United States Environmental Protection Agency

Technical Fact Sheet – 1,4-Dioxane

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At a Glance

- Flammable liquid and a fire hazard. Potentially explosive if exposed to light or air.
- Found at many federal facilities because of its widespread use as a stabilizer in chlorinated solvents, paint strippers, greases, and waxes.
- Short-lived in the atmosphere, may leach readily from soil to ground water, migrates rapidly in ground water, and is relatively resistant to biodegradation in the subsurface.
- Classified as "likely to be carcinogenic to humans" by all routes of exposure.
- Contact may cause eye and skin irritation and burns, coughing, or shortness of breath.
- No federal drinking water standards have been established. Many states and EPA regions have set guidelines and action levels.
- Modifications to existing sample preparation procedures may be needed to achieve the increased sensitivity needed for dioxane detection. High-temperature sample preparation techniques improve the recovery of dioxane.
- Common treatment technologies include advanced oxidation processes and ex situ bioremediation.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary of the contaminant 1,4-dioxane, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information.

1,4-Dioxane is a probable carcinogen and has been found in groundwater at sites throughout the United States. The physical and chemical properties and behavior of 1,4-dioxane create challenges for its characterization and treatment. It is highly mobile and has not been shown to readily biodegrade in the environment. This fact sheet is intended for use by site managers faced with addressing 1,4-dioxane at cleanup sites or in drinking water supplies and for those in a position to consider whether 1,4-dioxane should be added to the analytical suite for site investigations.

What is 1,4-Dioxane?

- 1,4-Dioxane is a synthetic industrial chemical that is completely miscible in water (EPA 2006).
- Synonyms include dioxane, dioxan, p-dioxane, diethylene dioxide, diethylene oxide, diethylene ether, and glycol ethylene ether (Mohr 2001).
- 1,4-Dioxane is unstable at elevated temperatures and pressures and is potentially explosive if exposed to light or air (Alexeeff 1998).
- It is used as a stabilizer for chlorinated solvents such as 1,1,1-trichloroethane (TCA); a solvent for impregnating cellulose acetate membrane filters; a wetting and dispersing agent in textile processes; and as a laboratory cryoscopic solvent for molecular mass determinations (ATSDR 2012; EPA 2006).
- It is used in many products, including paint strippers, dyes, greases, varnishes, and waxes. 1,4-Dioxane is also found as an impurity in antifreeze and aircraft deicing fluids and in some consumer products [deodorants, shampoos, and cosmetics] (ATSDR 2012; EPA 2006; Mohr 2001).
- 1,4-Dioxane is a likely contaminant at many federal facilities because of its widespread use.
- Residues may be present in manufactured food additives, 1,4-dioxane-containing food packaging materials, or on food crops treated with pesticides that contain 1,4-dioxane [such as, vine-ripened tomatoes] (DHHS 2011).
- It is also a by-product in the manufacture of polyethylene terephthalate (PET) plastic and is used as a purifying agent in the manufacture of pharmaceuticals (Mohr 2001).

What is 1,4-Dioxane? (continued)

Exhibit 1: Physical and Chemical Properties of 1,4-Dioxane
(ATSDR 2012; EPA IRIS 2010)

Property	Value
CAS Number	000123-91-1
Physical Description (physical state at room temperature)	Flammable liquid with a faint, pleasant odor
Molecular weight (g/mol)	88.11
Water solubility (mg/L at 25^{o}C)	Soluble in water
Boiling point (^{o}C)	101.1 ^{o}C at 760 mm Hg
Vapor pressure at 25^{o}C (mm Hg)	38.1
Specific gravity	1.033
Octanol-water partition coefficient (log K_{ow})	-0.27
Organic carbon partition coefficient (log K_{oc})	1.23
Henry's law constant at 25 ^{o}C (atm cm^3/mol)	4.80 X 10^{-6}

Notes: g/mol – grams per mole; mg/L – milligrams per liter; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury; atm m^3/mol – atmosphere-cubic centimeters per mole.

