



TECHNICAL FACT SHEET – DNT

At a Glance

- ❖ Nitroaromatic explosive that exists as six isomers. 2,4- and 2,6-DNT are the most common forms.
- ❖ Not naturally found in the environment.
- ❖ Used as an intermediate in the production of ammunition, polyurethane polymers, dyes, herbicides, plastics, and automobile airbags.
- ❖ Commonly found in waste streams of DNT manufacturing or processing facilities.
- ❖ Expected to remain in water for long periods of time because of its relatively low volatility and moderate water solubility unless broken down by light, oxygen, or biota.
- ❖ Identified adverse effects in the blood, nervous system, liver, and kidney in animals after exposure.
- ❖ Classified as a Class B2 (probable human) carcinogen.
- ❖ Health-based goals, exposure limits, and state drinking water guidelines have been developed.
- ❖ Standard detection methods include gas chromatography (GC) and high-performance liquid chromatography (HPLC).
- ❖ Common treatment technologies include adsorption, chlorination, ozonation, ultraviolet radiation, alkaline hydrolysis, and 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 dinitrotoluene (DNT), 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 field personnel who may address DNT contamination at cleanup sites or in drinking water supplies.

The widespread use of DNT in manufacturing munitions, polyurethane foams, and other chemical products has contributed to extensive soil and groundwater contamination (Xu et al. 2012). DNT can be transported in surface water or groundwater because of its moderate solubility and relatively low volatility, unless degraded by light, oxygen, or biota. As a result, releases to water are important sources of human exposure and remain a significant environmental concern. DNT is considered toxic to most organisms and chronic exposure may result in organ damage (EPA 2008; IRIS 1990). DNT is currently identified as a priority pollutant by the EPA and is on the EPA's Drinking Water Contaminant Candidate List 2 for possible regulation under the Safe Drinking Water Act. EPA has developed a 10-Day Health Advisory for 2,4- and 2,6-DNT and has established an ambient water quality criteria.

What is DNT?

- ❖ DNT is a nitroaromatic explosive that exists as six isomers: 2,4- and 2,6-DNT are the two major forms of the chemical. The other four forms (2,3-DNT, 2,5-DNT, 3,4-DNT, and 3,5-DNT) make up only 5 percent of the technical grade DNT (Tg-DNT)(ATSDR 1998; Lent et al. 2012).
- ❖ DNT is not found naturally in the environment. It is usually produced by mixing toluene with nitric and sulfuric acids and is an intermediate in 2,4,6-trinitrotoluene (TNT) manufacturing (ATSDR 1998; EPA 2008).
- ❖ 2,4- and 2,6-DNT are the most common isomers produced during TNT synthesis (Han et al. 2011).
- ❖ DNT mixtures are predominantly used in the production of polyurethane polymers. It is also used as an intermediate in the production of dyes, plastics, herbicides, and automobile airbags (ASTDR 1998; EPA 2008; Lent et al. 2012; Paca et al. 2011).
- ❖ DNT is also widely used in manufacturing explosives and propellants, as a gelatinizing, plasticizing, and waterproofing agent. It is also used as a modifier for smokeless gunpowder (ATSDR 1998; Clausen et al. 2011; EPA 2007). There are currently a small number of DNT manufacturing facilities within the United States (EPA 2008).
- ❖ DNT is commonly deposited at military ranges and found in waste streams and soil near munitions manufacturing and processing facilities (Clausen et al. 2011).

What is DNT? (continued)

Exhibit 1: Physical and Chemical Properties of 2,4- and 2,6-DNT
(ATSDR 1998; EPA 2008; HDSB 2012; OSHA 2012)

| Property | 2,4-DNT | 2,6-DNT |
|--|----------------------------|-----------------------|
| Chemical Abstracts Service (CAS) Number | 121-14-2 | 606-20-2 |
| Physical Description (physical state at room temperature and atmospheric pressure) | Yellow solid | Yellow to red solid |
| Molecular weight (g/mol) | 182.14 | 182.14 |
| Water solubility (mg/L at 22°C) | 270 | 180 |
| Melting Point (°C) | 71 | 66 |
| Boiling point (°C) | 300 (slight decomposition) | 285 |
| Vapor pressure at 22°C (mm Hg) | 1.47×10^{-4} | 5.67×10^{-4} |
| Specific gravity/Density | 1.32 @ 71°C | 1.28 @ 111°C |
| Octanol-water partition coefficient (log K_{ow}) | 1.98 | 2.10 |
| Organic-carbon partition coefficient (log K_{oc}) | 1.65 | 1.96 |
| Henry's law constant (atm m ³ /mol) | 8.79×10^{-8} | 9.26×10^{-8} |

Notes: g/mol – grams per mole; mg/L – milligrams per liter; °C – degree Celsius; mm Hg – millimeters of mercury; atm m³/mol – atmosphere-cubic meters per mole.

