Human Services
Division of Health
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Statement of Issues and Background

Statement of Issues

On March 15, 2005, a member of the Division of Engineering, within the Arkansas Department of Health and Human Services' Division of Health (DOH), performed a routine inspection of Warm Springs Christian Center's (WSCC) public water system (Appendix A, Figures 1-3). The inspector detected an odor of gasoline in the water, and subsequently collected water samples. Tests performed on the samples showed benzene at levels that exceeded the calibration curve set for the measuring instrument, indicating an unusually high level of the chemical in the water.

In early April of 2005, DOH's Northeast Regional Epidemiologist fielded a community member's complaint about health issues they suspected were related to the contaminated water at WSCC. Together with the DOH's Chief Environmental Epidemiologist, a request was made for the assistance of the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate risk associated with the contaminated water. DOH program personnel evaluated the sample data and prepared this health consultation under a cooperative agreement with ATSDR. This health consultation characterizes exposures to benzene. It describes the possible health affects that the relative exposure represents.

Background

WSCC has operated as a grocery store, restaurant, and service station since 1995 (Appendix A, Figures 1-3). The store is located at 13478 on Highway 251 in Randolph County, approximately 17 miles north-northeast of the county seat, Pocahontas. The area is primarily rural and sparsely populated, with approximately a dozen homes located near the store. WSCC is reported to serve about 125 people per day. Census figures for 2000 indicate the zip code area in which the store is located has a population of 345 people [1].

WSCC's groundwater system is defined by the U.S. Environmental Protection Agency (EPA) as a transient non-community (TNC) public water system – one that provides water in a place such as a gas station or campground where people do not remain for long periods of time [2]. TNC public water systems are required to have an initial nitrate/nitrite and bacteriological (coliform) test of the water followed by routine bacteriological samples. The Division of Engineering, whose primary function is to regulate and oversee public water systems in the state of Arkansas, determines the frequency for the submittal of bacteriological samples by the TNC public water systems [3].

No construction documents are available for WSCC's groundwater well (i.e., year drilled, well depth, casing depth, grout depth, etc.). However, wells in the area, including WSCC's well, are drilled in the Cotter and Jefferson City sequence of dolomitic rocks. These formations are known for limestone and/or dolomitic limestone that have solution channels developed along the tensional fractures in the area. Carbonate outcrops in the area could provide relatively rapid pathways for unfiltered surface water to compromise the wells [4].

During a routine triennial inspection conducted on March 15, 2005, by a water quality engineer for the Division of Engineering, an odor of gasoline was detected in the water. The inspector returned on March 17th with sampling equipment and collected groundwater samples. The samples contained levels of benzene exceeding the calibration curve set for the measuring instrument, indicating an unusually high level of the chemical in the water. Additional samples were needed to determine the precise level of the contaminant in the groundwater.

On March 22, 2005, DOH personnel requested WSCC to discontinue using the well because of the contaminated water. The March 17th groundwater sample results for the WSCC well led the investigation to also include nearby residential wells. Table 1 lists the laboratory identifier assigned to the four groundwater wells that were tested for the presence of gasoline. 61WellHE represents WWCC's well. The three other wells that were tested are residential wells. Appendix A, Figure 3 shows the location of each well considered in this report.

Table 1. Identifiers assigned to groundwater wells that were tested by DOH laboratory for presence of gasoline.

Site Identifier	Well Type
61WellHE	Public
61Well-A	Residential
61Well-B	Residential
61Well-C	Residential

The inspector returned on April 20, 2005, to collect additional water samples from WSCC's well (61WellHE) and from nearby residential wells. The groundwater from 61WellHE, using an adjusted standard for benzene, again exceeded the calibration curve for the contaminant. On May 2, 2005, the inspector returned to collect additional samples. From these samples, the DOH's laboratory was able to determine the concentration of benzene at 0.358 milligrams per liter of water (mg/L).

The 61Well-A well's supply line, a private well located approximately 140 feet northeast of 61WellHE, was disconnected by the owner of the home because of the odor of gasoline in the water. Groundwater collected from the 61Well-A well on May 2, 2005, had a concentration of 0.019 mg/L of benzene. The 61Well-A well's owner was able to tie onto the adjacent home's private well (61Well-B), which has to date tested negative for the presence of gasoline contaminants. 61Well-B is located approximately 225 feet north of 61WellHE. About 300 feet southwest of the WSCC fuel tanks, is a private well identified as 61Well-C. Analytical results from 61Well-C were negative for the presence of gasoline contaminants.

The contaminant of concern addressed in this health consultation is benzene. ATSDR's Reference Dose Media Evaluation Guide (RMEG) for benzene is 0.04 mg/L for children and 0.1 mg/L for adults [5]. Other contaminants (components of gasoline) that were tested for in the groundwater from WSCC's well and nearby private wells are not being considered for discussion because the detected levels were far below ATSDR comparison values.

The highest concentration of benzene detected in the 61WellHE well was 0.358 mg/L (8.95 and 3.58 times higher than the established ATSDR's RMEG for a child and adult, respectively.) Groundwater collected from the 61Well-A well on May 2, 2005, had a concentration of 0.019 mg/L of benzene (2.1 and 5.2 times lower than the established RMEG for a child and adult, respectively).

