United States
Environmental Protection
Agency

Technical Fact Sheet – Dinitrotoluene (DNT)

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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.
- Adverse effects identified 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, screening levels 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 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 and Jing 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; EPA IRIS 1990). EPA currently classifies DNT as a priority pollutant. In addition, EPA has developed a 1-Day and 10-Day health advisory for 2,4- and 2,6-DNT and has established an ambient water quality criterion for 2,4-DNT.

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 technical grade DNT (Tg-DNT)(ATSDR 2013b; Lent and others 2012a).
- 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 2013b; EPA 2008).
- 2,4- and 2,6-DNT are the most common isomers produced during TNT synthesis (Han and others 2011).
- DNT mixtures are predominantly used in the production of polyurethane polymers. These mixtures are also used as an intermediate in the production of dyes, plastics, herbicides and automobile airbags (ASTDR 2013b; EPA 2008; Paca and others 2011).
- DNT is also widely used in manufacturing explosives and propellants as a gelatinizing, plasticizing and waterproofing agent in industries such as the munitions and mining industry. It is also used as a modifier for smokeless gunpowder in the munitions industry. There are currently a small number of DNT manufacturing facilities within the United States (ATSDR 2013b; EPA 2007a; EPA 2008).

What is DNT? (continued)

- DNT is commonly deposited through live-fire and blow-in-place detonations at military ranges and found in waste streams and soil near munitions manufacturing and processing facilities (Clausen and others 2011; EPA 2012b).

Exhibit 1: Physical and Chemical Properties of 2,4- and 2,6-DNT
(ATSDR 1998; EPA 2008; HSDB 2013)

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 at 22°C (mg/L)	300	180
Melting Point (°C)	71	66
Boiling point (°C)	300 (slight decomposition)	285
Vapor pressure at 25 °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	1.72 or 2.10 (estimated)
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}

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degree Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.

What are the environmental impacts of DNT?

- DNT is commonly found in surface water, groundwater and soil at hazardous waste sites that contain buried ammunitions waste or waste from facilities that manufacture or process DNT (EPA 2008; Darko-Kagya and others 2010; Lent and others 2012a).
- DNT is a component of many single-base gun propellants and can leach from the gun propellant matrix into soils. The most likely location where gun propellant-derived DNT may be deposited is up to 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 (EPA 2012b; Racine and others 1992; USACE 2007)
- According to the 2011 Toxic Release Inventory, an estimated 4,881 pounds of 2,4-DNT from six U.S. industrial facilities and three Army ammunition plants, and 1,201 pounds of 2,6-DNT from three U.S. industrial facilities were released to the air in 2011 (EPA TRI 2011).
- As of 2007, 2,4- and 2,6-DNT have been identified at more than 98 sites on the EPA National Priorities List (NPL) (HazDat 2007).
- Because of their low vapor pressures and low Henry's Law constants, 2,4- and 2,6-DNT do not usually volatize from water or soil. The isomers are usually released to air in the form of dusts or aerosols from manufacturing plants or adsorbed to other suspended particles (EPA 2008).
- 2,4- and 2,6-DNT have only a slight tendency to sorb to sediments, suspended solids or biota based on their relatively low organic-carbon partition coefficients (EPA 2008).
- The retention of DNT in soil depends on the chemistry and content of the soil organic matter (Clausen and others 2011; Singh and others 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 2013b; EPA 2008).
- In water and soil, DNT degrades into a variety of degradation products through several mechanisms in the environment, including oxidation, photolysis, ozonation and chlorination and biodegradation (ATSDR 2013b; EPA 2008).

What are the environmental impacts of DNT? (continued)

- 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; HSDB 2013).
- Photolysis is the primary means for 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 (EPA 2008; NAVFAC 2003).
- Biodegradation of 2,4- and 2,6-DNT in water can occur under both aerobic and anaerobic conditions (EPA 2008).
- Bradley and others (1994) found that microorganisms indigenous to surface soil and aquifer materials collected at a munitions-contaminated site were able to transform 2,4- and 2,6-DNT to amino-nitro intermediates within 70 days (ATSDR 2013b; Bradley and others 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 2013b; 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 2013b; EPA 2008; McFarlane and others 1987).
- DNT’s bioavailability and toxicity to plants are greatly altered by soil properties. Studies have found that the toxicity of 2,4- and 2,6-DNT for various plant species is significantly and inversely correlated with soil organic matter content (Rocheleau and others 2010).

