



## Reported health effects linked with trichloroethylene (TCE), tetrachloroethylene (PCE), benzene, and vinyl chloride (VC) exposure

---

### Reported health effects linked with TCE, PCE, benzene, and VC exposure in people

**Q:** What did the 1998 ATSDR health study "Volatile Organic Compounds in Drinking Water and Adverse Pregnancy Outcomes" at Camp Lejeune find?

**A:** Overall, the study found a link between PCE-contaminated drinking water and lower birth weights for infants of older mothers and mothers with histories of fetal loss. PCE-contaminated drinking water was also linked with small-for-gestational-age infants for older mothers and mothers with two or more prior fetal losses. This study could not look at fetal deaths because existing records were not complete. Because of errors in the exposure information available at that time, ATSDR will reanalyze this study when the water modeling is completed.

**Q:** What have other studies found about the persistent health effects of TCE, PCE, benzene, and VC?

**A:** The effects of exposure to any chemical depend on—

- When you are exposed (during pregnancy, in infancy),
- How much you are exposed to,
- How long you are exposed,
- How you are exposed (breathing, drinking), and
- What your personal traits and habits are.

Therefore, not everyone who is exposed to TCE, PCE, benzene, or VC will develop a health problem.

A limited number of studies have been done that looked at the health problems in children and adults related to drinking water contaminated with TCE and PCE. Only one study (in New Jersey) has looked at the health problems in children related to drinking water contaminated with benzene or VC. However, too few children were exposed to benzene or VC in that study to reach any conclusion about health problems. No studies have looked at the health problems in adults related to drinking water contaminated with benzene and VC.

A much larger number of studies have looked at health problems among workers exposed to TCE, PCE, benzene, and VC. Below is a list of the types of health outcomes that have been found to be linked to TCE, PCE, benzene, and VC. The numbers in parentheses indicate the reference for the study. All of the references are listed at the end.

### **Reported health problems in children who were exposed in the womb from their**

**mother drinking water contaminated with TCE and/or PCE include—**

- Leukemia (1-3 (#01))
- Small for gestational age (4-6 (#04))
- Low birth weight (6-8 (#06))
- Fetal death (4 (#04), 7 (#07), 9 (#09))
- Major heart defects (7 (#07), 10 (#10))
- Neural tube defects (4 (#04), 7 (#07), 9 (#09))
- Oral cleft defects (including cleft lip) (4 (#04), 7 (#07), 9 (#09))
- Chonal atresia (nasal passages blocked with bone or tissue) (4 (#04), 9 (#09))
- Eye defects (4 (#04), 9 (#09))

**Reported health problems in children who were exposed in the womb from their mother working with TCE and/or PCE include—**

- Low birth weight (11 (#11))
- Miscarriage (12 (#12), 13 (#13))
- Major malformations (11 (#11))

**Reported health problems in people of all ages from drinking water contaminated with TCE and/or PCE include—**

- Non-Hodgkins lymphoma (1 (#01), 12 (#12))
- Bladder cancer (17 (#17))
- Breast cancer (18 (#18))
- Lung cancer (14 (#14))

**Reported health problems in people of all ages from working with TCE and/or PCE include—**

- Hodgkins disease (15 (#15))
- Non-Hodgkins lymphoma (15 (#15))
- Cervical cancer (15 (#15))
- Kidney cancer (15 (#15))
- Liver/biliary cancer (15 (#15))
- Ovarian cancer (15 (#15))
- Prostate cancer (15 (#15))
- Neurological effects (delayed reaction times problems with short-term memory, visual perception, attention, and color vision) (13 (#13))

**Reported health problems in people of all ages from working with benzene include—**

- Non-Hodgkin's lymphoma (19 (#19), 20 (#20))
- Leukemias (21 (#21), 22 (#22))
- Multiple myeloma (23 (#23))
- Aplastic anemia (24 (#24))

- Miscarriage (24 (#24))

### **Reported health problems in people of all ages from working with VC include—**

- Liver cancer (25 (#25), 26 (#26))
- Soft tissue sarcoma (26 (#26))
- Brain cancer (26 (#26))
- Lung cancer (27 (#27))
- Liver cirrhosis (28 (#28))

Workers are exposed to much higher levels of TCE, PCE, benzene, and VC than are people who drink contaminated water. Therefore, the health problems seen in people who worked with TCE, PCE, benzene, and VC may not be seen in people who drank contaminated water.

For health problems not listed in the tables—

- Studies, so far, do not support a link with the particular health outcome and TCE, PCE, benzene, or VC exposure, or
- There is not enough information to see if the outcome is linked to TCE, PCE, benzene, or VC exposure.