What are the environmental impacts of DNT?

- ❖ DNT is commonly found in air, surface water, groundwater, and soil of hazardous waste sites that contain buried ammunitions waste or waste from facilities that manufacture or process DNT (EPA 2008; Darko-Kagya et al. 2010; Lent et al. 2012).
- ❖ DNT is used directly as an additive in single base gun propellants and can leach from the gun propellant matrix into soils. The most likely source of where gun propellant derived DNT may occur is within 10 meters in front of the firing point on small arms ranges or at open burn/open detonation (OB/OD) units where propellants are destroyed (Taylor et al. 2012).
- ❖ According to the latest Toxic Release Inventory, there were an estimated 10,438 pounds of 2,4-DNT from six facilities and 2,601 pounds of 2,6-DNT from three facilities released to the air in 2010 (TRI 2010).
- ❖ 2,4- and 2,6-DNT have been identified in environmental media of at least 122 of 1,467 current or former EPA National Priorities List (NPL) hazardous waste sites (ATSDR 1998).
- ❖ Because of their low vapor pressures and low Henry's Law constants, 2,4- and 2,6-DNT do not usually volatilize from water or soil. The isomers are usually released to air in the form of dusts or aerosols or adsorbed to other suspended particles (ATSDR 1998; Clausen et al. 2011; EPA 2008).
- ❖ 2,4- and 2,6-DNT only have a slight tendency to sorb to sediments, suspended solids, or biota based on their relatively low organic-carbon partition coefficients (ATSDR 1998; EPA 2008).
- ❖ The retention of DNT in soil depends on the chemistry and content of the soil organic matter (SOM) (Clausen et al. 2011; Singh et al. 2010).
- ❖ Unless broken down by light, oxygen, or biota, DNT is expected to remain in water for long periods of time because of its relatively low volatility and moderate water solubility. As a result, DNT has the potential to be transported by groundwater or surface water (ATSDR 1998; EPA 2008).
- ❖ DNT can degrade by several mechanisms in the environment, including oxidation, photolysis, and biodegradation in water and soil into a variety of degradation products (ATSDR 1998; EPA 2008).
- ❖ Vapor-phase 2,4- and 2,6-DNT have an estimated half-life of 75 days in the atmosphere and are broken down by photodegradation (EPA 2008).
- ❖ Photolysis is the primary route of DNT degradation in oxygenated water. The photodegradation of 2,6-DNT was assessed under simulated solar radiation in a seawater solution. Within 24 hours, 2,6-DNT had been reduced by 89 percent and after 72 hours had been fully degraded. Without solar radiation, 2,6-DNT was reduced by only 3.2 percent after 92 hours (ATSDR 2009; NAVFAC 2003).

What are the environmental impacts of DNT? (continued)

- ❖ Biodegradation of 2,4- and 2,6-DNT can occur under both aerobic and anaerobic conditions (EPA 2008).
- ❖ Bradley et al. (1994) found that microorganisms indigenous to surface soil collected at a munitions-contaminated site were able to transform 2,4- and 2,6-DNT to amino-nitro intermediates within 70 days (ATSDR 1998; Bradley et al. 1994).
- ❖ 2,4- and 2,6-DNT have relatively low octanol-water partition coefficients and, as a result, are not expected to bioaccumulate significantly in animal tissue (ATSDR 1998; EPA 2008).
- ❖ As a result of its moderate solubility, DNT can be transferred to plants via root uptake from soil and is expected to accumulate readily in plant materials (ATSDR 1998; EPA 2008).
- ❖ The bioavailability and toxicity of DNT to plants is greatly altered by soil properties. A recent study found that the toxicity of 2,4-DNT for various plant species was significantly and inversely correlated with SOM content (ATSDR 1998; Rocheleau et al. 2010).

