Emerging Contaminant - 1,4 Dioxane

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FACT SHEET

At a Glance

- Flammable liquid and a fire hazard. Potentially explosive if exposed to light or air.
- Classified as a Group B2 (probable human) carcinogen.
- Should be handled as a carcinogen - with extreme caution.
- Contact may cause eye and skin irritation and burns, coughing, or shortness of breath.
- Can migrate considerably ahead of other ground water contaminants.
- 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.
- May be regulated as hazardous waste when used as a solvent stabilizer.
- No federal drinking water standards have been established. Many states and EPA regions have set guidelines and action levels.
- Modifications to existing sample preparative procedures may be needed to achieve increased sensitivity 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

An "emerging contaminant" is a chemical or material that is characterized by a perceived, potential or real threat to human health or the environment or lack of published health standards. A contaminant may also be "emerging" because of the discovery of a new source or a new pathway to humans, or a new detection method or treatment technology has been developed (DoD 2006). This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary for 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. This fact sheet is intended for use by site managers faced with addressing 1,4-dioxane at a cleanup site 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 investigation.

What is 1,4-dioxane?

- 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).
- Unstable at elevated temperatures and pressures. Potentially explosive if exposed to light or air (Alexeeff 1998).

Exhibit 1: Physical and Chemical Properties of 1,4-Dioxane (CHEMFATE 2003)

Property	Value
CAS Number	000123-91-1
Physical Description (room temperature)	Flammable liquid with a faint, pleasant odor
Molecular weight (g/mol)	88.10
Water solubility (mg/L)	Soluble in water
Boiling point (^{o}C)	101.1 ^{o}C at 760 mm Hg
Vapor pressure at 25^{o}C (mm Hg)	38.0
Specific gravity	1.033
Log octanol-water partition coefficient (log K_{ow})	-0.27
Log organic carbon partition coefficient (log K_{oc})	1.23
Henry's law constant (atm m^3/mol)	4.88 X 10^{-6}

Notes:
g/mol – gram per mole; mg/L – milligrams per liter; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury.

What is 1,4-dioxane? (continued)

- 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 process; and as a laboratory cryoscopic solvent for molecular mass determinations (ATSDR 2006; EPA 2006).
- Used in many products, including paint strippers, dyes, greases, varnishes, and waxes. Found as an impurity in antifreeze and aircraft deicing fluids and in some consumer products (deodorants, shampoos, and cosmetics) (Mohr 2001; ATSDR 2006; EPA 2006).
- Also a by-product in the manufacture of polyethylene terephthalate (PET) plastic and used as a purifying agent in the manufacture of pharmaceuticals (Mohr 2001).
- Residues may be present in manufactured food additives, dioxane-containing food packaging materials, or on food crops treated with pesticides that contain dioxane, such as vine-ripened tomatoes (USDHHS 2002).
- Likely contaminant at many federal facilities because of its widespread use.
- Potential exposure could occur during its production and use as a stabilizer or solvent (USDHHS 2002).

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

- Typically found at solvent release sites and PET manufacturing facilities (Mohr 2001).
- Identified at 27 of the 1,662 sites on EPA's National Priorities List (NPL); potentially present but not analyzed for at many others (ATSDR 2006).
- Short-lived in the atmosphere, with a six to ten hour half life (Mohr 2001). Breakdown products include aldehydes and ketones.
- May migrate rapidly in ground water, ahead of other contaminants, and does not volatilize rapidly from surface water bodies (EPA 2006).
- Weakly retarded by sorption to soil particles and may move rapidly from soil to ground water (EPA 2006).
- Relatively resistant to biodegradation (Mohr 2001; ATSDR 2006).
- Does not bioconcentrate in the food chain (Mohr 2001; ATSDR 2006).

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

- Classified as a Group B2 (probable human) carcinogen (EPA IRIS 2005; IARC 1999).
- "Reasonably anticipated to be a human carcinogen" (USDHHS 2002).
- Carcinogenic Oral Slope Factor is 1.1E-2 milligrams/kilogram/day (mg/kg/day), with a lifetime cancer risk of 1 in 10^{-4} for a drinking water concentration of 0.3 parts per million (ppm) (EPA IRIS 2005; ATSDR 2006).
- Toxicity currently being reassessed under the EPA Integrated Risk Information System (IRIS) (EPA IRIS 2005).
- Exposure may occur through inhalation of vapors, ingestion of contaminated food and water, or dermal contact (USDHHS 2002).
- Inhalation is the most common route of human exposure – 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 2006).
- Workers at industrial sites are at greatest risk of repeated inhalation exposure (USDHHS 2002).
- Exposure may result in irritation of the eyes, nose, throat, and lungs, possible drowsiness, vertigo, headache, and anorexia (ATSDR 2006).
- Chronic exposure may result in dermatitis, eczema, drying and cracking of skin, and possible liver and kidney damage (EPA 1996; ATSDR 2006).
- Weakly genotoxic; reproductive effects are unknown (ATSDR 2006).

