



TECHNICAL FACT SHEET– NDMA

At a Glance

- ❖ Formerly used in the production of rocket fuel, antioxidants and softeners for copolymers. Currently used only for research purposes.
- ❖ Unintended byproduct of chlorination of wastewater at wastewater treatment plants that use chloramines for disinfection, raising significant concern as a drinking water contaminant.
- ❖ Highly mobile in soil, with potential to leach into groundwater.
- ❖ Oral route is the primary human exposure pathway.
- ❖ Classified as a B2 (probable human) carcinogen.
- ❖ Listed as a priority pollutant by the EPA, but no federal standard has been established for drinking water.
- ❖ Detection methods include solid phase extraction, gas chromatography and liquid chromatography.
- ❖ Most common NDMA water cleanup method is via photolysis by ultraviolet radiation. Potential for aerobic and anaerobic NDMA biodegradation also exists.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant N-Nitrosodimethylamine (NDMA), 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 and other field personnel who may address NDMA contamination at cleanup sites or in drinking water supplies.

NDMA is a drinking water contaminant of concern because of its miscibility with water, as well as its carcinogenicity and toxicity.

What is NDMA?

- ❖ NDMA is a semivolatile organic chemical that forms in both industrial and natural processes (Cal/EPA 2006; Mitch and others 2003b).
- ❖ NDMA is not currently produced in pure form or commercially used in the United States, except for research purposes. It was formerly used in production of liquid rocket fuel, antioxidants, additives for lubricants and softeners for copolymers (ATSDR 1989; HSDB 2013).
- ❖ NDMA can be unintentionally produced in and released from industrial sources through chemical reactions, such as those that involve alkylamines. Potential industrial sources include amine manufacturing plants, tanneries, pesticide manufacturing plants, rubber and tire manufacturers, fish processing facilities, foundries, dye manufacturers and surfactant industries (ATSDR 1989).
- ❖ NDMA is also an unintended byproduct of the chlorination of wastewater and drinking water at treatment plants that use chloramines for disinfection (Bradley and others 2005; Mitch and others 2003).

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Exhibit 1: Physical and Chemical Properties of NDMA
(ATSDR 1989; Cal/EPA 2006; HSDB 2013; NIOSH 2016)

Property	Value/Description
Chemical Abstract Systems (CAS) number	62-75-9
Physical description (physical state at room temperature)	Yellow liquid with faint or no odor
Molecular weight (g/mol)	74.08
Water solubility at 25°C	Miscible
Melting point (°C)	-25 (estimated)
Boiling point (°C)	152 to 154
Specific gravity/Density at 20°F/4°C (g/mL)	1.005 to 1.006
Vapor pressure at 20°C (mm Hg)	2.7
Organic carbon partition coefficient (log K_{oc})	1.07 (estimated)
Octanol-water partition coefficient (log K_{ow})	-0.57
Henry's law constant at 20°C (atm-m ³ /mol)	2.63 x 10 ⁻⁷ (ATSDR 1989) 1.08 x 10 ⁻⁶ (HSDB 2013)

Abbreviations: g/mol – grams per mole; °C – degrees Celsius; g/mL – grams per milliliter; mm Hg – millimeters of mercury; atm-m³/mol – atmosphere-cubic meters per mole.

Existence of NDMA in the environment

- ❖ NDMA contamination may be found in air, soil and water (ATSDR 1999).
- ❖ When released to the air, NDMA is expected to exist solely as vapor in the ambient atmosphere and is broken down quickly by sunlight within minutes (HSDB 2013).
- ❖ When released to soil, NDMA can be highly mobile and will either volatilize or leach into groundwater (ATSDR 1999; HSDB 2013).
- ❖ In water, NDMA is completely miscible and is not expected to sorb onto solid particles or sediment. NDMA may break down in water as a result of exposure to sunlight or by natural biological processes. The potential for bioconcentration in aquatic organisms is low based on an estimated bioconcentration factor of 3 (ATSDR 1999; HSDB 2013; WHO 2008).
- ❖ At rocket engine testing facilities in California, NDMA has been found at high concentrations in groundwater on site (up to 400,000 nanograms per liter [ng/L]) and also in downgradient drinking water wells (up to 20,000 ng/L) (Mitch and others 2003b).
- ❖ In a 2002 survey conducted by the California Department of Health Services (CDHS), elevated concentrations of NDMA were detected in locations where wastewater treatment plant effluent was used for aquifer recharge and near facilities that use unsymmetrical dimethylhydrazine (UDMH)-based rocket fuel (CDHS 2002; Mitch and others 2003b).
- ❖ As of March 2011, NDMA was the predominant nitrosamine detected in samples obtained from public water systems, which were monitored as part of the unregulated contaminant monitoring rule (UCMR). The EPA uses the UCMR to monitor contaminants that are suspected to be present in drinking water but that do not currently have health-based standards under the Safe Drinking Water Act (EPA 2011a; EPA 2014).
- ❖ The second UCMR was analyzed for NDMA occurrence and trends across the U.S. NDMA occurrence was strongly associated with chloramine use. Elevated NDMA was more common in surface water systems than groundwater systems. Smaller utilities were found to have the most extreme NDMA levels (Woods and Dickenson 2015)

What are the routes of exposure and potential health effects of NDMA?

