Letter Health Consultation

LAJOLLA SPRING CAVE COMPLEX

STANTON, MISSOURI

Prepared by
Missouri Department of Health and Senior Services

DECEMBER 12, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

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

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LETTER HEALTH CONSULTATION

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Missouri Department of Health and Senior Services
Division of Community and Public Health
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December 5, 2014

Tonya Howell
Remedial Project Manager
U.S. Environmental Protection Agency Region VII
11201 Renner Blvd.
Lenexa, KS 66219

Re: Letter Health Consultation, LaJolla Spring Cave Complex, Stanton, Missouri

Dear Ms. Howell:

The Missouri Department of Health and Senior Services (DHSS) developed this letter of health consultation to evaluate the results of air sampling conducted within the LaJolla Spring Cave Complex, a popular tourist destination, in Stanton, Missouri. Specifically, DHSS reviewed volatile organic compound (VOC) concentrations in cave air samples collected between March 2013 and August 2014, to identify potential human health risks to workers from vapor intrusion (VI) within the cave. DHSS concludes that inhalation exposure to trichloroethylene (TCE) in cave air poses a health risk to individuals currently working in the cave (i.e., an urgent public health hazard) and recommends prompt action to prevent or reduce exposure by informing the workers of the health risks and implementing measures to mitigate vapor intrusion into the cave. Potential human health risk to visitors of the cave is being evaluated separately from this health consultation.

Background and Basis for Decision

VOC concentrations in cave air are believed to be related to the Oak Grove Village Well site, located in Oak Grove Village/Sullivan, Missouri, which has an undefined TCE groundwater plume that affected public and private drinking water wells in the area (1). During past site investigations, dye traces were conducted to assist in defining groundwater flow directions and to determine hydrologic conditions. Based on the site investigation and the dye tracing results, TCE and other VOCs are believed to be migrating in groundwater from the site to LaJolla Spring, which surfaces in a large commercially-operated cave before it drains into the Meramec River (2,3). To determine whether air inside the cave was being impacted by the contamination in the area, previous air sampling was conducted between 2002-2005 and found to have elevated levels of TCE ranging from non-detect to 1,700 $\mu g/m^3$ (2,3). Due to the airborne contaminant levels found within the cave complex, an additional area of the cave was opened in 2005 to generate more airflow, which reduced contaminant levels at the time. Sampling was resumed in 2013 as part of additional site investigations. Air samples have been collected at seven locations within the cave complex during six sampling events between March 2013 and August 2014 as shown in Table 1. This sampling shows elevated TCE levels ranging from non-detect to 252 $\mu g/m^3$, which exceed the U.S. Environmental Protection Agency (EPA) Vapor Intrusion Screening Levels (VISLs) of 8.8 $\mu g/m^3$ for non-cancer effects and 3.0 $\mu g/m^3$ for cancer effects, established for assessing

risk of indoor air exposure by the VI pathway in a commercial setting (4).

Table 1. TCE Concentrations (µg/m^3) in Cave Air

Sample Location	Mar. 2013	Aug. 2013	Jan. 2014	Mar. 2014	Jun. 2014	Aug. 2014
Gift Shop	<1.2	97.5	5.37	1.13	125	143
Ticket Counter	NS	NS	NS	4.83	183	193
Ballroom[a]	5.16 / 4.57	138	20	4.51	169	133
Theater Room	4.19	<0.43	12.3	4.35	1.29	0.698
Loot Rock[b]	7.09	153 / 164	33.8 / 40.1	14 / 13.9	220 / 217	224 / 189
Lassie	18.2	117	48.8	21.4	196	176
Jungle Room	22.4	177	64.8	17.4	252	240
Background Ambient Air	<1.2	0.483	<0.43	<0.43	1.18	0.806

[a] Results for March 2013 include a sample collected from the Ballroom and a sample collected from the Ballroom Stage.
[b] Results include the original sample and field duplicate sample.
NS = Not sampled