Following up on the groundwater tests performed by the DOH's laboratory, Arkansas Department of Environmental Quality (ADEQ) – Regulated Storage Tanks Division personnel inspected the WSCC's fuel tanks on April 12, 2005. According to an ADEQ inspection checklist dated April 12, 2005, WSCC has in place two 10,000-gallon steel gasoline tanks, one 10,000-gallon steel diesel tank, and one 3,000-gallon steel diesel tank. All four tanks were installed in January 1995, and are located above ground. An earthen berm is in place to control spills. The inspection summary describes a failed line tightness test on the gasoline product line [6]. It is not known whether this deficiency is the only factor that contributed to the contamination of the groundwater.

In a letter to the owner of WSCC, dated June 21, 2005, ADEQ requested that a work plan and cost estimate for conducting an initial site characterization (ISC) be prepared. The ISC is to include information about the site and the nature of the release. The owner was also asked to locate and sample all water wells potentially impacted by the release within a 500-foot radius of the site.

DOH/ATSDR cooperative agreement staff initially visited the WSCC site on June 29, 2005. During the site visit no distressed vegetative cover was noted outside of the earthen berm that might indicate the topsoil was contaminated by fuel from the above ground storage tanks. Nor did it appear that the groundwater was being used to water lawns or gardens (no gardens were noted) in the immediate area of the WSCC site.

A follow-up site visit was conducted on November 10, 2005, that provided DOH/ATSDR cooperative agreement staff with information necessary to complete a community health needs assessment in order to address health concerns and to develop greater capacity to work with various federal and state agencies at the site. During the visit, the staff could smell gasoline in the air of WSCC's parking lot. Following the site visit, ADEQ was informed of the gasoline odor.

Discussion

To assess the potential health risks associated with contaminants at this site, we compared contaminant concentrations to health comparison values. Health comparison values, such as a RMEG, are media specific contaminant concentrations that are used to screen contaminants for further evaluation.

Potential exposure pathways to the chemical of concern (benzene) at the WSCC site were evaluated to determine if consumers could be exposed to potentially unsafe levels. DOH considered dermal contact (absorption through skin), ingestion (drinking and eating), and inhalation (breathing) as potential routes of exposure (Appendix A, Figure 4). Exposure pathways consist of the following five elements:

1. A source of contamination,
2. A release mechanism into water, soil, air, food chain (biota) or transfer between media (i.e., the fate and transport of environmental contamination),
3. An exposure point or area (e.g., drinking water well, residential yard),
4. An exposure route (e.g., ingestion, dermal contact, inhalation), and
5. A receptor population (i.e., residents, children, workers).

For a person to be exposed to a contaminant, the exposure pathway must contain all of the elements listed above, resulting in a completed exposure pathway. In some cases, a potential exposure pathway might exist in which at least one of the elements of the exposure pathway is missing, but could exist. Potential pathways indicate that exposure to a contaminant could have occurred, could be occurring, or could occur in the future. Potential exposure pathways refer to those pathways where (1) exposure is documented, but there is not enough information available to determine whether the environmental medium is contaminated, or (2) an environmental medium has been documented as contaminated, but it is unknown whether people have been, or may be, exposed to the medium, or may be exposed in the future. Additionally, an eliminated pathway is one where at least one element of the exposure pathway is missing, and therefore, exposure will never occur.

Observations made during the site visits by DOH/ATSDR cooperative agreement staff were used as one means of evaluating the existence of the five elements of a potential exposure pathway. No observational evidence exists that topsoil outside of the earthen berm surrounding the above ground fuel storage tank was contaminated. No indication that the groundwater was being used to water lawns or gardens (no gardens were noted) in the immediate area of the WSCC site was evident during the site visits. Therefore, because one or more of the exposure pathway elements were missing for the biota and soil/sediment pathways, they were eliminated as potential exposure pathways.

Comparison Values

ATSDR comparison values are media- and chemical-specific concentrations used as screening values in the preliminary identification of site-specific “contaminants of concern”. The latter term should not be misinterpreted as an implication of “hazard”. As ATSDR uses the phrase, a contaminant of concern only to describe a chemical substance detected at the site in question and selected for further evaluation of potential health effects. Generally, a chemical is selected as a contaminant of concern because its maximum concentration in air, water, or soil at the site exceeds one of ATSDR’s comparison values.

While concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. The purpose behind highly conservative, health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health hazards before they can become actual public health consequences. Thus, comparison values are designed to be preventive, rather than predictive, of adverse health effects. The probability that such effects will actually occur depends, not on environmental concentrations alone, but on unique combinations of site-specific conditions and individual lifestyle and genetic factors that affect the route, magnitude, and duration of actual exposure.

The following paragraphs describe various comparison values that ATSDR uses to select chemicals for further evaluation, and other non-ATSDR values that are sometimes used to put chemical concentrations into a meaningful frame of reference.

- **Reference dose media evaluation guide (RMEG)** is a concentration of a contaminant in air, water or soil that corresponds to EPA's reference dose for that contaminant when default values for body weight and intake rates are taken into account.
- **Minimal risk level (MRL)** is 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, noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic).
- **EPA's reference dose (RfD)** is an estimate of the daily exposure to a contaminant unlikely to cause non-carcinogenic adverse health effects.
- **EPA's Hazard Quotient (HQ)** is a ratio, which can be used to estimate if risk to harmful effects is likely or not due to the contaminant in question.