What are the health effects of DNT?

- ❖ Potential exposure pathways include inhalation, dermal contact, and incidental ingestion, usually in occupational settings (ATSDR 1998; EPA 2008).
- ❖ Studies indicate that 2,4- and 2,6-DNT are readily adsorbed via oral or inhalation exposure. In addition, studies have found that 2,4- and 2,6-DNT can be adsorbed through skin in toxic amounts (EPA 2008; HDSB 2012).
- ❖ Toxicity to humans has been evaluated in DNT factory workers, munitions handlers, and mining workers (EPA 2008).
- ❖ Adverse health effects posed by chronic DNT exposure have been identified in the central nervous system, heart, and circulatory system of humans (EPA 2008).
- ❖ Identified symptoms from exposure to DNT include nausea, dizziness, methemoglobinemia, anemia, and cyanosis (EPA 2008; Darko-Kagya et al. 2010; OSHA 2012).
- ❖ Studies of workers indicate that exposure to 2,4- and 2,6-DNT can lead to increased incidence of mortality from ischemic heart disease (EPA 2008; HDSB 2012).
- ❖ A study by Brüning et al. (1999) found 25 percent of 183 miners exposed to DNT via inhalation or dermal contact indicated signs of liver disorder (ATSDR 2009; Brüning et al. 1999).
- ❖ Brüning et al. (1999) also studied 500 cases of underground copper-miners exposed (many through direct skin contact) to DNT in Germany. The study identified 14 cases of renal cell cancer, five cases of bladder carcinoma, and one case of renal pelvic carcinoma (Brüning et al. 1999; ATSDR 2009).
- ❖ 2,4- and 2,6-DNT have both shown adverse neurological, hematological, reproductive, hepatic, and renal effects in animal studies with rats, mice, and dogs (EPA 2008; OSHA 2012; Xu et al. 2012).
- ❖ The Oral LD₅₀ (the dose that is lethal to 50 percent of the animals tested) values for 2,4- and 2,6-DNT indicate that both isomers are moderately to highly toxic to rats and mice (EPA 2008).
- ❖ Animal studies have shown that both 2,4- and 2,6-DNT are hepatocarcinogens and can cause liver cancer in rats (ATSDR 1998; HDSB 2012).
- ❖ Studies indicate that the hepatocarcinogenicity of Tg-DNT could be attributed to the 2,6-DNT isomer (ATSDR 1998; Lent et al. 2012).
- ❖ EPA classified the mixture of 2,4- and 2,6-DNT as a Class B2 (probable human) carcinogen (ATSDR 1998; IRIS 1990; HDSB 2012).
- ❖ The cancer risk assessment for the 2,4- and 2,6-DNT mixture is based on an oral slope factor of 6.8×10^{-1} milligrams per kilogram per day (mg/kg/day) and drinking water unit risk of 1.90×10^{-5} micrograms per liter ($\mu\text{g/L}$) (EPA 2008; IRIS 1990).
- ❖ The Integrated Risk Information System (IRIS) established an oral reference dose (RfD) of 0.002 mg/kg/day for 2,4-DNT based on neurotoxicity and the presence of Heinz bodies and biliary tract hyperplasia (IRIS 1993). EPA has also developed an RfD of 0.001 mg/kg/day for 2,6-DNT (EPA 2011).
- ❖ The drinking water equivalent levels are 0.1 milligrams per liter (mg/L) for 2,4-DNT and 0.04 mg/L for 2,6-DNT (EPA 2011).