What are the routes of exposure and the health effects of DNT?

- Potential exposure pathways include inhalation, dermal contact and incidental ingestion, usually in occupational settings (ATSDR 2013b; 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; HSDB 2013).
- Toxicity to humans has been evaluated in DNT factory workers, munitions handlers and mining workers. 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 prolonged exposure to DNT include nausea, dizziness, methemoglobinemia, jaundice, anemia and cyanosis (EPA 2008; Darko-Kagya and others 2010; OSHA 2013).
- Studies of workers indicate that exposure to 2,4- and 2,6-DNT can lead to increased incidences of mortality from ischemic heart disease (EPA 2008; HSDB 2013).
- A study conducted by Brüning and others found 25 percent of 183 miners exposed to DNT via inhalation or dermal contact indicated signs of liver disorder (Brüning and others 1999).
- Brüning and others 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 and others 1999).
- 2,4- and 2,6-DNT have both shown adverse impacts to neurological, hematological, reproductive, hepatic and renal functions in animal studies of rats, mice and dogs (EPA 2008; Xu and Jing 2012).
- The Oral LD_{50} (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; Hartley and others 1994).
- In a recent study, symptoms such as cyanosis, anemia, increased splenic mass and hepatocellular lesions were observed in rats exposed to 2,4- and 2,6-DNT for 14 days (Lent and others 2012b).
- Animal studies have also shown that both 2,6- and Tg-DNT are hepatocarcinogens and can cause liver cancer in rats (HSDB 2013; Lent and others 2012a).
- Studies indicate that the hepatocarcinogenity of Tg-DNT could be attributed to the 2,6-DNT isomer (ATSDR 2013b; Lent and others 2012a).

What are the routes of exposure and the health effects of DNT? (continued)

- EPA classified the mixture of 2,4- and 2,6-DNT as a Class B2 (probable human) carcinogen based on multiple benign and malignant tumor types at multiple sites in rats and malignant renal tumors in male mice (EPA IRIS 1990).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has classified DNT as a Group A3 carcinogen — confirmed animal carcinogen with unknown relevance to humans (ACGIH 2011).

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

- EPA's Integrated Risk Information System (IRIS) database includes a chronic oral reference dose (RfD) of 2 x 10^{-3} milligrams per kilogram per day (mg/kg/day) for 2,4-DNT based on neurotoxicity and the presence of Heinz bodies and biliary tract hyperplasia in animals (EPA IRIS 1993).
- Based on a provisional peer-reviewed toxicity value (PPRTV) assessment conducted by the EPA for both 2,6-DNT and Tg-DNT, EPA established a provisional chronic RfD screening value of 3 x 10^{-4} mg/kg/day for 2,6-DNT and 9 x 10^{-4} mg/kg/day for Tg-DNT. The PPRTV assessments are developed for use in the EPA Superfund program and provide toxicity values and information about adverse effects of the chemical (EPA 2013a, b).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.05 mg/kg/day for acute-duration oral exposure (14 days or less),0.007 mg/kg/day for intermediate-duration oral exposure (15 to 364 days) and 0.001 mg/kg/day for chronic-duration oral exposure (365 days or more) to 2,4-DNT (ATSDR 2013a, b).
- For 2,6-DNT, an MRL of 0.09 mg/kg/day has been derived for acute-duration oral exposure and 0.004 mg/kg/day was derived for intermediate-duration oral exposure (ATSDR 2013a, b).
- The cancer risk assessment for the 2,4- and 2,6-DNT mixture is based on an oral slope factor of 6.8 x 10^{-1} mg/kg/day and a drinking water unit risk of 1.90 x 10^{-5} micrograms per liter (µg/L) (EPA 2008; EPA IRIS 1990).
- EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for 2,4- and 2,6-DNT mixture is 0.005 µg/L (EPA IRIS 1990).
- The EPA has established drinking water health advisories for DNT, which are drinking water-specific risk level concentrations for cancer (10^{-4} cancer risk) and concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations (EPA 2012a).
    - EPA established a 1-day and 10-day health advisory of 1.0 mg/L for 2,4-DNT in drinking water for a 10-kilogram (kg) child.
    - For 2,6-DNT, EPA established a 1-day health advisory of 0.4 milligrams per liter (mg/L) and a 10-day health advisory of 0.04 mg/L in drinking water for a 10-kg child .
    - The drinking water equivalent levels for 2,4- and 2,6-DNT are 0.1mg/L and 0.04 mg/L.
- EPA established an ambient water quality criterion 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 1 x 10^{-6} risk level (EPA 2008).
- EPA has calculated a residential soil screening level (SSL) of 1.6 milligrams per kilogram (mg/kg) and an industrial SSL of 5.5 mg/kg for 2,4-DNT. The soil-to-groundwater risk-based SSL is 2.8 x10^{-4} mg/kg (EPA 2013c).[1]
- For 2,6-DNT, EPA has calculated a residential SSL of 3.3 x 10^{-1} mg/kg and an industrial soil screening level of 1.2 mg/kg. The soil-to-groundwater risk-based SSL is 5.8 x10^{-5} mg/kg (EPA 2013c).
- EPA has also calculated a residential SSL of 7.2 x 10^{-1} mg/kg and an industrial SSL of 2.5 mg/kg for the mixture of 2,4- and 2,6-DNT. The soil-to-groundwater risk-based SSL is 1.3 x10^{-4} mg/kg (EPA 2013c).
- For 2,4-DNT, EPA has calculated a residential air screening level of 2.7 x 10^{-2} micrograms per cubic meter (µg/m^3) and an industrial air screening level of 1.4 x 10^{-1} µg/m^3 . EPA has not established an ambient air screening level for 2,6-DNT or the mixture of 2,4- and 2,6- DNT (EPA 2013c).

