Emerging Contaminant –
1,4-Dioxane
September 2009

FACT SHEET

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 a Group B2 (probable human) carcinogen.
- 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 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 a lack of published health standards. A contaminant may also be “emerging” because a new source or a new pathway to humans has been discovered, or a new detection method or treatment technology has been developed (DoD 2008). 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 emerging 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 ground water 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 2006; 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 2006; EPA 2006; Mohr 2001).
- 1,4-Dioxane is a likely contaminant at many federal facilities because of its widespread use.
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What is 1,4-Dioxane? (continued)

- 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 2002).

- 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).

Exhibit 1: Physical and Chemical Properties of 1,4-Dioxane (ATSDR 2006)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS Number</td>
<td>000123-91-1</td>
</tr>
<tr>
<td>Physical Description</td>
<td>Flammable liquid with a faint, pleasant odor</td>
</tr>
<tr>
<td>Molecular weight (g/mol)</td>
<td>88.10</td>
</tr>
<tr>
<td>Water solubility (mg/L at 25°C)</td>
<td>Soluble in water</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>101.1 °C at 760 mm Hg</td>
</tr>
<tr>
<td>Vapor pressure at 25°C (mm Hg)</td>
<td>38.1</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.033</td>
</tr>
<tr>
<td>Octanol-water partition coefficient (log K_{ow})</td>
<td>-0.27</td>
</tr>
<tr>
<td>Organic carbon partition coefficient (log K_{oc})</td>
<td>1.23</td>
</tr>
<tr>
<td>Henry’s law constant (atm m^3/mol)</td>
<td>4.80 X 10^{-6}</td>
</tr>
</tbody>
</table>

Notes: g/mol – gram per mole; mg/L – milligrams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; Atm m^3/mol – atmosphere-cubic meters per mole.

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

- It is weakly retarded by sorption to soil particles and may move rapidly from soil to ground water (EPA 2006).

- It is relatively resistant to biodegradation and does not bioconcentrate in the food chain (ATSDR 2006; Mohr 2001).

- It has been identified at 31 of the 1,689 sites on EPA’s National Priorities List (NPL); it may be present (but samples were not analyzed for it) at many other sites (ATSDR 2006).

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 2002).

- Chronic exposure may result in dermatitis, eczema, drying and cracking of skin, and possible liver and kidney damage (ATSDR 2006; EPA OSW 1996).

-弱ly genotoxic; reproductive effects are unknown (ATSDR 2006).

- Classified as a Group B2 (probable human) carcinogen (EPA IRIS 2005; IARC 1999) and is "reasonably anticipated to be a human carcinogen" (DHHS 2002).

- Toxicity currently being reassessed under the EPA Integrated Risk Information System (IRIS) (EPA IRIS 2005).
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What are the health effects of 1,4-Dioxane? (continued)

- The carcinogenic Oral Slope Factor is 1.1 \times 10^{-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 milligrams per liter (mg/L) (ATSDR 2006; EPA IRIS 2005).

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

- Water 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 2002). However, a maximum contaminant level (MCL) is not necessary to determine a cleanup level.
  - EPA Regions 3 and 6 have calculated a screening level of 6.1 micrograms per liter (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 2008a and b).
  - 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 85 µg/L in drinking water or ground water. Only Colorado has established an enforceable cleanup standard: facilities must achieve a 6.1 µg/L level by March 2005 and a 3.2 µg/L level by March 2012 (CDPHE 2009).

- 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 mg/L (EPA OSW 1996; 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 work shift (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 1997).

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 (VOC) (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 azeotropic distillation (SW-846 Method 5031) (EPA 2000, 2006).
- It is recommended that ground water 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 have been 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).
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What technologies are being used to treat 1,4-Dioxane? (continued)

- 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, 2006; Purific ES Inc. 2006; Odah et al. 2005).

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


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

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, by phone at (703) 603-8712 or by e-mail at cooke.maryt@epa.gov.