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

- ❖ For 2,4-DNT, a minimal risk level (MRL) of 0.05 mg/kg/day was derived for acute-duration oral exposure and 0.002 mg/kg/day for chronic-duration oral exposure (ATSDR 2011).
- ❖ For 2,6-DNT, a MRL of 0.004 mg/kg/day was derived for intermediate-duration oral exposure (ATSDR 2011).
- ❖ EPA established health advisories for 1-day, 10-day, and longer-term (up to 7 years) exposures. The one-day health advisory is 1.0 mg/L for 2,4-DNT and 0.4 mg/L for 2,6-DNT based on a 10-killogram (kg) child (EPA 2011).
- ❖ 2,4- and 2,6-DNT are regulated by the Clean Water Effluent Guidelines in 40 Code of Federal Regulations (CFR) Part 401 (ATSDR 1998).
- ❖ EPA established an ambient water quality criteria of 0.11 µg/L for ingestion of water and organisms and 9.1 µg/L for ingestion of organisms only for 2,4-DNT at a 10^{-6} risk level (EPA 2008).
- ❖ EPA has calculated a residential soil screening level of 1.6 milligrams per kilogram (mg/kg) and the industrial soil screening level of 5.5 mg/kg for 2,4- DNT. The soil-to-groundwater soil screening level (SSL) is 2.8×10^{-4} for 2,4-DNT (EPA 2012).
- ❖ For 2,6-DNT, EPA has calculated a residential soil screening level of 61 mg/kg and the industrial soil screening level of 620 mg/kg. The SSL is 2.0×10^{-2} for 2,6-DNT (EPA 2012).
- ❖ 2,4- and 2,6-DNT are designated as hazardous substances under section 311(b)(2)(A) of the Federal Water Pollution Control Act (HDSB 2012).
- ❖ 2,4-DNT is a listed substance under the Resource Conservation and Recovery Act (RCRA) Toxicity Characteristic Leaching Procedure (TCLP) organics list. If soils or wastes containing 2,4-DNT fail the TCLP criteria for DNT, then they would be classified as RCRA characteristic hazard waste, and would be required to be treated to meet the RCRA DNT standard, 0.13 mg/L in leachate based on the TCLP test (CFR 2006).
- ❖ The Occupational Safety and Health Administration (OSHA) set an average 8-hour time-weighted average (TWA) permissible exposure limit (PEL) for DNT in workplace air of 1.5 milligrams per cubic meter (mg/m^3) (OSHA 2012).
- ❖ The National Institute for Occupational Safety and Health (NIOSH) considers DNT a potential carcinogen and has established a recommended exposure limit (REL) of $1.5 \text{ mg}/\text{m}^3$ for DNT as a TWA for a standard 10-hour workday and 40-hour workweek (OSHA 2012; NIOSH 2010).
- ❖ The American Conference of Governmental Industrial Hygienist's (ACGIH) threshold limit value (TLV) for DNT is $1.5 \text{ mg}/\text{m}^3$ as a TWA for a conventional 8-hour work day and 40-hour work week (OSHA 2012).
- ❖ Per EPA requirements, spills or releases to the environment of more than 1,000 pounds of DNT must be reported immediately to the federal government (ATSDR 1998).
- ❖ Both 2,4- and 2,6-DNT are identified as toxic substances under Section 313 of the Emergency Planning and Community Right to Know Act under Title III of the Superfund Amendments and Reauthorization Act (SARA) (ATSDR 1998).
- ❖ Various states have established drinking water guidelines for both 2,4- and 2,6-DNT, including Florida (0.05 µg/L for each isomer), Maine (0.5 µg/L for each isomer), and Wisconsin (0.05 µg/L for each isomer). New Hampshire has established a drinking water guideline for 2,4-DNT of 0.11 µg/L (HDSB 2012).

What detection and site characterization methods are available for DNT?

- ❖ Common analytical methods for DNT isomers rely on gas chromatography (GC) and high-performance liquid chromatography (HPLC) (ATSDR 1998; EPA 2008).
- ❖ GC is usually used in combination with various detectors including flame ionization detector, electron capture detector (ECD), hall electrolytic conductivity detector, thermionic specific detector, Fourier transform infrared, or mass spectrometry (MS) (ATSDR 1998).
- ❖ Capillary GC columns with ECD have been developed to detect 2,4-DNT in both air and surface particulate samples (ATSDR 1998).
- ❖ Surface-enhanced raman spectroscopy (SERS) was shown to detect 2,4-DNT vapor at a concentration level of 5 parts per billion (ppb) or less in air (ATSDR 2009; Sylvia et al. 2000).
- ❖ Cross-reactive optical microsensors can detect DNT in water vapor at a level of 23 ppb in clean, dry air (ATSDR 2009, Albert and Walt 2000).