- ❖ NDMA exposure may occur through (1) ingesting food that contains nitrosamines, such as smoked or cured meats and fish; (2) ingesting food that contains alkylamines, which can cause NDMA to form in the stomach; (3) drinking contaminated water; (4) drinking malt beverages (such as beer and whiskey) that may contain low levels of nitrosamines formed during processing; (5) using toiletry and cosmetic products such as shampoos and cleansers that contain NDMA; and (6) breathing or inhaling cigarette smoke. Workplace exposure can occur at tanneries, pesticide manufacturing plants and rubber and tire plants (ATSDR 1989, 1999).
- ❖ The oral route, including consumption of contaminated food and water, is the primary human exposure pathway for NDMA (ATSDR 1989; Cal/EPA 2006).
- ❖ Exposure to high levels of NDMA may cause liver damage in humans (ATSDR 1999; HSDB 2013).
- ❖ Potential symptoms of overexposure include headache; fever; nausea; jaundice; vomiting; abdominal cramps; enlarged liver; reduced function of liver, kidneys and lungs; and dizziness (HSDB 2013; OSHA 2005).
- ❖ EPA has classified NDMA as a B2 (probable human) carcinogen based on the induction of tumors at multiple sites in different mammal species exposed to NDMA by various routes (EPA IRIS 2002).
- ❖ The U.S. Department of Health and Human Services (DHHS) states that NDMA is reasonably anticipated to be a human carcinogen (NTP 2014).
- ❖ DHHS states that NDMA caused tumors in numerous species of experimental animals, at several different tissue sites, and by several different routes of exposure. Tumors occurred primarily of the liver, respiratory tract, kidney and blood vessels (NTP 2014; IARC 1998).
- ❖ The American Conference of Governmental Industrial Hygienists (ACGIH) has classified NDMA as a Group A3 confirmed animal carcinogen with unknown relevance to humans (HSDB 2013).

Are there any federal and state guidelines and health standards for NDMA?

- ❖ EPA has not derived a chronic oral reference dose (RfD) or a chronic inhalation reference concentration (RfC) for evaluating NDMA's noncancer effects in the EPA's Integrated Risk Information System database (EPA IRIS 2002).
- ❖ EPA has derived a RfD of 8.0×10^{-6} mg/kg-day and an RfC of 4.0×10^{-5} mg/m³ as Provisional Peer-Reviewed Toxicity Values (PPRTVs) for evaluating noncancer effects (EPA 2007).
- ❖ EPA has assigned an oral slope factor for carcinogenic risk of 51 milligrams per kilogram per day (mg/kg-day)⁻¹, a drinking water unit risk of 1.4×10^{-3} per microgram per liter (µg/L)⁻¹ and an inhalation unit risk of 1.4×10^{-2} µg per cubic meter (m³) (EPA IRIS 2002).
- ❖ For tap water, EPA calculated a screening level of 0.11 ng/L for NDMA, based on a 10^{-6} lifetime excess cancer risk (EPA 2017).
- ❖ EPA's screening levels for soil are 2.0×10^{-3} milligrams per kilogram (mg/kg) for residential and 3.4×10^{-2} mg/kg for industrial (based on 10^{-6} cancer risk). The soil screening level for protection of groundwater is 2.7×10^{-8} mg/kg (EPA 2017).
- ❖ EPA's screening levels for air are 7.2×10^{-5} micrograms per cubic meter (µg/m³) for residential and 8.8×10^{-4} µg/m³ for industrial (based on 10^{-6} cancer risk) (EPA 2017).
- ❖ Various states have established drinking water and groundwater guidelines, including the following:

State	Guideline (µg/L)	Source
Alabama	0.0013	ADEM 2008
Alaska	0.017	AL DEC 2008
California	0.003	Cal/EPA 2006
Colorado	0.00069	CDPHE 2013
Delaware	0.001	DE DNR 1999
Florida	0.0007	FDEP 2005
Indiana	0.0049	IDEM 2015
Massachusetts	0.01	MADEP 2004
Mississippi	0.00131	MS DEQ 2002
New Jersey	0.0007	NJDEP 2015
North Carolina	0.0007	NCDENR 2015
Pennsylvania	0.0014	PADEP 2011
Texas	0.018	TCEQ 2016
Washington	0.000858	WA DEP 2015
West Virginia	0.0013	WV DEP 2009

- ❖ EPA included NDMA on the fourth Contaminant Candidate List (CCL4), which is a list of unregulated contaminants that are known to or anticipated to occur in public water systems and may require regulation under the Safe Drinking Water Act (EPA 2016b).
- ❖ In addition, EPA added NDMA to its UCMR 2, requiring many large water utilities to monitor for NDMA (EPA 2015).

What detection and site characterization methods are available for NDMA?