Benzene

Benzene is a colorless liquid with a sweet odor. It evaporates into the air very quickly and dissolves slightly in water. It is highly flammable and is formed from both natural processes and human activities. Benzene ranks in the top 20 chemicals for production volume. Natural sources of benzene include volcanoes and forest fires. Benzene is also a natural part of crude oil, gasoline, and cigarette smoke [5].

Benzene can pass into the air from water and soil where it reacts with other chemicals in the air and breaks down within a few days. It breaks down more slowly in water and soil, and can pass through the soil into groundwater. Benzene does not build up in plants or animals [5].

Breathing very high levels of benzene can result in death, while high levels can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. Eating or drinking foods containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, and death [5].

The major effect of benzene from long-term (365 days or longer) exposure is on the blood. Benzene causes harmful effects on the bone marrow and can cause a decrease in red blood cells leading to anemia. It can also cause excessive bleeding and can affect the immune system, increasing the chance for infection [5].

Some women who breathed high levels of benzene for many months had irregular menstrual periods and a decrease in the size of their ovaries. It is not known whether benzene exposure affects the developing fetus in pregnant women or fertility in men [5].

The U.S. DOH has determined that benzene is a known human carcinogen. Long-term exposure to high levels of benzene in the air can cause leukemia, cancer of the blood-forming organs [5].

The above description of benzene is from ATSDR ToxFAQs™ available online at http://www.atsdr.cdc.gov/toxfaq.html. This description is for informational purposes only and not necessarily associated with this site. The ATSDR ToxFAQs™ is a series of summaries about hazardous substances developed by the ATSDR Division of Toxicology. Information for this series is excerpted from the ATSDR Toxicological Profiles and Public Health Statements. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. Benzene found at this site is below chronic or long-term exposure levels that would be expected to cause adverse health effects.

Because benzene is a volatile organic chemical, there is a potential exposure pathway for this chemical from drinking the water and the inhalation of vapors during bathing and showering with contaminated water. In addition to inhalation of vapors, a person bathing and showering in contaminated water will be exposed to benzene through dermal contact or adsorption through the skin. The groundwater from WSCC's well and nearby private wells was tested for components of gasoline. Benzene was detected in the 61WellHE well (0.358 mg/L), used by WSCC, at levels above its respective RMEG. Although benzene was detected in the 61Well-A well (0.019 mg/L), the concentration was below the RMEG value. Samples collected from the 61Well-B and the 61Well-C wells on May 2, 2005, were below detection limits for benzene. An exposure pathway to benzene has been completed via the receptor population's use of the 61WellHE and 61Well-A wells.

WSCC discontinued use of their well (61WellHE) on May 22, 2005, at the request of the DOH. The owner of the 61Well-A well disconnected their supply line and tied onto the adjacent home's private well (61Well-B), which has to date tested negative for the presence of benzene. It is difficult to determine accurately the exposure time for either the WSCC patrons or the users of the 61Well-A well. Because of the lack of information regarding when the well water was first contaminated, we used the period since the last inspection of the 61WellHE well by the Division of Engineering (3 years) to calculate risk.

Estimations of the amount of benzene a person could potentially be exposed to during bathing and showering can be determined by utilizing several mathematical equations that calculate an estimated exposure to benzene through inhalation. Details of these calculations for benzene are provided in Appendix C of this report. The highest concentration of benzene detected in the 61Well-A well (0.019 mg/L) – which would have been used for bathing and showering – was used in calculating potential exposure during bathing and showering. The estimated inhalation exposure levels were determined to be below ATSDR's acute and intermediate MRLs. Table 2 of Appendix B provides a summary of the calculation results for assessing the estimated inhalation exposure to benzene vapors from bathing and showering.

Estimated Daily Exposure

The estimation of the daily exposure dose involves determining contaminant concentrations at points of potential human exposure and developing assumptions regarding the extent of human exposure in the completed exposure pathways. For this evaluation, the maximum concentration detected for the contaminant of concern (benzene) in the well water is considered as the concentration at the point of potential exposure. Individuals are assumed to have consumed the contaminated groundwater for a period of 3 years. This span of time covers the period between inspections of the TNC public water system by the Division of Engineering. Appendix B, Table 3 summarizes the results of the calculations used to estimate the daily exposure dose. Additional parameters used in the calculation of the daily exposure dose can be seen in Table 4 of Appendix C. These assumptions were intended to represent the worst-case scenario.

Dermal contact was considered as a potential route of exposure to benzene via bathing/showering. The highest concentration of benzene detected in the residential wells was 0.019 mg/L. The estimated daily-absorbed dose of benzene for a child weighing 16 kilograms (kg) with an exposure to 6,600 square centimeters (cm^2) of skin for a 10-minute bath/shower per day was 1.55×10^{-8} milligrams per kilograms per day (mg/kg/day). This value is five orders of magnitude less than the EPA dermal chronic reference dose for benzene of 0.004 mg/kg/day. No adverse health effects are expected to occur as a result of dermal exposure to benzene at these concentrations.