What are the environmental impacts of 1,4-Dioxane?

- 1,4-Dioxane is typically found at solvent release sites and PET manufacturing facilities (Mohr 2001).
- It is short-lived in the atmosphere, with a 6- to 10-hour half-life (Mohr 2001). Breakdown products include aldehydes and ketones.
- It may migrate rapidly in groundwater, ahead of other contaminants, and does not volatilize rapidly from surface water bodies (EPA 2006).
- It is weakly retarded by sorption to soil particles and may move rapidly from soil to groundwater (EPA 2006).
- It is relatively resistant to biodegradation and does not bioconcentrate in the food chain (ATSDR 2012; Mohr 2001).
- It has been detected in at least 31 of the 1,689 current or former sites on EPA's National Priorities List (NPL); it may be present (but samples were not analyzed for it) at many other sites (ATSDR 2012).

What are the health effects of 1,4-Dioxane?

- Potential exposure could occur during production and use of 1,4-dioxane as a stabilizer or solvent (DHHS 2011).
- Exposure may occur through inhalation of vapors, ingestion of contaminated food and water, or dermal contact (DHHS 2011).
- Inhalation is the most common route of human exposure; it is also readily adsorbed through the lungs, skin, and gastrointestinal tract. Distribution is rapid and uniform in lung, liver, kidney, spleen, colon, and skeletal muscle tissue (ATSDR 2012).
- Workers at industrial sites are at greatest risk of repeated inhalation exposure (DHHS 2011).
- Short-term exposure may result in irritation of the eyes, and throat (ATSDR 2012).
- Chronic exposure may result in dermatitis, eczema, drying and cracking of skin, and liver and kidney damage (ATSDR 2012; EPA OSW 1996).
- 1,4-Dioxane is weakly genotoxic and reproductive effects are unknown; however, a developmental study on rats indicated that the developing fetus may be a target of toxicity (ATSDR 2012; EPA IRIS 2010).
- The oral slope factor for carcinogenic risk is 1 x 10^{-1} milligrams per kilogram per day (mg/kg-day) and the drinking water unit risk is 2.9 x 10^{-6} per microgram per liter (µg/L). EPA has classified 1,4-dioxane as "likely to be carcinogenic to humans" by all routes of exposure (EPA IRIS 2010).
- The chronic oral reference dose (RfD) is 0.03 mg/kg-day (EPA IRIS 2010).
- The EPA's drinking water equivalent level (DWEL) is 1 milligrams per liter (mg/L) (EPA 2012a).

Are there any federal and state standards and guidelines for 1,4-Dioxane?