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[1] Screening Levels are developed using risk assessment guidance from the EPA Superfund program. These risk-based concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data. These calculated screening levels are generic and not enforceable cleanup standards but provide a useful gauge of relative toxicity.

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

- For tap water, EPA has calculated screening levels of 2.0 x 10^{-1} µg/L for 2,4-DNT, 4.2 x 10^{-2} µg/L for 2,6-DNT, and 9.2 x 10^{-2} µg/L for 2,4- and 2,6- DNT mixture (EPA 2013c).[2]
- In 2005, 2,4- and 2,6-DNT were included on the second drinking water Contaminant Candidate List, 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 (SDWA). In 2008, the EPA made a determination not to regulate either isomer with a national primary drinking water regulation based on the infrequent occurrence of the isomers at levels of concern in public water supply systems (EPA OGWDW 2008).
- 2,4- and 2,6-DNT are designated as hazardous substances under Section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act. Any discharge of these chemical over a threshold level of 10 pounds into navigable waters is subject to reporting requirements (EPA 2011).
- 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 produce leachate with concentrations equal to or greater than the TCLP threshold (0.13 mg/L) for 2,4- DNT, they are classified as RCRA characteristic hazard waste and would require treatment (EPA 2006a).
- The Occupational Safety and Health Administration set a general industry permissible exposure limit of 1.5 milligrams per cubic meter (mg/m^3) based on a time-weighted average (TWA) over an 8-hour workday for airborne exposure to DNT (OSHA 2013).
- The National Institute for Occupational Safety and Health (NIOSH) considers DNT a potential occupational carcinogen and has established a recommended exposure limit (REL) of 1.5 mg/m^3 based on a TWA over a 10-hour workday and 40-hour workweek for airborne exposure to DNT (OSHA 2013; NIOSH 2010).
- NIOSH has also established an immediately dangerous to life or health (IDLH) concentration of 50 mg/m^3 for DNT (NIOSH 2010).
- The ACGIH has set a threshold limit value (TLV) of 0.2 mg/m^3 based on a TWA over an 8-hour workday and 40-hour work week for airborne exposure to DNT (ACGIH 2011).
- 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 (EPA 1999).
- Under the Comprehensive Environmental Response, Compensation, and Liability Act, the EPA has established a reportable quantity limit of 10 pounds for 2,4-DNT, 100 pounds for 2,6-DNT, and 10 pounds for the mixture of 2,4- and 2,6-DNT. EPA requires that all spills and releases to the environment that equal or exceed these quantities be reported immediately to the National Response Center (EPA 2011).
- Various states have established drinking water guidelines for 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 (HSDB 2013).

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[2] Tap water screening levels differ from the IRIS drinking water concentrations because the tap water screening levels account for dermal, inhalation and ingestion exposure routes; age-adjust the intake rates between the child and adult based on body weight; and time-adjust for exposure duration or days per year. The IRIS drinking water concentrations consider only the ingestion route, account only for adult-intake rates and do not time-adjust for exposure duration or days per year.

What detection and site characterization methods are available for DNT?

