Technical Fact Sheet – 2,4,6-Trinitrotoluene (TNT)

May 2012

At a Glance

- Highly explosive, yellow, odorless solid.
- Synthetic product that does not occur naturally in the environment.
- Has been used extensively in the manufacture of explosives and accounts for a large part of the explosives contamination at active and former U.S. military installations.
- Sorbed by most soils, limiting its migration to water.
- Not expected to persist for a long period of time in surface waters because of transformation processes.
- Classified as a Group C (possible human) carcinogen.
- Primarily damages the liver and blood systems if inhaled or ingested.
- SW8515 is a field screening method used to detect TNT in soil by colorimetric screening.
- The primary laboratory methods include liquid and gas chromatography.
- Potential treatment technologies include in situ bioremediation, granular activated carbon treatment, composting, and incineration.

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 2,4,6-trinitrotoluene (TNT), including its 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 TNT contamination at cleanup sites or in drinking water supplies.

Major manufacturing of TNT began in the U.S. in 1916 at the beginning of World War I. It was produced in enormous quantities both commercially and at government ammunition plants for use in military munitions in World War I and World War II (Steen 2007). During the 1940s through the 1970s, Department of Defense (DoD) ammunitions plants and depots demilitarized off-specification, unserviceable, and obsolete munitions based on steam-out and melt-out processes to recover TNT and TNT-containing explosive fillers such as Composition B (TNT/ hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX] mixture). These processes often generated significant quantities of explosives-contaminated wastewaters. The untreated wastewater was discharged into unlined impoundments, lagoons, ditches and playas, which resulted in significant levels of soil and ground water contamination. Ground water contamination from TNT was first reported in the late 1980s (Spalding and Fulton 1988).

TNT is still widely used in U.S. military munitions and accounts for a large part of the explosives contamination at active and former U.S. military installations. With its manufacturing impurities and environmental transformation products, TNT presents various health and environmental concerns.

What is TNT?

- TNT is a yellow, odorless solid that does not occur naturally in the environment. It is made by combining toluene with a mixture of nitric and sulfuric acids (ATSDR 1995).
- Effluent from TNT manufacturing was a major source of munitions constituent contamination in soils, ground water, and occasionally surrounding surface water and sediment at Army ammunition plants. TNT production ended in the mid-1980s in the United States; however, contamination of soils and ground water remains in some areas (EPA 2005; MMR 2001).
- It is a highly explosive, single-ring nitroaromatic compound that is a crystalline solid at room temperature (CRREL 2006).

What is TNT? (continued)

- TNT is one of the most widely used military high explosives, partly because of its insensitivity to shock and friction. It has been used extensively in the manufacture of explosives since the beginning of the 20th century and is used in military cartridge casings, bombs, and grenades (ATSDR 1995).
- It has been used either as a pure explosive or in binary mixtures. The most common binary mixtures of TNT are cyclotols (mixtures with RDX) and octols (mixtures with High Melting Explosive [HMX]) (ATSDR 1995; MMR 2001).
- In addition to military use, small amounts of TNT may be used for industrial explosive applications, such as deep well and underwater blasting. Other industrial uses include chemical manufacturing as an intermediate in the production of dyestuffs and photographic chemicals (MMR 2001).
- TNT is commonly found at hand grenade ranges, antitank rocket ranges, artillery ranges, bombing ranges, munitions testing sites, and open burn/open detonation (OB/OD) sites (CRREL 2006).

Exhibit 1: Physical and Chemical Properties of TNT
(ATSDR 1995; EPA 1999)

Property	Value
CAS Number	118-96-7
Physical Description (physical state at room temperature)	yellow, odorless solid
Molecular weight (g/mol)	227
Water solubility (mg/L at 20^{o}C)	130
Octanol-water partition coefficient (K_{OW})	1.6
Soil organic carbon-water coefficient (K_{OC})	300
Boiling point (^{o}C)	240 (Explodes)
Melting point (^{o}C)	80.1
Vapor pressure at 25^{o}C (mm Hg)	1.99 x10^{-4}
Specific gravity	1.654
Henry's Law Constant (atm-m^3/mol at 20^{o}C)	4.57 x10^{-7}

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere time cubic meter per mole.