Q: How are studies in animals and people different?

A: In studies done in laboratory animals, such as mice, the animals are exposed to much higher levels of chemicals than are people. Animals are also exposed in different ways than are people. In animal studies, we know the exact types and levels of chemicals the animals are exposed to. We can't tell for certain the exact levels people are exposed to. Also, people are usually exposed to multiple chemicals. Medications, alcohol intake, and lifestyle factors also play a role in how these chemicals affect people.

### **Reported health effects linked with TCE, PCE, benzene, and VC exposure in animals**

Q: What health effects are seen in animal studies of PCE exposure?

A: Results of animal studies showed that PCE can cause liver and kidney damage. The studies also showed that PCE can cause liver cancer in animals. Exposure at very high levels of PCE can be harmful to the unborn pups of pregnant rats and mice. Changes in behavior were seen in the offspring of rats that breathed high levels of the chemical while they were pregnant. Behavioral changes included being hyperactive. Various neurological problems were seen in both the mother and offspring. Neurological problems included being unable to coordinate muscles and decreased movement.

Q: What health effects are seen in animals from TCE exposure?

A: Results of animal studies showed that TCE may cause liver, kidney, or lung cancer. The studies also showed that TCE can cause neurological problems and liver and kidney damage in animals. Neurological problems included being unable to coordinate muscles and decreased movement.

Q: What health effects are seen in animals from benzene exposure?

A: Results of animal studies showed that benzene may cause Zymbal-gland (ear canal) carcinoma, oral-cavity tumors, skin cancer, lymphoma, lung tumors, ovarian tumors, and mammary-gland carcinoma.

Q: What health effects are seen in animals from VC exposure?

A: Results of animal studies showed that VC may cause tumors in the liver, lung, mammary-gland, Zymbal-gland (ear canal), kidney, skin, and stomach, and angiosarcoma (blood-vessel tumors) and adenocarcinoma (tumors of the linings of organs) at various sites. VC also caused genetic damage including mutations, DNA damage, chromosome damage or loss, chromosomal aberrations (changes in chromosome structure or number), and sister chromatid exchange.

## Reported health effects linked with TCE, PCE, benzene, and VC exposure in both people and animals

Q: What health effects are seen in both people and animals from TCE, PCE, benzene, and VC exposure?

A: When there are studies in people, results of animal studies are used to help support any observed links. Results of animal studies are used when there are no studies in people. Reported health effects seen in both people and animals include—

- Lung cancer
- Kidney cancer
- Liver cancer
- Lymphoma
- Breast cancer
- Neurological effects

Some health effects seen in people cannot be tested for in animals.

## References

1. Cohn P, Klotz J, Bove F, Fagliano J. 1994. Drinking water contamination and the incidence of leukemia and non-Hodgkin's lymphoma. *Environ Health Perspect* 102:556-61.
2. Costas K, Knorr RS, Condon SK. 2002. A case-control study of childhood leukemia in Woburn, Massachusetts: the relationship between leukemia incidence and exposure to public drinking water. *Sci Total Environ* 300:23-35.
3. New Jersey Department of Health and Senior Services. 2003. Case-control study of childhood cancers in Dover Township (Ocean Country), New Jersey. Trenton, New Jersey: New Jersey Department of Health and Senior Services.
4. Massachusetts Department of Public Health, Centers for Disease Control and Prevention, Massachusetts Health Research Institute. 1996. Final report of the Woburn environmental and birth study. Boston, Massachusetts: Massachusetts Department of Public Health.