What detection and site characterization methods are available for DNT? (continued)

- ❖ A continuous countercurrent liquid-liquid extraction method is capable of extracting DNT from surface water samples (ATSDR 1998).
- ❖ Reversed-phase, high-performance liquid chromatography (RP-HPLC) enables the direct analysis of aqueous samples to identify DNT in wastewater. The detection limit for 2,4-DNT was 10 µg/L (Jenkins et al. 1986; ATSDR 1998).
- ❖ Negative ion mobility spectrometry is a sensitive and selective technique that has been used to identify trace amounts of 2,4-DNT and other explosive vapors (ATSDR 1998).
- ❖ Pressurized fluid extraction and gas and liquid chromatography-mass spectrometry can also be used to detect DNT in soil (ATSDR 2009; Campbell et al. 2003).
- ❖ In soils, a sonic extraction-liquid chromatographic method has been used to detect DNT (ATSDR 1998).
- ❖ EPA Method 8330B, HPLC using a dual wavelength ultraviolet (UV) detector, has been used for the detection of ppb levels of certain explosive and propellant residues, such as 2,4- and 2,6 DNT, in water, soil, or sediment (EPA 2006).
- ❖ There are currently no EPA approved analytical methods for the other four (lesser) isomers (3-DNT, 2,5-DNT, 3,4-DNT, and 3,5-DNT).

What technologies are being used to treat DNT?

- ❖ Remediation technologies for DNT contaminated soil and groundwater sites typically involve the use of a separation process, advanced oxidation processes, chemical reduction, bioremediation, and phytoremediation (Reddy et al. 2011).
- ❖ Adsorption on a solid phase, such as granular adsorbent, is the basic method to collect DNT from the atmosphere. This treatment is followed by removal with solvents such as chloroform, acetone, or methane (ATSDR 1998; EPA 2008).
- ❖ Munitions wastewater containing DNT is commonly treated by activated carbon adsorption followed by incineration of the spent carbon (Chen et al. 2011).
- ❖ As a result of its high efficiency and ease of operation, electrochemical oxidation has been applied successfully to treat DNT-contaminated wastewater (Chen et al. 2011).
- ❖ Nanotechnology has emerged as a potential technology for the reductive degradation of DNT in soil and groundwater. Studies have been able to successfully enhance transport of the nanoscale iron particles (NIPs) and degrade 2,4-DNT in soil using lactate-modified NIPs (Darko-Kagya et al. 2010; Reddy et al. 2011).
- ❖ Recent batch experiments demonstrated that in situ chemical oxidation using iron sulfide activated persulfate was able to completely degrade DNT in water (Oh et al. 2011).
- ❖ Researchers have been assessing potential bioremediation technologies for soil and wastewater since physical and chemical methods can be relatively expensive and produce concentrated waste streams that require further treatment (Nishino and Spain 2001; Wang et al. 2011).
- ❖ Studies have found that 2,4-DNT is more easily degraded than 2,6-DNT by bioremediation in soil and groundwater. In addition, sequential treatment systems may be needed to treat soil or water containing both isomers (Nishino and Spain 2001).
- ❖ Recent studies have achieved a 2,4-DNT removal efficiency above 99 percent in wastewater using a sequential anaerobic/aerobic biodegradation treatment method (Kuşçu et al. 2011; Wang et al. 2011).
- ❖ A study was conducted to determine the lowest concentrations of DNT isomers that could support sustained growth of DNT degrading microorganisms under aerobic conditions. Study results suggested that bioremediation (including natural attenuation) of DNT-contaminated groundwater may be an effective treatment option (Han et al. 2011).
- ❖ Common methods of treatment of DNT in soils are incineration and bioremediation (Darko-Kagya et al. 2010; FRTR 2007).
- ❖ Recent field demonstrations for soil have employed alkaline hydrolysis successfully to treat high concentrations of 2,4- and 2,6-DNT to meet cleanup criteria (Britto et al. 2010).
- ❖ A protocol document for application of alkaline hydrolysis to treat DNT and other explosives in soil ("Management of Munitions Constituents in Soil using Alkaline Hydrolysis") has been developed by the U.S. Army Engineer and Development Center (ERDC) in Vicksburg, Mississippi (USACE 2011).

Where can I find more information about DNT?

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- ❖ Hazardous Substances Data Bank (HDSB). 2012. "Dinitrotoluene," "2,4- Dinitrotoluene," and "2,6- Dinitrotoluene." <http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB>
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Where can I find more information about DNT? (continued)

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