- Federal and State Standards and Guidelines:
  - 1,4-Dioxane may be regulated as hazardous waste when used as a solvent stabilizer (EPA OSW 1996).
  - No federal drinking water standards have been established (DHHS 2011; ATSDR 2012). However, a maximum contaminant level (MCL) is not necessary to determine a cleanup level.
  - A minimal risk level (MRL) of 2 parts per million (ppm) was derived for acute-duration inhalation exposure, 0.2 ppm for intermediate-duration inhalation exposure, and 0.03 ppm for chronic-duration inhalation exposure (ATSDR 2012).
  - A MRL of 5 mg/kg/day was derived for acute-duration oral exposure, 0.5 mg/kg-day for intermediate-duration oral, and 0.1 mg/kg-day for chronic-duration oral exposure (ATSDR 2012).
  - EPA established a 1-day health advisory of 4.0 mg/L and a 10-day health advisory of 0.4 mg/L for 1,4-dioxane based on a 10-killiogram (kg) child (EPA 2012a).
  - EPA has calculated a screening level of 6.7×10^{-1} µg/L for 1,4-dioxane in tap water, based on a 1 in 10^{-6} lifetime excess cancer risk. This screening level is not enforceable but provides a useful gauge of relative toxicity (EPA 2012c).
  - EPA has calculated a residential soil screening level of 4.9 milligrams per kilogram (mg/kg) and an industrial soil screening level of 1.7×10^{1} mg/kg (EPA 2012c).
  - EPA has also calculated residential air screening level of 3.2×10^{-1} micrograms per cubic meter (µg/m^3) and an industrial air screening level of 1.6 µg/m^3 (EPA 2012c).
  - The soil-to-groundwater risk-based soil screening level (SSL) is 1.4×10^{-4} mg/kg (EPA 2012c).
- Workplace Exposure Limits:
  - The Occupational Safety and Health Administration (OSHA) set an average 8-hour time-weighted average (TWA) airborne permissible exposure limit (PEL) of 360 milligrams per cubic meter (mg/m^3) or 100 mg/L (NIOSH 2007; OSHA 1998).
  - The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for dermal exposure is 25 mg/L, and the recommended airborne exposure limit is 20 mg/L averaged over an 8-hour TWA (ACGIH 1998; EPA OSW 1996).
  - The National Institute for Occupational Safety and Health (NIOSH) has set 500 mg/L as the concentration that is immediately dangerous to life or health (IDLH) and recommended 1 mg/L as the airborne exposure limit (NIOSH 2007).
- Other State and Federal Standards and Guidelines:
  - State regulators often use drinking water action levels and health advisories to establish site cleanup goals. Cleanup levels vary by state, ranging from 3 to 50 µg/L in drinking water. Colorado has established an interim groundwater quality cleanup standard of 0.35 µg/L (ATSDR 2012; CDPHE 2012).
  - The Food and Drug Administration set 10 ppm as the limit for 1-4-dioxane in glycerides and polyglycerides for use in products such as dietary supplements. FDA also surveys raw material and products contaminated with 1,4-dioxane (ATSDR 2012).
  - 1,4-Dioxane is exempted from tolerances for pesticide chemicals in or on raw agricultural commodities, and it has been classified as a toxic inert ingredient of pesticide products (EPA 2012b).
  - 1,4-Dioxane is listed as a hazardous air pollutant under the Clean Air Act (CAA) (EPA 2012b).
  - A reportable quantity of 100 pounds has been established under CERCLA (EPA 2012b).

What detection and site characterization methods are available for 1,4-Dioxane?

- As a result of the limitations in the analytical methods to detect 1,4-dioxane, it has been difficult to identify its occurrence in the environment. Modifications to existing sample preparation procedures may be needed to achieve increased sensitivity for 1,4-dioxane detection (EPA 2006).
- Conventional analytical methods produced sensitivity levels that were about 100 times greater for 1,4-dioxane as compared with those for volatile organic compounds (VOCs) (Mohr 2001).
- High-temperature sample preparation techniques improve the recovery of 1,4-dioxane. These techniques include purging at elevated temperature (SW-846 Method 5030C); equilibrium headspace analysis (SW-846 Method 5021); vacuum distillation (SW-846 Method 8261A); and azeotrophic distillation (SW-846 Method 5031) (EPA 2000, 2006).
- It is recommended that groundwater samples be analyzed for 1,4-dioxane where TCA is a known contaminant.

What technologies are being used to treat 1,4-Dioxane?

- Pump-and-treat (P&T) remediation is potentially applicable when the ex situ treatment is tailored for the unique properties of 1,4-dioxane (EPA 2006).
- Commercially available advanced oxidation processes (AOP) using hydrogen peroxide with ultraviolet (UV) light or ozone is used to treat 1,4-dioxane (EPA 2006; EPA OSW 1996).
- Ex situ bioremediation using a fixed-film, moving-bed biological treatment system is also used to treat 1,4-dioxane (EPA 2006).
- Phytoremediation is being explored as a means to remove the compound from shallow groundwater. Research on hybrid poplars has demonstrated their ability to take up and effectively degrade or deactivate 1,4-dioxane (EPA 2001, EPA 2012b).
- Microbial degradation in engineered bioreactors has been documented under enhanced conditions or where selected strains of bacteria capable of degrading 1,4-dioxane are cultured (EPA 2006, 2010).
- Photocatalysis has been shown to remove 1,4-dioxane in aqueous solutions (Purifics ES Inc. 2006; Vescovi et al. 2010).
- Other in-well combined treatment technologies being assessed include air sparging; soil vapor extraction; and dynamic subsurface groundwater circulation (Odah et al. 2005).

