

Letter Health Consultation

BREAKDOWN CAVE SITE
CHRISTIAN COUNTY, MISSOURI

NOVEMBER 21, 2007

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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LETTER HEALTH CONSULTATION

BREAKDOWN CAVE SITE

CHRISTIAN COUNTY, MISSOURI

Prepared By:

Missouri Department of Health and Senior Services
Division of Community and Public Health
Bureau of Environmental Epidemiology
under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry



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Dear Mr. Gouzie and Mr. Beard:

This letter is in response to water and air samples collected by Missouri Department of Natural Resources (DNR) in Breakdown Cave. DNR collected water samples on August 1, 2006 and air samples on August 28, 2006 from Breakdown Cave located in Christian County, Missouri. During this investigation, MDNR detected levels of chemicals in water and air and requested the Missouri Department of Health and Senior Services (DHSS) review and comment on the findings. DHSS works with the federal Agency for Toxic Substances and Disease Registry (ATSDR) to provide health information and recommendations to individuals and communities regarding chemical exposures. This letter health consultation is a more in-depth response following a letter sent to DNR September 12, 2006.

As you have previously discussed with DHSS staff, the Missouri State University, some organizations, and school groups use this cave system for tours as an educational tool. An estimated 200 visitors tour the cave each year with each tour lasting two to three hours. The cave manager, Mr. Beard, spends the most amount of time in the cave system with up to 18 visits per year with the typical amount of time spent in the cave being 2 to 5 hours per visit but has been as long as 11 hours. For the purposes of this paper, we will focus on the cave manager's time spent in the cave as the maximum exposure duration for all visitors. Since the cave manager spends the most time in the cave, using his exposure duration will be protective for all other visitors.

During a tour in June of 2006, a gasoline-like odor was detected which prompted investigation by DNR. A film was also noticeable on some of the water in the cave. Water samples were collected by DNR on August 1, 2006, and air samples were collected by DNR on August 28, 2006. Testing of air samples detected 8,300 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) of hexane, 1,400 $\mu\text{g}/\text{m}^3$ of cyclohexane, 4,500 $\mu\text{g}/\text{m}^3$ of 2,2,4-trimethylpentane, and 590 $\mu\text{g}/\text{m}^3$ of heptane. See Table 1. Testing of the water sample detected 0.61 $\mu\text{g}/\text{L}$ of benzene and 1.19 $\mu\text{g}/\text{L}$ of tetrachloroethene. See Table 2. Acetone was detected in a trip blank at 1,230 $\mu\text{g}/\text{L}$, but it was not detected in the actual sample.

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**Table 1. Results of Air Sampling
Collected by DNR in Breakdown Cave on August 28, 2006
and Chemical-specific Comparison Values**

(All values in $\mu\text{g}/\text{m}^3$)

Chemical Name	Concentration Detected	Health-Based Comparison Value (source)	Occupational Standards (source)
Hexane	8,300	2000 (ATSDR Chronic EMEG)	180,000 (NIOSH REL)
Cyclohexane	1,400	6,000 (EPA Reference Concentration)	1,050,000 (NIOSH REL)
2,2,4-Trimethylpentane	4,500	3,336 (Missouri's 24-hour Health-Based Ambient Air Level)	NA
Heptane	590	NA	350,000 (NIOSH REL)

$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter

EMEG = Environmental Media Evaluation Guide. See Appendix 1 for further information on EMEGs.

NIOSH REL = National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (RELs)

NA = Not Available

**Table 2. Results of Water Sampling Collected by
DNR in Breakdown Cave on August 1, 2006**

Chemical Name	Concentration Detected in $\mu\text{g}/\text{L}$	Health-Based Comparison Value in $\mu\text{g}/\text{L}$ (source)
Benzene	0.61	40 (RMEG for Child)
Tetrachloroethene	1.19	100 (RMEG for Child)