The maximum calculated cancer risk for a child (more vulnerable than an adult) consuming water from the WSCC groundwater well, using the parameters outlined in Appendix C, Table 4, over his/her entire lifetime (70 years) is 1.2×10^{-4} or 1 excess cancer in 10,000 exposed people. Literature on cancer risk models indicates that cancer risks of 1 in 10,000 exposed people represents some risk of cancer, as compared to 1 in 1,000,000 which represents no risk of cancer (Appendix C, Table 5) [7]. However, patrons of WSCC are typically transitory (thus the name TNC public water system) and the maximum length of time of exposure to benzene contamination in the well has been estimated to be 3 years. Consumers may have experienced acute and intermediate exposures to benzene; however, residents were not likely to have experienced chronic exposures to benzene. Therefore, lifetime cancer risk as a result of residential exposures to benzene from the WSCC well is expected to be lower than the calculations indicate.

Using EPA's HQ approach, a non-cancer risk was calculated for those using the 61WellHE well and the 61Well-A well. The highest HQ value of 0.78 was obtained by combining the use of both wells in question. A HQ of less than one indicates that harmful effects are not likely [8]. Therefore, adults are not being or have not been exposed to levels of contamination through the ingestion of groundwater from either the 61WellHE or 61Well-A well that would be expected to cause adverse health effects.

For a child weighing 16 kg, the estimated daily exposure dose of benzene through the drinking of groundwater from 61WellHE well was calculated at 2.3×10^{-3} mg/kg/day or 0.037 mg per day. This estimate, when compared to EPA's RfD, is 1.7 times lower than the lowest level at which the most sensitive effects of benzene toxicity is expected to occur. For adults weighing 70 kg and drinking groundwater from the same well, the estimated daily exposure dose was calculated at 6.6×10^{-4} mg/kg/day, which is 6 times lower than the lowest level at which the most sensitive effects of benzene toxicity is expected to occur. Therefore, the ingestion of groundwater from the 61WellHE well by a transient population is not being or has not been exposed to levels of contamination that would be expected to cause adverse health effects.

The highest estimated daily ingestion of benzene was calculated at 3.1×10^{-3} mg/kg/day using a combination of ingestion rates for a person that may have used both the 61WellHE and the 61Well-A wells during the time frame in question. The parameters used in this calculation are outlined in Appendix C, Table 4. This level is below EPA's RfD for benzene, and is therefore not likely to have a measurable health effect during a lifetime.

Community Health Concerns

In April of 2005, DOH personnel fielded general health questions from community members of Warm Springs. These questions related to exposure to contaminated groundwater from the 61WellHE well. This health consultation was prepared to address the community's concern.

Child Health Considerations

We recognize that the unique vulnerabilities of children demand special attention. Critical periods exist during development, particularly during early gestation, but also throughout pregnancy, infancy, childhood and adolescence [9]. Children may exhibit differences in absorption, metabolism, storage, and excretion of toxicants, resulting in higher biologically effective doses to target tissues. Depending on the affected media, they also may be more exposed than adults because of behavior patterns specific to children.

Exposure to well water above the chronic oral RfD for benzene (40 parts per billion) may adversely impact children's health (noncarcinogenic) if the water was ingested for many years. The highest level of benzene detected was in the 61WellHE well at 0.358 mg/L. It is expected that very limited impact to children's health has occurred at the site from consumption of groundwater because the consumption of contaminated water did not occur over a long time period (no more than 3 years). Also, the highest level of benzene was recorded in a well that served a transient population. Concentration of benzene in the 61Well-A was recorded at 0.019 mg/L, which is below RMEG comparison values.

As previously discussed, children were not impacted from acute and/or intermediate inhalation exposure from bathing and showering in water contaminated with benzene.

Conclusions

At the WSCC site, benzene was detected in the groundwater well identified as 61WellHE at a level above ATSDR's health comparison value. The private groundwater well 61Well-A also contained benzene but at levels below which benzene toxicity is expected to occur. *Because of the vulnerability of a child to environmental hazards, health risks described below were compared to health comparison values developed as a protective measure for children.* It can be assumed that these comparison values are more sensitive than those used for an adult, and therefore a more conservative protective health measure overall.

- Dermal contact with benzene was calculated at five orders of magnitude less than the EPA dermal chronic reference dose for benzene of 0.004 mg/kg/day. No adverse health effects are expected to occur as a result of dermal exposure to benzene at these concentrations.
- Estimated inhalation exposure to benzene vapors from bathing and showering did not exceed ATSDR's MRL values.
- Estimated daily ingestion rates were calculated and determined to be below EPA's RfD for benzene.
- EPA's HQ threshold of 1 was not exceeded; therefore, exposure to benzene at the highest level detected at this site is not likely to cause harmful effects.
- The estimated cancer risk was calculated to be 1.2×10^{-4} or 1 excess cancer in 10,000 exposed people represents some risk of cancer, as compared to 1 in 1,000,000 which represents no risk of cancer, the calculations are based on a lifetime exposure (70 years), not the more probable 3 years exposure period.
- No observational evidence exists that topsoil outside of the earthen berm surrounding the above ground fuel storage tank was contaminated.
- No indication that the groundwater was being used to water lawns or gardens in the immediate area of the WSCC site was evident during the site visits.