Air samples were collected over a 24-hour period; therefore, DHSS converted the measured concentrations from Table 1 to worker-equivalent exposure concentrations to account for shorter worker exposure time of 8 hours/day. These time-adjusted worker exposure concentrations are shown in Table 2 and were calculated as follows:

$$\text{TCE Worker Exposure Concentration } (\mu g/m^3) = \text{TCE Concentration in Air } (\mu g/m^3) \times \left(\frac{8\ hours/day}{24\ hours/day}\right)$$

In this evaluation, DHSS compared these worker-equivalent exposure concentrations to indoor air guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR) for TCE, (i.e., ATSDR's chronic minimal risk level (MRL) and cancer risk evaluation guide (CREG)). An MRL is an estimate of daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects. A CREG is a comparison value used to identify concentrations of cancer-causing substances that are unlikely to result in an increase of cancer rates in an exposed population over a lifetime exposure and are based on a theoretical excess lifetime cancer risk of 1E-6 (i.e., 1 additional cancer case per 1 million exposed people).

Table 2. Time-Adjusted TCE Worker Exposure Concentrations (µg/m^3) in Cave Air[a]

Sample Location	Mar. 2013	Aug. 2013	Jan. 2014	Mar. 2014	Jun. 2014	Aug. 2014
Gift Shop	NA	**32.5**	**1.8**	**0.38**	**41.7**	**47.7**
Ticket Counter	NA	NA	NA	**1.6**	**61**	**64.3**
Ballroom[b]	**1.7**	**46**	**6.7**	**1.5**	**56.3**	**44.3**
Theater Room	**1.4**	NA	**4.1**	**1.5**	**0.43**	0.23
Loot Rock[b]	**2.4**	**54.7**	**13.4**	**4.7**	**73.3**	**74.7**
Lassie	**6.1**	**39**	**16.3**	**7.1**	**65.3**	**58.7**
Jungle Room	**7.5**	**59**	**21.6**	**5.8**	**84**	**80**
Comparison Values[c]						
non-cancer	***2.0 (ATSDR Chronic MRL)***					
cancer	***0.24 (ATSDR CREG)***					

[a] Highlighted values exceed the non-cancer comparison value; Values in bold exceed the cancer comparison value.
[b] Calculations based on the maximum detected result for the Ballroom and Loot Rock locations where more than one sample was collected from a given location during the same sampling event.
[c] ATSDR's chronic MRL and EPA's inhalation reference concentration (RfC), which are concentrations unlikely to cause adverse non-cancer health effects (RfC established by EPA in 2011 (5) and adopted by ATSDR as its chronic MRL in 2013 (6)); ATSDR's CREG, based on an excess lifetime cancer risk of 1E-6 (a concentration expected to cause no more than 1 additional cancer case in 1,000,000 exposed people), (6).
NA = Not Applicable

Measured concentrations within the cave vary over time and by location; however, the comparison in Table 2 shows the majority of worker exposure concentrations within the cave exceed the comparison values for both non-cancer and cancer effects. A detailed evaluation of potential health effects from worker exposure is provided in the following section.

Based on our evaluation, DHSS concludes that inhalation exposure to TCE in cave air poses a health risk to individuals working in the cave (i.e., an urgent public health hazard). The short-term health risk of primary concern is cardiac malformation in a developing fetus due to maternal exposure to TCE. The primary long-term health risks of TCE exposure include effects to the immune system, kidney and liver cancers, and non-Hodgkins lymphoma.

Due to the short-term health risks associated with TCE exposure, DHSS recommends prompt action to prevent TCE exposures to female workers of child-bearing age and reduce TCE exposures for all other workers by implementing measures to mitigate vapor intrusion into the cave. To assist EPA and the community, DHSS is available to provide health education and answer people's questions about possible health effects and to evaluate additional sampling data as it becomes available.