$\mu\text{g}/\text{L}$ = micrograms per liter

RMEG = reference dose media evaluation guides

DHSS has compared the concentrations of chemicals detected in Breakdown Cave to ATSDR comparison values (CVs). ATSDR has developed CVs that are media-specific concentrations used by health assessors to select environmental contaminants of concern. Contaminant concentrations that are less than the CV are unlikely to pose a health threat. Contaminant levels above the CV do not necessarily indicate that a health threat is present, but that further evaluation of the chemical and pathways is needed. When CVs are exceeded, exposure patterns and chemical concentrations detected at the site may be compared to no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect levels (LOAELs). NOAELs are the highest tested dose of a chemical that has been reported to have no adverse health effects on people or animals, and LOAELs are the lowest tested dose of a chemical that has been reported to cause adverse health effects on people or animals. CVs, NOAELs, and LOAELs are typically separated into three exposure durations called acute, intermediate, and chronic. Acute exposure is defined as exposure that occurs for less than 14 days. Intermediate exposure occurs for more than 14 days but less than 365 days. Chronic exposure occurs for more than 365 days. Please see Appendix 1: TOXICOLOGICAL EVALUATION for more information on CVs and for information on the chemicals detected in Breakdown Cave.

Hexane, cyclohexane, 2,2,4-trimethylpentane and heptane were detected in air samples taken by DNR in Breakdown Cave. You have reported that the cave manager spends the most amount of time in the cave, so he would have the greatest duration of exposure to these chemicals. Even though the cave manager may visit the cave more than 14 times a year, his visits to the cave are infrequent and separated by several days or weeks. Because of this, we have determined the most appropriate CVs to apply to this kind of exposure would be acute CVs. However, very little is known about the health effects of these chemicals, and no acute CVs are available for any of the chemicals detected in the air at Breakdown Cave. In addition, comparison values are determined for ambient air and may be different for confined spaces like what may be found in caves.

Occupational exposure standards are available for hexane, cyclohexane, and heptane. See Table 1. National Institute for Occupational Safety and Health (NIOSH) has established recommended exposure limits (RELs) based on human or animal health effects data, and on concentrations of chemicals that can feasibly be achieved by engineering controls and measured by analytical techniques. RELs are based on subchronic exposure durations for a 40-hour workweek with up to a 10-hour workday. NIOSH RELs are derived to be used in occupational settings where employers are required to use proper monitoring and safeguards and are typically not applied to sites outside of a work setting.

Because hexane was detected in the air at a higher concentration and has lower health-based comparison values and occupational standards than the other chemicals detected in Breakdown Cave, hexane is the chemical of most concern for human health in Breakdown Cave. The concentration of hexane in the cave did exceed ATSDR's chronic EMEG for hexane. Because of this, scientific literature was searched to find appropriate inhalation NOAELs or LOAELs to apply to this site.

We chose a NOAEL of 1,441,453 $\mu\text{g}/\text{m}^3$ reported from a study with low exposure concentrations and the most similar exposure durations to the cave manager's exposure to Breakdown Cave. The NOAEL was then divided by a safety factor of 100, resulting in a final derived comparison value of 14,410 $\mu\text{g}/\text{m}^3$. Because we feel that this derived comparison value is conservative, and because this value is greater than the 8,300 $\mu\text{g}/\text{m}^3$ concentration of hexane detected in Breakdown Cave, no adverse health effects are expected from being exposed to the concentration of hexane detected in the cave for the amount of time you reported being in the cave.

It does appear that concentrations of these chemicals in the cave air fluctuate significantly, based on the fact that odors are present at some times and not at others. Because the source has not been identified, other chemicals may also be present in the cave air especially during the periods of stronger odor you described. However, only one set of air samples has been collected, so we do not know how much the concentrations of these chemicals may fluctuate. For these reasons, health effects associated with acute exposure to these chemicals or others in the air in Breakdown Cave are not known at this time.

Benzene and tetrachloroethene were detected in water samples taken by DNR in Breakdown Cave. See Table 2. The primary route of exposure to benzene and tetrachloroethene in Breakdown Cave is through incidental ingestion of the water in the cave. Concentrations of

benzene and tetrachloroethene detected in Breakdown Cave were below acute CVs. See Table 2. It is expected that very little if any water from the cave is ingested. Since concentrations of benzene and tetrachloroethene are below acute CVs, no adverse health effects are expected from exposure to the water in Breakdown Cave.