Definitive conclusions are limited because of the uncertainty regarding the possible length of exposure to the benzene-contaminated water. Furthermore, the concentration of benzene at the time the groundwater was sampled may not be representative of the contaminants concentration during the 3 year period the chemical is suspected to have been present. Therefore, on the basis of data reviewed, the contamination of the 61WellHE and 61Well-A wells with fuel from the above ground tanks used by WSCC poses *No Apparent Public Health Hazard.*

Recommendations

- DOH concurs with ADEQ's recommendation that the owner(s) of WSCC – or potentially responsible party (PRP) – identify all private groundwater wells within a radius of 500-feet of WSCC's above ground fuel tanks.
- DOH concurs with ADEQ's recommendation that the groundwater wells within a 500-foot radius of WSCC's above ground fuel tanks be sampled by the PRP to assess the pathway of the benzene plume; DOH further recommends that the wells be periodically monitored to ensure the release remains contained.

Public Health Action Plan

The purpose of the Public Health Action Plan (PHAP) is to ensure that this Health Consultation not only identifies any public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The PHAP implemented by DOH for WSCC is as follows:

<u>Completed Actions</u>

- DOH's Division of Engineering collected water samples March - May 2005.
- DOH personnel, on March 22, 2005, asked WSCC to voluntarily close their business to the public because of levels of benzene detected in their water source.
- ADEQ conducted an inspection of WSCC's above ground fuel tanks April 2005.
- DOH/ATSDR cooperative agreement staff conducted an initial site visit in June 2005 and a follow-up site visit in November 2005.
- DOH informed ADEQ of gasoline odors in WSCC's parking lot during a site visit in November 2005.

<u>Future Activities</u>

- DOH will continue to review available sampling data to better determine public health risk.
- DOH will complete a community needs assessment.
- DOH will conduct health education in the community as needed, and/or requested.

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Certification

This health consultation for Warm Springs Christian Center was prepared by the Arkansas Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedure existing at the time the health consultation was initiated. Editorial review was completed by the cooperative agreement partner.

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The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

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Appendices

Appendix A – Figures

Figure 1. Warm Springs Christian Center

Figure 2. Fuel tanks and groundwater well that serve Warm Springs Christian Center

Figure 3. Aerial photo depicting wells sampled and Warm Springs Christian Center fuel tanks