Effects of Worker Exposure to TCE

Non-Cancer Health Effects

Several animal and epidemiological studies have shown evidence that exposure to low concentrations of TCE may increase the risk of gestational or early postnatal development of cardiac malformations (5). Exposure to low concentrations of TCE may also increase the risk of immunological effects, as indicated by studies reporting decreased thymus weight and increased antibody production in animals (5).

EPA's reference concentration (RfC), adopted by ATSDR as a Minimal Risk Level (MRL), of 2.0 $\mu g/m^3$ for inhalation exposure, was based on studies showing the development of cardiac malformations in rats over approximately three weeks of gestational exposure and immunological effects in mice after 30 weeks of exposure (5). In their review of those studies, EPA derived TCE concentrations that might be expected to have the same effects in humans. The 99^{th} percentile of these human equivalent concentrations (HECs) are 21 $\mu g/m^3$ TCE with an uncertainty factor of 10 applied for exposures potentially associated with cardiac malformations and 190 $\mu g/m^3$ TCE with an uncertainty factor of 100 applied for exposures potentially associated with immunological effects (5).

Nearly half of all the worker-equivalent exposure concentrations exceed this estimated effect level for cardiac malformations (21 $\mu g/m^3$). This indicates that pregnant workers with short-term exposure to TCE in cave air may have an increased risk of cardiac malformations to their developing fetuses if the exposure occurs during fetal heart development in the first trimester of pregnancy.

TCE concentrations fluctuate from sampling locations within the cave and additionally fluctuate between sampling rounds with higher concentrations associated with the warmer months of the year. In addition, the sampling results cover only limited time periods which make it difficult to determine long-term exposure levels. Because VOC concentrations have not been regularly monitored, DHSS cannot draw definitive conclusions about potential non-cancer health concerns due to chronic (long-term) exposures within the cave; however, the historical sampling data combined with the recent data collected periodically over an 18-month time period give some indication of possible long-term exposures in the cave. The worker-equivalent exposure concentrations are well within the range of

uncertainty applied to the HEC for immunological effects (1.9 µg/m^3 to 190 µg/m^3). This evidence supports the conclusion drawn that workers may be at increased risk of adverse non-cancer health effects from chronic inhalation exposure to TCE in cave air.

Interpretation of epidemiological and animal studies supporting the association between TCE and cardiac malformations has been controversial. Some epidemiological studies have reported no significant increases in congenital cardiac malformations following maternal exposure to TCE (7). In addition, EPA has recognized that there are limits to the animal study used in developing the RfC. However, the results of the selected animal study are supported by the general weight of evidence from multiple studies, including epidemiological studies that, as a whole, consistently provide evidence that TCE exposure in humans may cause a variety of cardiac defects if exposure occurs within the critical developmental window (7).

Additional studies have provided substantial evidence that, at sufficient dose and exposure duration, TCE is toxic to the nervous system, kidney, liver, and male reproductive system and is associated with other developmental effects (6). The most sensitive effects of TCE exposure appear to be developmental effects (including fetal cardiac malformations), kidney toxicity, and immunological effects (5). Immunological studies, including epidemiological studies, indicate that chronic exposure to a sufficient dose of TCE may increase the risk of development of autoimmune diseases, including scleroderma (a hardening of the skin), and hypersensitivity skin disorder, as well as possible suppression of the immune system (7).

Cancer Risk

EPA classifies TCE as carcinogenic to humans. The National Toxicology Program (NTP) has determined that TCE is reasonably anticipated to be a human carcinogen based on evidence from animal studies and limited evidence from human studies (8). Long-term TCE exposure is associated with liver and kidney cancers and non-Hodgkins lymphoma by multiple routes of exposure, including inhalation exposure (5,6). Because kidney cancer may develop by a mutagenic route of exposure to TCE, there is increased cancer risk from exposure to TCE during childhood (5,6).