CONCLUSIONS

Based on the concentrations of chemicals detected by DNR and the amount of time spent in the cave, we do not think that there is a health threat to the cave manager or to other individuals visiting Breakdown Cave. For these reasons, Breakdown Cave is considered a *No Apparent Public Health Hazard*. This category is used for sites where exposure to site-related chemicals might have occurred in the past or is still occurring, but the exposures are not at levels likely to cause adverse health effects. However, because of uncertainties associated with Breakdown Cave, such as unknown range of chemical concentrations in the cave over time, lack of health information on the chemicals detected in the cave, and not knowing the source of the contamination, it is difficult to determine actual health risks. Because of this, we have made recommendations to minimize your and other visitors' exposures.

RECOMMENDATIONS

Although the health effects of acute exposure to the chemicals detected in the air of Breakdown Cave is not known, we recommend actions to decrease the contaminant concentrations in Breakdown Cave or minimize individual's exposure to these chemicals. Further air and water testing should also be considered to determine whether or not there are fluctuations of these chemical concentrations in different locations in the cave and at different times. The effects many of these chemicals have on sensitive populations, such as children and expectant women, are not known, and they should take special precautions if visiting the cave. Individuals with respiratory problems such as asthma may experience increased severity of symptoms due to irritant properties of some of these chemicals and should take special precautions if visiting the cave.

1. If tours continue to be given at Breakdown Cave, individuals should reduce their exposure to contaminants by:
 - not entering the cave when chemical odors are detectable.
 - minimizing time spent in cave.
 - practicing good personal hygiene, which includes not eating or drinking inside the cave and washing hands after leaving the cave and before eating.
2. Very little is known about the chemicals detected in the air in Breakdown Cave, and little information is known about concentration fluctuations within the cave. As a precaution, children under 6 years old, pregnant women, and individuals with respiratory problems, such as asthma, should limit the amount of time they spend in the cave.

3. Gas-powered engines should never be used in a confined space without proper ventilation. This is especially true in Breakdown Cave given that most of the chemicals detected in the air in Breakdown Cave are also found in gasoline exhaust.
4. Further samples should be collected and health risks reevaluated, especially if the frequency and/or length of tour visits increase.

PUBLIC HEALTH ACTION PLAN

This Public Health Action Plan (PHAP) for the Breakdown Cave contains an explanation of the actions to be taken by the Missouri Department of Health and Senior Services (DHSS), the Agency for Toxic Substances and Disease Registry (ATSDR), and other stakeholders. The purpose of the PHAP is to ensure that this public health consultation not only identifies public health hazards, but provides an action plan to mitigate and prevent adverse human health effects resulting from past, present, and future exposures to hazardous substances at or near the site. Below is a list of commitments of public health actions to be implemented by DHSS, ATSDR, or other stakeholders at the site:

1. If additional sampling is conducted, DHSS/ATSDR will review additional sampling data as it becomes available and provide guidance regarding possible health risk if necessary.
2. DHSS/ATSDR will address health concerns and questions as they arise.
3. DHSS/ATSDR will provide health education and literature when requested.

If you have questions or concerns, please contact Jeff Wenzel or Jonathan Garoutte of my staff at (573) 751-6102 or toll-free at (866) 628-9891.

Sincerely,

Cherri Baysinger
Bureau Chief
Bureau of Environmental Epidemiology

Cc: Julieann Warren, MDNR
CB:JG:AB

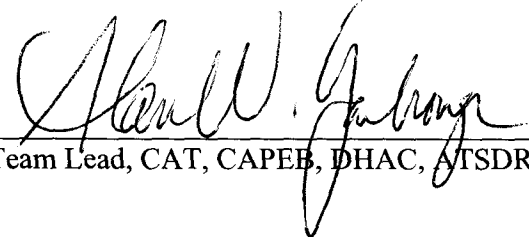
CERTIFICATION

The Missouri Department of Health and Senior Services (DHSS) prepared this Evaluation of Air and Water Data from Breakdown Cave Letter Health Consultation under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodologies and procedures existing at the time the health consultation were initiated. The Cooperative Agreement partner completed the editorial review.