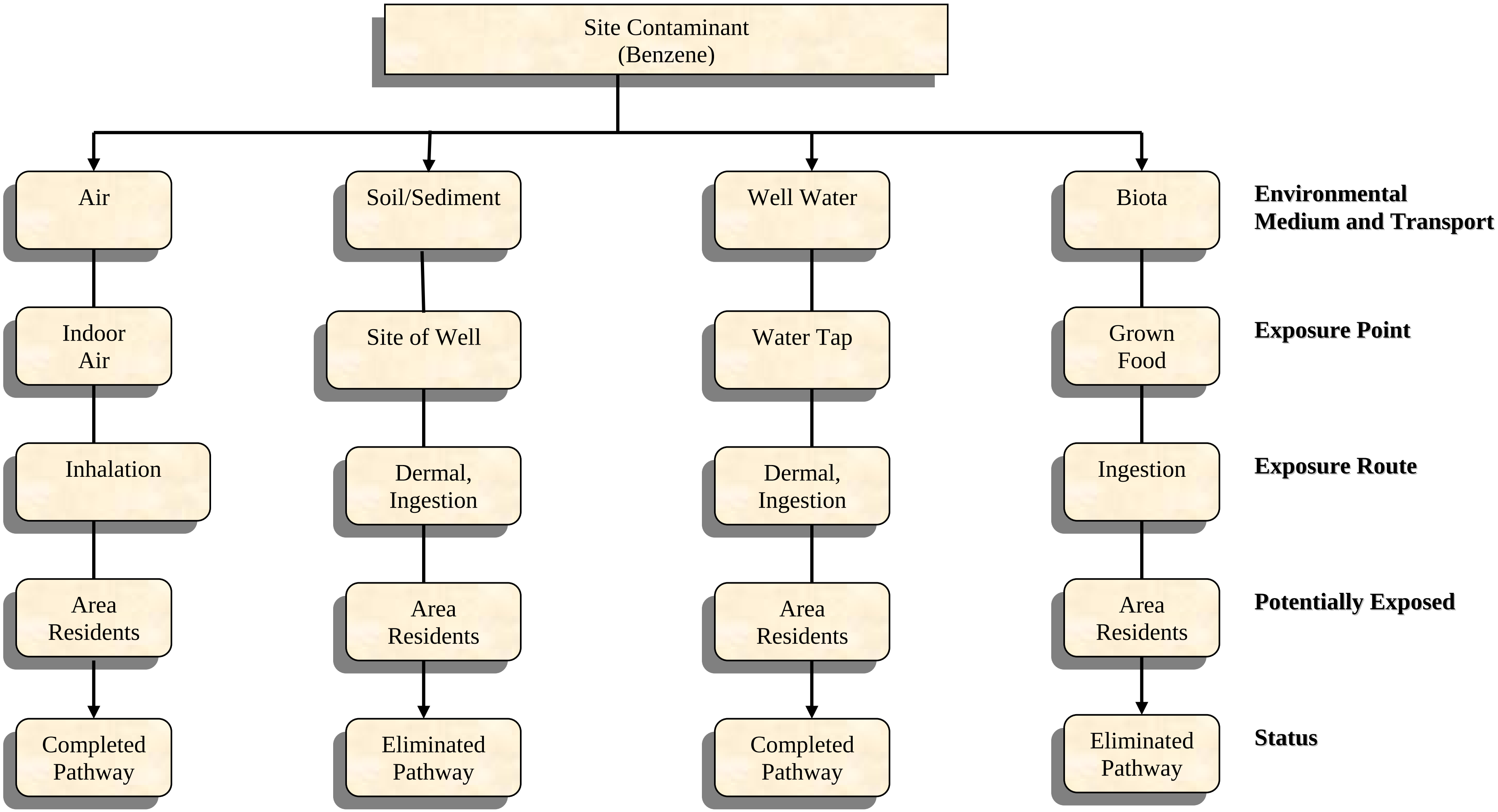

Figure 4. Exposure pathway evaluation

Appendix B – Tables

Table 2. Estimated inhalation exposure to benzene vapors from bathing and showering

Chemical	Estimated Acute Vapor Exposure	Acute Exposure MRL*	Estimated Intermediate and Chronic Vapor Exposure Level	Intermediate Exposure MRL*
Benzene	28.5	50	2.9	4

Values are in ppb or parts per billion
Note: Calculations are shown in Appendix C.
*MRL = minimum risk level = An 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.

Table 3. Groundwater sample results for benzene – **Drinking Water Ingestion**

Well water concentration by well type (mg/L)		ATSDR Comparison Value (mg/L)		Cancer Slope Factor (mg/kg/day)	Maximum Cancer Risk	Non-Cancer Risk	RfD† (mg/kg/day)	Estimated Daily Exposure Dose from Ingestion (mg/kg/day)	
Type	Maximum	Adult	Child					Adult	Child
Public	0.358	0.1*	0.04*	0.055	1.2×10^{-4}	0.57	4.0×10^{-3}	6.6×10^{-4}	2.3×10^{-3}
Residential	0.019	0.1*	0.04*	0.055	9.3×10^{-5}	0.43	4.0×10^{-3}	5.2×10^{-4}	1.7×10^{-3}
Combination	0.019-0.358	0.1*	0.04*	0.055	1.7×10^{-4}	0.78	4.0×10^{-3}	9.0×10^{-4}	3.1×10^{-3}

Note: samples collected by Arkansas Department of Health and Human Services – Division of Engineering
(mg/L) = milligram per liter; (mg/kg/day) = milligram per kilogram per day
*Reference Dose Media Evaluation Guide (RMEG) represent concentrations of substances (in air, water and soil) to which humans may be exposed without experiencing adverse health effects.
†RfD = Reference Dose = an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of harmful effects during a lifetime.

Appendix C – Calculations

Parameters – Table 4

The parameters used in the calculation of an estimated daily ingestion rate are defined in the table below. Because WSCC's well (61WellHE) serves a transient non-community population an exposure frequency of 156 days per year (3 days per week) was used in assessing exposure. In assessing risk for residential use of the 61Well-A well an exposure frequency of 350 days per year was used. When calculating the estimated daily ingestion rate for residents that may frequent WSCC a total of 156 days at 0.358 mg/L and 194 days at 0.019 mg/L were used.

When calculating the risk of drinking the groundwater from the 61WellHE well an ingestion rate of 0.24 liters per day for a child and 0.30 liters per day for an adult were used. The ingestion rate used in calculating risk for residential use was 1.5 liters per day and 2.0 liters per day for a child and an adult, respectively. These assumptions were intended to represent the worst-case scenario. Appendix B, Table 3 shows the calculation results.

Table 4. Parameters used in the calculation of the estimated daily exposure dose for the associated conditions

Parameter		Default Value		Units
		Child	Adult	
Exposure Parameters – General				
• Body Weight	BW	16	70	kg
• Averaging Time	AT	1,095.7	1,095.7	days
• Exposure Duration	ED	3	3	years
Exposure Parameters – 61WellHE				
• Exposure Frequency	EF	156	156	days/year
• Contaminant Concentration	C	0.358	0.358	mg/L
• Ingestion Rate	IR	0.24	0.30	L/day
Exposure Parameters – 61Well-A				
• Exposure Frequency	EF	350	350	days/year
• Contaminant Concentration	C	0.019	0.019	mg/L
• Ingestion Rate	IR	1.5	2.0	L/day
Exposure Parameters – Combination				
• Exposure Frequency	EF	156	156	days/year
		194	194	
• Contaminant Concentration	C	0.358	0.358	mg/L
		0.019	0.019	
• Ingestion Rate	IR	0.24	0.30	L/day
		1.5	2.0	

The following equation was used for calculating an estimated daily exposure dose:

$$\text{Estimated exposure dose} = \frac{(C \times IR \times EF \times ED)}{BW \times AT}$$

Acute Exposures

When adults and children bathe or shower in water contaminated with volatile organic chemicals VOCs, such as benzene, these chemicals will get into the body in two ways. First, these chemicals will evaporate from the water into indoor air where adults and children will be exposed when they breathe the air; secondly, these chemicals can penetrate the skin during the time that a resident is bathing or showering.