5. Agency for Toxic Substances and Disease Registry. 1998. Volatile organic compounds in drinking water and adverse pregnancy outcomes: U.S. Marine Corps Camp Lejeune, North Carolina. Atlanta: US Department of Health and Human Services.
6. Sonnenfeld N, Hertz-Picciotto I, Kaye WE. 2001. Tetrachloroethylene in drinking water and birth outcomes at the US Marine Corps Base at Camp Lejeune, North Carolina. *Am J Epidemiol* 154(10):902-8.
7. Bove FJ, Fulcomer MC, Klotz JB, Esmart J, et al. 1995. Public drinking water contamination and birth outcomes. *Am J Epidemiol* 141:850-62.
8. Rodenbeck SE, Sanderson LM, Rene A. 2000. Maternal exposure to trichloroethylene in drinking water and birthweight outcomes. *Arch Environ Health* 55:188-194.
9. Bove F, Shim Y, Zeitz P. 2002. Drinking water contaminants and adverse pregnancy outcomes: a Review. *Environ Health Perspect* 110(S): 61-73.
10. Goldberg SJ, Lebowitz MD, Graver EJ, Hicks S. 1990. An association of human congenital cardiac malformations and drinking water contaminants. *J Am Coll Cardiol* 16:155-164.
11. Khattak S, K-Moghtader G, McMartin K, Barrera M, et al. 1999. Pregnancy outcome following gestational exposure to organic solvents: a prospective controlled study. *JAMA* 281(12): 1106-09.
12. Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. 1999. Public health goal for trichloroethylene in drinking water. Sacramento, California.
13. Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. 2001. Public health goal for tetrachloroethylene in drinking water. Sacramento, California.
14. Paulu C, Aschengrau A, Ozonoff D. 1999. Tetrachloroethylene-contaminated drinking water in Massachusetts and the risk of colon-rectum, lung, and other cancers. *Environ Health Perspect* 107(4):265-71.
15. Wartenberg D, Reyner D, Scott CS. 2000. Trichloroethylene and cancer: epidemiologic evidence. *Environ Health Perspect* 108(S2):161-176.
16. Morgan RW, Kelsh MA, Zhao K, Heringer S. 1998. Mortality of aerospace workers exposed to trichloroethylene. *Epidemiology* 9(4):424-31.
17. Aschengrau A, Zierler S, Cohen A. 1993. Quality of community drinking water and the occurrence of late adverse pregnancy outcomes. *Arch Environ Health* 48:105-13.
18. Aschengrau A, Rogers S, Ozonoff D. 2003. Perchloroethylene-contaminated drinking water and the risk of breast cancer: additional results from Cape Cod, Massachusetts, USA. *Environ Health Perspect* 111(2):167-73.
19. Steinmaus C, Smith AH, Jones RM, Smith MT. 2008. Meta-analysis of benzene exposure and non-Hodgkin's lymphoma: Biases could mask an important association. *Occup. Environ. Med.* 65(6):371-8.
20. Mehlman MA. 2006. Causal relationship between non-Hodgkin's lymphoma and exposure to benzene and benzene-containing solvents. *Ann. N.Y. Acad. Sci.* 1076:120-128.

21. Rinsky RA, Hornung RW, Silver SR, Tseng CY. 2002. Benzene exposure and hematopoietic mortality: A long-term epidemiologic risk assessment. *Am J Ind Med.* 42(6):474-80
22. Glass DC, Gray CN, Jolley DJ, Gibbons C, et al. 2003. Leukemia risk associated with low-level benzene exposure. *Epidemiology.* 14(5):569-577.
23. Infante PF. 2006. Benzene Exposure and Multiple Myeloma: A Detailed Meta-analysis of Benzene Cohort Studies. *Ann. N.Y. Acad. Sci.* 1076:90-109.
24. Khan HA. 2007. Short Review: Benzene's toxicity: a consolidated short review of human and animal studies. *Hum Exp Toxicol.* 26; 677-685.
25. Bosetti C, La Vecchia C, Lipworth L, McLaughlin JK. 2003. Occupational exposure to vinyl chloride and cancer risk: a review of the epidemiologic literature. *European Journal of Cancer Prevention.* 12:427-430.
26. Boffetta P, Matisane L, Mundt KA, Dell LD. 2003. Meta-analysis of studies of occupational exposure to vinyl chloride in relation to cancer mortality. *Scand J Work Environ Health.* 29:220-229.
27. Scelo G, Constantinescu V, Csiki I, Zaridze D, et al. 2004. Occupational exposure to vinyl chloride, acrylonitrile and styrene and lung cancer risk (Europe). *Cancer Causes Control.* 15:445-452.
28. Grosse Y, Baan R, Straif K, Secretan B, et al. 2007. Carcinogenicity of 1,3-butadiene, ethylene oxide, vinyl chloride, vinyl fluoride, and vinyl bromide. *Oncology: The Lancet.* 8:679-680.