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

- Water Standards and Guidelines:
  - May be regulated as hazardous waste when used as a solvent stabilizer (EPA 1996).
  - No federal drinking water standards (USDHHS 2002). However, Maximum Contaminant Level (MCL) is not necessary to establish a cleanup level.
  - EPA Regions 3 and 6 have calculated a screening level of 6.1 parts per billion (ppb) for dioxane in tap water, based on a 1 in 10^{-6} lifetime excess cancer risk. These standards are not enforceable but provide a useful gauge of relative toxicity (EPA 2007a and b).
  - State regulators often use drinking water action levels and health advisories to establish appropriate site cleanup goals (EPA 2006).
  - Cleanup guidelines vary by state, ranging from 3 to 85 ppb in drinking water or ground water. Only one state (Colorado) has established an enforceable standard – facilities need to have met a 6.1 ppb limit by March 2005 and a 3.2 ppb limit by March 2010 (EPA 2006).
- Workplace Exposure Limits:
  - The Occupational Safety and Health Administration (OSHA) airborne permissible exposure limit (PEL) is 360 milligrams per cubic meter (mg/m^3) or 100 ppm (EPA 1996; OSHA 1998).
  - The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for dermal exposure is 25 ppm, and the recommended airborne exposure limit is 20 ppm averaged over an 8-hour work shift (EPA 1996; ACGIH 1998).
  - The National Institute for Occupational Safety and Health (NIOSH) has set 500 ppm as the concentration that is immediately dangerous to life or health (IDLH) and recommended 1 ppm as the airborne exposure limit (NIOSH 1997).

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

- It is recommended that dioxane be analyzed for in ground water samples where TCA is a known contaminant.
- As a result of the limitations in the analytical methods used for dioxane, it has been difficult to evaluate its occurrence in the environment (EPA 2006).
- Conventional analytical methods produced sensitivity levels that were about 100 times greater for dioxane as compared with those for volatile organic compounds (VOC) (Mohr 2001).
- Modifications to existing sample preparative procedures may be needed to achieve increased sensitivity for dioxane detection (EPA 2006).
- High-temperature sample preparation techniques improve the recovery of dioxane. These 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; EPA 2006).

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 dioxane (EPA 2006).
- Common treatment technologies include:
  - Commercially available advanced oxidation processes (AOP) using hydrogen peroxide with ultraviolet (UV) light or ozone (EPA 1996; EPA 2006).
  - Ex situ bioremediation using a fixed-film, moving-bed biological treatment system (EPA 2006).
- Technologies being assessed include: phytoremediation using hybrid poplar trees; photocatalysis and in-well combined treatment technologies that involve in situ air stripping; air sparging; soil vapor extraction; enhanced bioremediation; and dynamic subsurface ground water circulation (EPA 2001; EPA 2006; Powell 2006; Odah and others 2005).

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

- Agency for Toxic Substances and Disease Registry (ATSDR). 2006. "Toxicological Profile for 1,4-Dioxane."
- Alexeeff, G. 1998. Office of Environmental Hazard Assessment. Memorandum: 1,4-Dioxane Action Level. www.oehha.ca.gov/water/pals/pdf/PAL14DIOXAN.pdf.
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- CHEMFATE. 2003. Database Listing for 1,4-Dioxane. www.syrres.com/esc/chemfate.htm.
- 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. Vol. 71. Pages 589-602.
- Mohr, T.K.G. 2001. "Solvent Stabilizers White Paper." Prepublication Copy. Santa Clara Valley Water District of California. San Jose, California.
- National Institute for Occupational Safety and Health (NIOSH). 1997. "Pocket Guide to Chemical Hazards." Cincinnati, Ohio. Page 120.
- 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. Vol. 15 (3). Pages 51-64.
- Powell, T. 2006. Photo-Cat Case Histories & Technology Briefing. www.purifics.com.
- U.S. Department of Defense (DoD). 2006. Emerging Contaminants. www.denix.osd.mil/denix/Public/Library/MERIT/merit.html.
- U.S. Department of Health and Human Services (USDHHS). 2002. 1,4-Dioxane, CAS No. 123-91-1, Report on Carcinogens, 10th Edition.
- U.S. Environmental Protection Agency (EPA). 1996. Solvents Study. Office of Solid Waste. 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 Integrated Risk Information System (IRIS). 2005. "1,4-Dioxane (CASRN 123-91-1)."
- EPA. 2006. "Treatment Technologies for 1,4-Dioxane: Fundamentals and Field Applications." EPA 542-R-06-009.
- EPA. 2007a. Region 3. Human Health Risk Assessment – Risk-Based Concentrations Table. www.epa.gov/region3.
- EPA. 2007b. Region 6. Human Health Medium-Specific Screening Levels. www.epa.gov/region6.

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

Contact Information

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