Where can I find more information about 1,4-Dioxane?

- Agency for Toxic Substances and Disease Registry (ATSDR). 2012. “Toxicological Profile for 1,4-Dioxane.” www.atsdr.cdc.gov/toxprofiles/tp187.pdf
- Alexeeff, G. 1998. Office of Environmental Hazard Assessment. Memorandum: 1,4-Dioxane Action Level. http://oehha.ca.gov/water/pals/pdf/PAL14DIOXAN.pdf
- American Conference of Governmental Industrial Hygienists (ACGIH). 1998. Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents Biological Exposure Indices for 1998. Cincinnati, Ohio.
- Colorado Department of Public Health and the Environment (CDPHE). 2012. Notice of Public Rulemaking Hearing. Regulation No. 31 and No. 41. http://www.sos.state.co.us/CCR/Upload/NoticeOfRulemaking/ProposedRuleAttach2012-00387.PDF
- International Agency for Research on Cancer (IARC). 1999. “Re-Evaluation of Some Organic Chemicals, Hydrazine and Hydrogen Peroxide.” Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. Volume 71. Pages 589 to 602.
- Mohr, T.K.G. 2001. “Solvent Stabilizers White Paper.” Prepublication Copy. Santa Clara Valley Water District of California. San Jose, California.

Where can I find more information about 1,4-Dioxane? (continued)

- National Institute for Occupational Safety and Health (NIOSH). 2007. "Pocket Guide to Chemical Hazards." Cincinnati, Ohio. Page 120. www.cdc.gov/niosh/docs/2005-149/pdfs/2005-149.pdf
- Occupational Safety and Health Administration (OSHA). 1998. "Occupational Safety and Health Standards, Toxic and Hazardous Substances." 29 Code of Federal Regulations 1910.1000.
- Odah, M.M., R. Powell, and D.J. Riddle. 2005. "ART in-well technology proves effective in treating 1,4-Dioxane contamination." Remediation Journal. Volume 15 (3), Pages 51 to 64.
- Purifics ES Inc. 2006. Case History: 1,4 Dioxane Remediation 1.
- U.S. Department of Health and Human Services (DHHS). 2011. 1,4-Dioxane, CAS No. 123-91-1, Report on Carcinogens, 12th Edition.
- U.S. Environmental Protection Agency (EPA) Office of Solid Waste (OSW). 1996. Solvents Study. EPA 530-R-96-017, 52 pages.
- EPA. 2000. "Method 8261. Volatile Organic Compounds by Vacuum Distillation in Combination with Gas Chromatography/Mass Spectroscopy (VD/GC/MS)." In: SW-846 Draft Update IVB.
- EPA. 2001. "Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup." EPA 542-R-01-006.
- EPA. 2006. "Treatment Technologies for 1,4-Dioxane: Fundamentals and Field Applications." EPA 542-R-06-009. www.epa.gov/tio/download/remed/542r06009.pdf
- EPA. 2012a. 2012 Edition of Drinking Water Standards and Health Advisories. http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf
- EPA. 2012b. "1,4 Dioxane" www.clu-in.org/contaminantfocus/default.focus/sec/1,4-Dioxane/cat/Overview/
- EPA. 2012c. Regional Screening Level (RSL) Summary Table. http://www.epa.gov/region9/superfund/prg/
- EPA Integrated Risk Information System (IRIS). 2010. "1,4-Dioxane (CASRN 123-91-1)." www.epa.gov/iris/subst/0326.htm
- Vescovi T., H. Coleman, and R. Amal. 2010. "The Effect of pH on UV-based advanced oxidation technologies- 1,4-dioxane degradation." Journal of Hazardous Materials. Volume 182. Pages 75 to 79.

Additional information on 1,4-dioxane can be found at www.cluin.org/dioxane.

Contact Information

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