Volatilization from showers

Scientists have studied how chemicals volatilize from shower water and have developed equations for estimating indoor air levels in the shower and bathroom [10-13]. Therefore, the maximum concentration (conc.) of a VOC in the bathroom can be estimated for a 10-minute shower and for the 20-minute period in the bathroom following a shower using the following equation:

C air max = (k) (Fw) (Ts) (Cw) / Va

where,

C air max = maximum conc. in air during the shower and after period in bathroom,
k = fraction of chemical that evaporates from water while showering (assumed to be 0.6),
Fw = flow rate of water through shower head in L/minute (assumed to be 8 liters/minute),
Ts = duration of shower in minutes (assumed to be 10 minutes),
Va = volume of shower and bathroom in liters, (assumed to be 10,000 liters, the Approximate size of a small bathroom), and
Cw = conc. of VOC in water in mg/L [12].

The following example shows how units cancel to arrive at mg VOC per cubic meter of air.

C air max = (k) (Fw) (Ts) (Cw) / Va
C air max = (%) (L/min) (min) (mg VOC/L) / L
C air max = mg VOC / L air
C air max = mg/L air x 1000 L air/m^3
C air max = mg/m^3.

Using benzene at 0.019 mg/L as an example, the following bathroom air concentration is estimated:

C air max = (0.6) (8 L water/min)(10 min) (0.019 mg/L water) / 10,000 L air
C air max = 0.0000912 mg/L air
C air max = 0.0000912 mg/L air x 1000 L air/m^3 = 0.0912 mg/m^3

To convert mg/m^3 to parts per million (ppm) start with the following equation:

$$ppm = \frac{mg/m^3 \times 24.45}{Mol.\ Wt.}$$

where,

ppm = the concentration of the chemical in parts per million
mg/m^3 = the concentration of the chemical in milligrams per cubic meter
24.45 = is the number of liters of air occupied by one mole of anything at standard temperature and pressure.
Mol. Wt. = Molecular Weight (i.e., the molar mass, in gram per mole) is substance specific.

Using the concentration calculated above:

$$ppm = \frac{(0.0912\ mg/m^3) \times 24.45}{78.11\ g}$$

ppm = 0.0285 or 28.5 parts per billion

To determine the amount of VOC exposure from inhalation, adults are assumed to inhale 1 cubic meter of air each hour [14].

Dermal intake converted to an air concentration

In addition to the exposure from breathing VOCs, people also absorb VOCs through their skin while showering and bathing. Using a skin permeability constant for VOCs, scientists have developed an equation for estimating the amount of VOC that is absorbed through the skin during a shower [15]. The VOC exposure via skin can be estimated using the following formula:

Skin dose =
(dermal permeability constant) (duration of exposure)(total body surface area)(percent of body surface area exposed)(VOC concentration in water)(fraction remaining after volatilization)

The units are ($L/cm^2 \times hr$) (hr) (cm^2) (%) (mg/L)(%), which cancel out to mg. The permeability constant for benzene can be found from U.S. EPA Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim and is determined to be 1.5×10^{-5} L/cm-hr. Forty percent of the VOCs are assumed to remain in the shower water after volatilization [10, 16].

Because exposure to VOCs via the skin does not pass first through the liver, skin exposure is likely to be more toxicologically similar to inhalation exposure rather than ingestion exposure. Like inhalation exposure, a VOC absorbed through the skin will be distributed throughout the body before reaching the liver for detoxification. Therefore, to evaluate both inhalation exposure and skin exposure, it is necessary to convert the dose from skin absorption to an air concentration. Adding the air concentration that exists in the bathroom from taking a shower and the air concentration that is equivalent to the skin dose gives a total concentration in air that can be used to evaluate toxicity of a VOC from both routes of exposure.

The following example using benzene shows the estimated dose from skin absorption and how to convert that estimated dose to an air concentration. First, it is necessary to estimate the skin dose, which has been shown in a previous equation.

Skin dose = (1.5 x 10^{-5} L/cm^2 x hr)(10/60hr)(20,000 cm^2)(1)(0.019 mg/L)(0.4).

Skin dose = 3.8 x 10^{-4} mg benzene

Next, it is necessary to convert the skin dose of 3.8 x 10^{-4} mg to an air concentration.

Air concentration from skin exposure =
Skin dose / inhalation rate x shower duration =
3.8 x 10^{-4} mg/ 1 m^3/hr x 1 hr/60 minutes x 10 minutes = 6.33 x 10^{-5} mg/m^3

Using the concentration calculated above to convert from mg/m^3 to ppm:

$$\text{ppm} = \frac{(6.33 \times 10^{-5}\ \text{mg/m}^3) \times 24.45}{78.11\ \text{g}}$$

ppm = 0.0000198 ppm or 0.0198 ppb

Therefore, a concentration of 6.33 x 10^{-5} mg/m^3 benzene in air will give an equivalent skin dose of 3.8 x 10^{-4} mg for a 10-minute shower. The total exposure from volatilization and from skin absorption is 28.5 ppb plus 0.0198 ppb, which is 28.52 ppb benzene in air.