### You can find more information in:

- Adams C, Keil D, Meyers K, et al. 2003. Lifetime exposure to trichloroethylene (TCE) modulates immune function. *Toxicologist* 72(S-1):375.
- Altmann L, Welge P, Mensing T, et al. 2002. Chronic exposure to trichloroethylene affects neuronal plasticity in rat hippocampal slices. *Environmental Toxicology and Pharmacology* 12(3):157-67.
- Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for Trichloroethylene. U.S. Department of Health and Human Services, Public Health Service, ATSDR.
- Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for Tetrachloroethylene. U.S. Department of Health and Human Services, Public Health Service, ATSDR.
- Berger T, Horner CM. 2003. In vivo exposure of female rats to toxicants may affect oocyte quality. *Reprod Toxicol* 17(3):273-81.
- Bushnell PJ, Oshiro WM. 2000. Behavioral components of tolerance to repeated inhalation of trichloroethylene (TCE) in rats. *Neurotoxicol Teratol* 22(2):221-9.
- Crofton KM, Zhao X. 1997. The ototoxicity of trichloroethylene: extrapolation and relevance of high-concentration, short-duration animal exposure data. *Fundam Appl Toxicol* 38(1):101-6.
- Ebrahim AS, Babakrishnan K, Sakthisekaran D. 1996. Perchloroethylene-induced alterations in glucose metabolism and their prevention by 2-deoxy-D-glucose and vitamin E in mice. *J Appl Toxicol* 16(4):339-48.
- Fisher JW, Channel SR, Eggers JS, et al. 2001. Trichloroethylene, trichloroacetic acid, and dichloroacetic acid: do they affect fetal rat heart development? *Int J Toxicol* 20(5):257-67.

- Forkert P, Lash L, Nadeau V, et al. 2002. Metabolism and toxicity of trichloroethylene in epididymis and testis. *Toxicol Appl Pharmacol* 182(3):244.
- Griffin JM, Blossom SJ, Jackson SK, et al. 2000. Trichloroethylene accelerates an autoimmune response by Th1 T cell activation in MRL +/+ mice. *Immunopharmacology* 46:123-37.
- Griffin JM, Gilbert KM, Lamps LW, et al. 2000. CD4(+) T-cell activation and induction of autoimmune hepatitis following trichloroethylene treatment in MRL+/+ mice. *Toxicol Sci* 57(2):345-52.
- Johnson PD, Goldberg SJ, Mays MZ, et al. 2003. Threshold of trichloroethylene contamination in maternal drinking waters affecting fetal heart development in the rat. *Environ Health Perspect* 111:289-92.
- Kumar P, Prasad A, Saxena DK, et al. 2000. Fertility and general reproduction studies in trichloroethylene exposed rats. *Indian Journal of Occupation Health* 43(3):117-26.
- Kumar P, Prasad AK, Maji BK, et al. 2001. Hepatotoxic alterations induced by inhalation of trichloroethylene (TCE) in rats. *Biomed Environ Sci* 14(4): 325-32.
- Mattsson JL, Albee RR, Yano BL, et al. 1998. Neurotoxicologic examination of rats exposed to 1,1,2,2-tetrachloroethylene (perchloroethylene) vapor for 13 weeks. *Neurotoxicol Teratol* 20(1):83-98.
- Mensing T, Welge P, Voss B, et al. 2002. Renal toxicity after chronic inhalation exposure of rats to trichloroethylene. *Toxicol Lett* 128(1-3):243-7.
- Muijser H, Lammers JH, Kullig BM. 2000. Effects of exposure to trichloroethylene and noise on hearing in rats. *Noise Health* 2(6): 57-66.
- Potter CL, Chang LW, Deangelo AB, et al. 1996. Effects of four trihalomethanes on DNA strand breaks, renal hyaline droplet formation and serum testosterone in male F-344 rats. *Cancer Letters* 106:235-42.
- Warren DA, Graeter LJ, Channel SR, et al. 2002. Trichloroethylene, trichloroacetic acid and dichloroacetic acid: does in utero exposure to these chemicals affect eye development? *Toxicologist* 66(1-S):24.
- Waseem M, Ali M, Dogra S, et al. 2001. Toxicity of trichloroethylene following inhalation and drinking contaminated water. *J Appl Toxicol* 21(6):441-4.
- Xu H, Wade MG, Anupriwan A, et al. 2003. Inhalation exposure to trichloroethylene of male mice causes impaired sperm function but has minimal effects on testis function. *Biol Reprod* 2003;68(Suppl 1):181-2.
- Zablony CL, Carney EW, Dugard PH. 2002. Evaluation of trichloroethylene in a rat inhalation developmental toxicity study. *Toxicologist* 66(1-S):237/

---

Page last reviewed: June 2, 2010

Page last updated: June 2, 2010

Content source: [Agency for Toxic Substances and Disease Registry](#)

---

Agency for Toxic Substances and Disease Registry, 4770 Buford Hwy NE, Atlanta, GA 30341

Contact CDC: 800-232-4636 / TTY: 888-232-6348