Technical Project Officer, CAT, CAPEB, DHAC

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



Team Lead, CAT, CAPEB, DHAC, ATSDR

REFERENCES

1. Agency for Toxic Substances and Disease Registry. Toxicological profile for hexane. Atlanta: US Department of Health and Human Services; 1999 July.
2. U.S. Environmental Protection Agency. Chemicals in the environment: cyclohexane (cas no. 110-82-7). http://www.epa.gov/chemfact/f_cycloh.txt
3. U.S. Environmental Protection Agency. Toxicological review of 2,2,4-trimethylpentane. 2007 July. <http://www.epa.gov/IRIS/toxreviews/0614-tr.pdf>
4. U.S. Environmental Protection Agency. 2,2,4-Trimethylpentane. <http://www.epa.gov/ttn/atw/hlthef/tri-pent.html>
5. Missouri Department of Natural Resources. Agency memo to Missouri Department of Health: Health-based ambient air level assessment for 2,2,4-trimethylpentane at HPI Products, Inc.; 1996 April.
6. National Library of Medicine, Toxicology Data Network (TOXNET). Heptane. Hazardous Substances Data Bank (HSDB); 2005 September.

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Attachments: Appendix 1: TOXICOLOGICAL EVALUATIONS

Appendix 1: TOXICOLOGICAL EVALUATION

This section will describe what is known, and what is not known, about environmental exposures to chemicals detected in the Breakdown Cave. An outline of possible health effects will be presented, and the likelihood of the contaminants causing cancer will be evaluated.

ATSDR has developed comparison values (CVs) that are media-specific concentrations used by health assessors to select environmental contaminants of concern. Contaminant concentrations that are less than the CV are unlikely to pose a health threat. Contaminant levels above the CV do not necessarily indicate that a health threat is present, but that further evaluation of the chemical and pathways is needed. Environmental media evaluation guides (EMEGs) and reference dose media evaluation guides (RMEGs) are CVs that have been derived for a variety of chemicals in various media. CVs can be derived for acute, intermediate, and chronic duration exposures. Acute exposure is defined as exposure that occurs for less than 14 days. Intermediate exposure occurs for more than 14 days but less than 365 days. Chronic exposure occurs for more than 365 days. Inhalation reference concentrations (RfCs) are derived by EPA to estimate continuous inhalation exposure over a human lifetime that is unlikely to pose a significant risk of adverse noncancer health effects.

Hexane

Hexane is made from crude oil and evaporates very easily into the air. Hexane is highly flammable, and its vapors can be explosive. Hexane is used to extract vegetable oils from crops, as a cleaning agent, in some glues and rubber cement, and makes up 1 – 3% of gasoline and can be found in exhaust and evaporative emissions. If hexane is spilled onto the ground or in water, most of the hexane will evaporate before being dissolved in the water or penetrating the soil. Hence, the most likely way an individual would be exposed to hexane would be through inhalation.

Workers exposed to high levels of hexane experienced nerve disorders, which caused numbness in their hands and feet followed by muscle weakness in their feet and lower legs. If exposure continued, the symptom grew worse and paralysis of the arms and legs developed. The medical term for this condition is peripheral neuropathy. Once workers were removed from the exposure, they recovered within 6 months to two years. There is no evidence that exposure to hexane increases the risk of cancer in humans, and no reliable information that hexane causes cancer in animals. (1)

Concentrations of hexane were detected in Breakdown Cave above ATSDR's chronic EMEG of 2000 $\mu\text{g}/\text{m}^3$ for inhalation exposure. ATSDR's chronic EMEGs are based on 24-hour daily exposures lasting for longer than 365 days. However, based on conversations with you, the most time an individual (you) may spend in the cave is 2 to 5 hours per visit with up to 18 visits per year. Very rarely, a visit may last 9 to 11 hours. Based on this information, a NOAEL was selected and divided by a safety factor of 100, which resulted in a final value of 14,410 $\mu\text{g}/\text{m}^3$. Because this value is greater than the 8,300 $\mu\text{g}/\text{m}^3$ concentration of hexane detected in Breakdown Cave, no adverse health effects are expected from being exposed to the concentration of hexane detected in the cave for the amount of time you reported being in the cave.