- ❖ For drinking water, EPA Method 521 uses solid phase extraction (SPE) and capillary column gas chromatography (GC) with large-volume injection and chemical ionization tandem mass spectroscopy (MS) (EPA 2004).
- ❖ For wastewater, EPA Method 607 uses methylene chloride extraction, GC and a nitrogen-phosphorus detector (NPD) (EPA 2007; EPA 2016a).
- ❖ For wastewater, EPA Method 1625 uses isotope dilution, GC and MS (EPA 2007; EPA 2016a).
- ❖ For groundwater, wastewater, soil, sediment and sludges, EPA SW-846 Method 8070 uses methylene chloride extraction, GC and a NPD (EPA 1996).
- ❖ For solid waste matrices, soil, air sampling media and water samples, EPA SW-846 Method 8270 uses GC and MS (EPA 1998).
- ❖ An analytical method has also been developed specifically to quantify NDMA precursors such as alkylamines in waste or wastewater (Mitch, and others 2003).
- ❖ A method using liquid chromatography tandem MS (LC/MS/MS) detects both thermally stable and unstable nitrosamines in drinking water (Zhao and others 2006).
- ❖ A study developed a method that is a combination of SPE and LC/MS/MS for determination of NDMA in surface water, groundwater and wastewater samples. The quantification limit identified was 2 ng/L (Topuz and others 2012).
- ❖ Modifications to GC-MS and GC-NPD methods including sample evapoconcentration and low concentration instrument calibration can be used to detect NDMA in soil to levels below 1 microgram per kilogram ($\mu\text{g}/\text{kg}$) (USACE 2009).

What technologies are being used to treat NDMA?

- ❖ The most common method to treat NDMA in drinking water systems is photolysis by ultraviolet radiation in the wavelength range of 225 to 250 nanometers (nm) (Mitch and others 2003b).
- ❖ Biological treatment, microfiltration and reverse osmosis treatment may be used to remove NDMA precursors from wastewater before chlorination (Mitch and others 2003b).
- ❖ Activated sludge, biological activated carbon and ultraviolet photolysis were found to be effective for NDMA mitigation in a study investigating 11 sites using ozone-based wastewater treatment trains (Gerry and others 2015).
- ❖ The Department of Defense's Strategic Environmental Research and Development Program (SERDP) is investigating abiotic, biotic and coupled abiotic/biotic processes to accelerate NDMA degradation in the subsurface (DoD SERDP 2008, 2009, 2012).
- ❖ A recent study of NDMA precursors found that photolysis and biodegradation were effective removal mechanisms for precursors in the water column (Woods and Dickenson 2016).
- ❖ Laboratory-scale studies have shown that aerobic and anaerobic biodegradation of NDMA to low ng/L concentrations in water and soil may be possible (Bradley and others 2005; DoD SERDP 2008).
- ❖ A laboratory-scale study demonstrated the potential for in-situ aerobic cometabolism of NDMA in the presence of methane- and benzene-amended groundwater highlighting possible attenuation mechanisms and rates for NDMA biotransformation in aerobic aquifers undergoing active remediation, natural attenuation or managed aquifer recharge with treated wastewater (Weidhaas and Dupont 2013).
- ❖ An Environmental Security Technology Certification Program demonstration project evaluated the technical effectiveness and cost of using a fluidized bed bioreactor (FBR) for treating NDMA in groundwater at a test facility. The FBR was found to be an effective means to treat NDMA, decreasing concentrations from 1 $\mu\text{g}/\text{L}$ to 4.2 ng/L. The cost of the full-scale FBR was determined to be significantly less than the comparable ultraviolet system over a 30-year remedial timeframe (ESTCP 2014).
- ❖ Laboratory-scale study results suggest that in-situ coupled abiotic/biotic processes may efficiently degrade NDMA in groundwater (DoD SERDP 2009).

- ❖ Membrane bioreactor (MBR) treatment was found to be effective in removing NDMA through biodegradation due to the presence of strong electron donating functional groups in their structure (Wijekoon and others 2013).
- ❖ An SERDP project was conducted to identify the organisms, enzymes and biochemical pathways involved in the aerobic biodegradation of NDMA. Laboratory-scale study results highlighted the importance of monooxygenases in the degradation of NDMA (DoD SERDP 2012).
- ❖ A SERDP field study was recently completed utilizing propane biosparging for in situ remediation of NDMA in groundwater. The field test results support that propane biosparging can be an effective approach to reduce the concentrations of NDMA in a groundwater aquifer by 3 to 4 orders of magnitude, and that concentrations in the low nanograms per liter (ng/L) range can be achieved with continuous treatment (DoD SERDP 2016).
- ❖ A laboratory-scale study observed the decomposition of NDMA in water using nanoscale zero-valent iron in the presence of aluminum and iron salts. The highest removal was found at a pH of 5. Improved removal was associated with a higher reaction temperature (Lin Lin and others 2013).

Where can I find more information about NDMA?

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Where can I find more information about NDMA? (continued)

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Where can I find more information about NDMA? (continued)

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