The worker-equivalent exposure concentrations exceed the ATSDR CREG (0.24 µg/m^3) for continuous inhalation exposure indicating there is a potential for increased cancer risks for workers in the cave complex. To further assess this potential, DHSS calculated excess cancer risks based on typical worker exposures. For this evaluation, cancer risks were determined from the minimum and maximum-detected TCE concentrations in the cave complex (0.698 and 252 µg/m^3, respectively) and an assumed worker exposure of 8 hours per day, 250 days per year, for an expected 25-year period of employment, using EPA's inhalation unit risk (IUR) of 4.1×10^{-6} per µg/m^3 (5).

$$CR = \left(\frac{CA \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times ED}{AT_c} \right) \times IUR$$

Where:
CA = Contaminant Concentration in Air (minimum=0.698 and maximum=252 µg/m^3)
ET = Exposure Time for Inhalation (8 hours/day)

EF = Exposure Frequency (250 days/year)
ED = Exposure Duration (25 years)
AT_c = Averaging Time for Carcinogens (28,470 days = 78 year lifetime × 365 days/year)
IUR = Chronic Inhalation Unit Risk (4.1×10^{-6} $(\mu g/m^3)^{-1}$)
Cancer Risk (*CR*) = 2.1E-7 to 7.6E-5

This represents possible cancer risks from worker exposure to TCE in the cave air, ranging from <1 in a population of 1,000,000 to approximately 8 excess cases in a population of 100,000, averaged over a lifetime; however, actual exposures have not been constant and have varied over time due to changes in the rates of vapor intrusion. Because sampling results cover only limited time periods and long-term exposure levels are not known, DHSS cannot draw definitive conclusions about cancer risks at the cave complex.

Conclusions

1. DHSS concludes that inhalation exposure to TCE in cave air poses a health risk to individuals currently working in the cave (i.e., an urgent public health hazard):
   - Pregnant workers with short-term exposure to TCE in cave air are at an increased potential risk of cardiac malformations to their developing fetuses if the exposure occurs during fetal heart development in the first trimester of pregnancy.
   - Workers with long-term exposure to TCE in cave air may be at increased risk of other adverse non-cancer health effects and possible increased cancer risks if exposure occurs over extended periods of time.

Recommendations

DHSS believes it is most protective to limit any potential adverse exposure whenever possible. To protect the current and future health of individuals working in the cave complex and individuals living or working in the area of the Oak Grove Village Well site, DHSS recommends EPA take the following actions:

1. Inform workers of elevated TCE concentrations in cave air and the potential health risks associated with TCE inhalation. DHSS recommends notifications be made as soon as possible.

2. Implement permanent measures to mitigate vapor intrusion into the cave as soon as possible. Consider implementing temporary measures to prevent TCE exposure to female workers of child-bearing age until permanent mitigation solutions are in place. Once a permanent solution is in place, conduct periodic monitoring to confirm that mitigation solutions are effective in reducing contaminant levels.

3. Fully characterize the extent of VOC migration within the area of the Oak Grove Village Well site and expand VI sampling to identify any neighboring commercial and/or residential buildings at risk of VI.

To assist the EPA, workers of the LaJolla Spring Cave Complex, and the community around the Oak Grove Village Well site, DHSS is available to:

1. Provide health education and answer people's questions about possible health effects.

2. Work with ATSDR to refer people with specific health needs to organizations such as the Association of Occupational and Environmental Clinics (AOEC), American College of Medical Toxicology (ACMT), and Pediatric Environmental Health Specialty Unit (PEHSU) as necessary.

3. Evaluate additional sampling data and information as it becomes available and provide further guidance regarding possible health risks as needed.

We appreciate the opportunity to be of assistance. If you have any questions, please contact Michelle Hartman at (573) 751-6102.

Sincerely,

Jonathan Garoutte, Chief
Bureau of Environmental Epidemiology

JG:DW:MH:mp

References

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Report Preparation

This Letter Health Consultation for the LaJolla Spring Cave Complex was prepared by the Missouri Department of Health and Senior Services under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

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