Cyclohexane

Cyclohexane is a colorless liquid that evaporates when exposed to air. Cyclohexane is highly flammable. Cyclohexane can be found in petroleum crude oil and cigarette smoke. It is used to make other chemicals, in fuels for camp stoves, and can be added to lacquers and resins, paint and varnish removers, and fungicides. If cyclohexane is spilled onto the ground or in water, it will evaporate when exposed to the air. (2) Cyclohexane can irritate eyes and mucous membranes in humans (3). Inhalation of large amounts of cyclohexane over a short period of time can affect the nervous system and cause headache, anesthesia, tremors, and convulsions. Health effects of longer-term exposure to cyclohexane through inhalation are not known. (2)

Inhalation is the most likely exposure route to cyclohexane in individuals visiting Breakdown Cave. Concentrations of cyclohexane detected in Breakdown Cave did not exceed EPA's RfC of $6,000 \mu\text{g}/\text{m}^3$. Since concentrations of cyclohexane did not exceed EPA's RfC, which is estimated for lifetime exposure, no adverse health effects are expected.

2,2,4-Trimethylpentane

2,2,4-Trimethylpentane, also called isooctane, is a colorless liquid that has a gasoline-like odor. 2,2,4-Trimethylpentane is used to derive high-octane fuels and is highly flammable. Exhaust and evaporative emissions from gas-powered engines may release 2,2,4-trimethylpentane into the atmosphere. If 2,2,4-trimethylpentane is spilled onto the ground or in water, much of it is expected to evaporate into the air. (3) Irritation of the lungs, edema, and hemorrhage have been reported in rodents exposed to 2,2,4-trimethylpentane; however, little is known about the health effects of 2,2,4-trimethylpentane on humans, both carcinogenic and noncarcinogenic (4).

The route of exposure of concern for 2,2,4-trimethylpentane in Breakdown Cave is through inhalation. There are very few health-based CVs for 2,2,4-trimethylpentane; however, DNR and DHSS did derive a value of $3,336 \mu\text{g}/\text{m}^3$ for 2,2,4-trimethylpentane for a 24-hour chronic health-based ambient air level based on Phillips Petroleum Company permissible exposure levels (5). Concentrations of 2,2,4-trimethylpentane detected in Breakdown Cave did exceed the 24-hour chronic health-based ambient air level derived by DNR and DHSS.

Since the concentration of 2,2,4-trimethylpentane detected exceeded the available CV, this concentration and exposure duration would be further investigated and compared to a NOAEL or LOAEL. However, few studies were found on acute inhalation exposure to 2,2,4-trimethylpentane suitable for deriving a NOAEL or LOAEL. Since hexane was detected in the air at a higher concentration than 2,2,4-trimethylpentane and has lower health-based comparison values, it is thought that hexane is of greater concern for human health in Breakdown Cave. Since no adverse health effects are expected from being exposed to the concentration of hexane detected in Breakdown Cave; similarly, no adverse health effects are expected from being exposed to the concentration of 2,2,4-trimethylpentane detected in Breakdown Cave.

Heptane

Heptane is a colorless liquid that has a gasoline-like odor. Heptane is a volatile, flammable liquid when exposed to heat or flame. Heptane can be released into the air from gasoline and other petroleum products. Little data is available on health effects of heptane on humans, both carcinogenic and noncarcinogenic. Individuals with impaired pulmonary function may experience increased severity of symptoms due to heptane's irritant properties. (6)

There are very few health-based CVs for heptane. No acute CVs for heptane were found. However, since hexane was detected in the air at a higher concentration than heptane and has lower occupational standards than heptane, it is thought that hexane is of greater concern for human health in Breakdown Cave. Since no adverse health effects are expected from being exposed to the concentration of hexane detected in Breakdown Cave, similarly, no adverse health effects are expected from being exposed to the concentration of heptane detected in Breakdown Cave.

Benzene and tetrachloroethene

The primary route of exposure to benzene and tetrachloroethene in Breakdown Cave is through ingestion. Benzene and tetrachloroethene were detected in Breakdown Cave below acute CVs in water samples collected by DNR. It is expected that very little if any water from the cave is ingested. Therefore, no adverse health effects are expected.

Children's Health

ATSDR and DHSS recognize that infants and children have unique characteristics that may make them more susceptible to chemical exposures than adults. Children crawl on the ground, experiment by putting things in their mouth and sometimes eating them, and may not wash their hands as often as needed. In general, children are more likely than adults to become exposed to contaminants in air or water. Because children are smaller and their bodies typically retain more of the contaminants, it usually takes less of a contaminant to cause adverse health effects in children than adults.

Information could not be found on children's susceptibility to health effects from hexane, cyclohexane, 2,2,4-trimethylpentane, and heptane. Tours of the cave are very rarely given to children under 6 years of age.