- DNT is commonly deposited in the environment as discrete particles with strongly heterogeneous spatial distributions. Unless precautions are taken, this variability causes highly variable soil data, which can lead to confusing or contradictory conclusions about the location and degree of contamination. As described in SW-846 Method 8330B, proper sample collection (using an incremental field sampling approach), sample processing (which includes grinding) and incremental subsampling are required to obtain reliable soil data (EPA 2006b).
- Common analytical methods for DNT isomers rely on gas chromatography (GC) and high-performance liquid chromatography (HPLC) (ATSDR 2013b; 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, thermal energy analyzer or mass spectrometry (MS) (ATSDR 2013b).
- Capillary GC columns with ECD have been developed to detect 2,4-DNT in both air and surface particulate samples (ATSDR 2013b).
- Surface-enhanced raman spectroscopy was shown to detect 2,4-DNT vapor at a concentration level of 5 parts per billion (ppb) or less in air (ATSDR 2013b; Sylvia and others 2000).
- Cross-reactive optical microsensors can detect 2,4-DNT in water vapor at a level of 23 ppb in clean, dry air (ATSDR 2013b, Albert and Walt 2000).
- A continuous countercurrent liquid-liquid extraction method is capable of extracting 2,4- and 2,6-DNT from surface water samples (ATSDR 2013b; Deroux and others 1996).
- Reversed-phase, HPLC enables the direct analysis of aqueous samples to identify DNT in wastewater. The estimated detection limit for 2,4-DNT is 10 µg/L (Jenkins and others 1986; ATSDR 1998).
- Negative-ion chemical ionization is a sensitive and selective technique that has been used to identify trace amounts of nitroaromatic compounds in complex aqueous mixtures (ATSDR 2013b; Feltes and others 1990).
- Pressurized fluid extraction and gas and liquid chromatography-MS can also be used to detect 2,4-DNT in soil (ATSDR 2013b; Campbell and others 2003).
- In soils, a sonic extraction-liquid chromatographic method has been used to detect 2,4-DNT in soils (ATSDR 2013b; Griest and others 1993).
- EPA SW-846 Method 8330, 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 2007c).
- EPA SW-846 Method 8095 uses capillary-column GC with an ECD to analyze for explosives, such as 2,4- and 2,6-DNT, in water and soil (EPA 2007b).
- EPA Method 529 uses solid phase extraction and capillary column GC and MS for the detection of 2,4- and 2,6-DNT in drinking water (EPA 2002).
- There are currently no EPA-approved analytical methods for the other four DNT isomers (2,3-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 separation processes, advanced oxidation processes, chemical reduction, bioremediation and phytoremediation (Rodgers and Bunce 2001).
- 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 2013b; EPA 2008).
- Munitions wastewater containing DNT is commonly treated by activated carbon adsorption followed by incineration of the spent carbon (Chen and others 2011).
- As a result of its high efficiency and ease of operation, electrochemical oxidation has been applied successfully to treat DNT-contaminated wastewater (Chen and others 2011).
- Nanotechnology has emerged as a potential technology for the reductive chemical degradation of DNT in soil and groundwater. Studies have shown that lactate-modification of nanoscale iron particles (NIPs) can enhance the transport of NIPs and chemical degradation of 2,4-DNT in soil (Darko-Kagya and others 2010; Reddy and others 2011).

What technologies are being used to treat DNT? (continued)

- Batch experiments demonstrated that in situ chemical oxidation using iron sulfide activated persulfate was able to degrade 2,4-DNT completely in water (Oh and others 2011).
- Researchers have been assessing potential bioremediation technologies for soil and wastewater contaminated with DNTs because physical and chemical methods can be relatively expensive and produce concentrated waste streams that require further treatment (Nishino and Spain 2001; Wang and others 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 and Sponza 2011; Wang and others 2011).
- A study was conducted to measure 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 and others 2011).
- Common methods to treat DNT in soils are incineration and bioremediation (Darko-Kagya and others 2010; FRTR 2007).
- Recent field demonstrations for soil have successfully employed alkaline hydrolysis to treat high concentrations of 2,4- and 2,6-DNT to meet cleanup criteria (Britto and others 2010).
- A protocol document for the 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 Corps of Engineers, Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi (USACE 2011).

Where can I find more information about DNT?

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- ATSDR. 2013b. “Toxicological Profile for Dinitrotoluenes.” www.atsdr.cdc.gov/toxprofiles/tp109.pdf
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