Chronic exposure

To evaluate chronic exposure, it is necessary to also include the additional VOC exposure that occurs the remainder of the day indoors.

To estimate the total exposure (exp.) of a specific VOC from bathing in contaminated water, the following exposures need to be considered:

Total exp. $_{\text{specific VOC}}$ = exp. $_{\text{shower inhalation}}$ + exp. $_{\text{bathroom inhalation}}$ + exp. $_{\text{skin dose}}$

Thus, the equation to estimate each exposure pathway is as follows:

(Conc. air max in mg/m^3) (1 m^3/hr) (10/60 hr) + (Conc. air max in mg/m^3)(1m^3/hr)(20/60 hr) + (L/cm^2 x hr)(hr)(cm^2)(% surface area)(mg/L)(% remaining)

As an example, the total exposure for bathing in benzene-contaminated water containing 0.019 mg/L benzene is:

Total exp. $_{benzene}$ = (1.4688 mg/m^3) (1 m^3/hr) (10/60 hr) + (1.4688 mg/m^3) (1 m^3/hr) (20/60 hr) + (1.5 x 10^{-5} L/cm^2 x hr)(10/60hr)(20,000 cm^2)(1)(0.306 mg/L)(0.4).

Total exp. $_{benzene}$ = 0.0152 mg + 0.0304 mg + 0.00038 mg = 0.04598 mg for a 10-minute shower and a 20-minute bathroom stay.

Using the maximum VOC detected, the exposure from summing all VOCs from bathing is estimated to be about 0.04598 mg. This, however, is not the total exposure of VOCs for the day since adults and children are exposed to VOCs from breathing indoor air during the remainder of the day. This estimate can be made by using results from actual indoor air measurements or estimates from published information. In the toxicological profile for benzene, a study was referenced that found average ambient benzene concentrations in homes at 7 µg/m^3. The exposure for a VOC can be estimated assuming a reasonable situation where someone stays at home most of the day. Typically men breathe about 23 cubic meters of air each day and women breathe about 21 cubic meters of air each day. Assuming that some time is spent away from the home each day, 20 m^3/day might be a reasonable, average upper-end exposure situation, and thus the VOC exposure can be estimated using the following formula:

VOC exp. $_{indoor\ air}$ = (conc. of VOC indoors in µg/m^3) (20 m^3/day) (1 mg/1000 µg)

Substituting into the above equation for benzene we can estimate the daily exposure to benzene from indoor air.

Indoor air exp. $_{benzene}$ = (7 µg/m^3) (20 m^3/day) (1 mg/1000 µg) = 0.140 mg/day

The next step is to convert the total daily exposure (in mg/day) for the VOC (based on shower exposure, bathroom air exposure, dermal exposure, and indoor air exposure) into a daily dose and a daily dose based on air concentration.

Total daily dose = 0.04598 + 0.140 = 0.18598 mg/day
Daily air concentration = 0.18598 mg/day ÷ 20 mg/m^3 = 0.0093 mg/m^3

Using the concentration calculated above to convert from mg/m^3 to ppm:

$$ppm = \frac{(0.0093\ mg/m^3) \times 24.45}{78.11\ g}$$

ppm = 0.0029 ppm or 2.9 ppb

Calculation of Hazard Quotient (HQ)

Risk can be estimated using the Hazard Quotient (HQ). An HQ is the average daily intake divided by the reference dose (RfD). RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of harmful effects during a lifetime. Appendix B Table 3 shows the calculation results using the following HQ equation:

$$HQ = DI / RfD$$

where,

HQ = Hazard Quotient (unitless)
DI = Daily Intake (milligram per kilogram per day = mg/kg/day)
RfD = Reference Dose (mg/kg/day)

After the calculation…

If…

HQ > 1.0 then harmful effects may be likely
HQ = 1.0 Not likely to cause harmful effects
HQ < 1.0 Harmful effects not likely

Calculation of Estimated Theoretical Risk for Cancer

To characterize potential carcinogenic effects, estimated risks that an individual will develop cancer over a lifetime of exposure (70 years) to a contaminant are calculated from projected intakes and the cancer slope factor. The cancer slope factor converts estimated daily intakes directly to an estimate of incremental risk [17].

The following calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a *lifetime* of exposure. Because of the uncertainties and conservatism inherent in deriving the cancer slope factors (CSFs), this is only an estimate of risk; the true risk is unknown and could be as low as zero. Appendix B, Table 3 shows the estimated theoretical risk calculation results using the following equation:

$$ER = CSF \times D$$

where,

ER = estimated theoretical risk (unitless)
CSF = cancer slope factor $(mg/kg/day)^{-1}$
D = estimated exposure dose (mg/kg/day)

Table 5. Understanding Cancer Risk Models		
Chance of new cancers	EPA Abbreviations	Risk
"One in one-million"	1/1,000,000; 1×10^{-6}	No Risk of cancer
"One in one-hundred thousand"	1/100,000; 1×10^{-5}	More risk, but acceptable
"One in ten-thousand"	1/10,000; 1×10^{-4}	Some risk, but allowable
"One in one-thousand"	1/1,000; 1×10^{-3}	High Risk of cancer
The Glynn Environmental Coalition, Inc. August, 2000		