What are the environmental impacts of TNT?

- TNT can be released to the environment through spills, firing of munitions, disposal of ordnance, and OB/OD of ordnance, leeching from inadequately sealed impoundments, and demilitarization of munitions. The compound can also be released from manufacturing and munitions processing facilities (ATSDR 1995).
- TNT has been identified in at least 20 of the 1,338 hazardous waste sites that have been proposed for inclusion on the National Priorities List (NPL) (ASTDR 1995).
- TNT is a crystalline solid at room temperature and TNT's water solubility (approximately 130 milligrams per liter [mg/L] at 20^{o}C) and vapor pressure are relatively low, but greater than those of RDX and HMX (CRREL 2006).
- Partition coefficients reported by most investigators indicate soils have a high capacity for rapid sorption of TNT. TNT not sorbed into soil is usually transformed rapidly under anaerobic conditions but may persist under aerobic conditions (CRREL 2006; USACE 1997).
- In the case of impact areas, the majority of the TNT may be degraded in the surface soil, but small quantities can reach shallow ground water (CRREL 2006).
- Once released to surface water, TNT undergoes rapid photolysis to a number of degradation products. 1,3,5-Trinitrobenzene (1,3,5-TNB) is the primary photodegradation product of TNT in environmental systems (ATSDR 1995; CRREL 2006).

What are the environmental impacts of TNT? (continued)

- TNT is one of the most widely used military high explosives, partly because of its insensitivity to shock and friction. It has been used extensively in the manufacture of explosives since the beginning of the 20th century and is used in military cartridge casings, bombs, and grenades (ATSDR 1995).
- Products of photolysis of TNT have been observed as a coating on TNT particles and as a fine powdered residue surrounding TNT particles on ranges that receive limited rainfall (CRREL 2007a).
- Generally, dissolved-phase TNT is broken down by biodegradation in water but at rates much slower than photolysis (ATSDR 1995; CRREL 2006).
- Biological degradation products of TNT in water, soil, or sediments include 2-amino-4,6-dinitrotoluene, 2,6-diamino-4-nitrotoluene, 4-amino-2,6-dinitrotoluene, and 2,4-diamino-6-nitrotoluene (CRREL 2007b; EPA 1999).
- TNT does not seem to bioaccumulate in animals, but can be taken up by plants (CRREL 2006).

What are the health effects of TNT?

- The toxicity of TNT to humans was well documented in the 20th century, with more than 475 fatalities and more than 17,000 cases of TNT poisoning during World War I and World War II manufacturing operations (Bodeau 1993).
- The primary routes of exposure in manufacturing environments are inhalation of dust and ingestion and dermal sorption of TNT particulates, and significant health effects were liver necrosis and aplastic anemia (ATSDR 1995).
- The highest exposures to TNT have been found in areas around Army ammunition plants where these explosives are manufactured, packed, loaded, or released through the demilitarization of munitions (ATSDR 1995).
- Potential exposure to TNT could occur by dermal contact or inhalation exposure, and the likely route is exposure to contaminated soils. However, exposure to contaminated ground water is also likely at sites with high infiltration rates such as washout lagoons or OB/OD areas (MMR 2001).
- EPA has assigned TNT a weight-of-evidence carcinogenic classification of C (possible human carcinogen) (IRIS 1993; OSHA 1999).
- The oral slope factor for carcinogenic risk is 3×10^{-2} milligrams per kilogram per day (mg/kg/day) (IRIS 1993).
- EPA assigned TNT a reference dose (RfD) of 5×10^{-4} mg/kg/day (IRIS 1993).
- Animal study results indicated that inhalation or ingestion of high levels of TNT may cause liver, blood, immune system, and reproductive damage (EPA 2005; MMR 2001).
- When TNT reaches the liver, it breaks down into several different substances. Not all of these substances have been identified (ATSDR 1995).
- At high levels in air, workers involved in the production of TNT experienced anemia and abnormal liver tests. After long-term exposure to skin and eyes, some people developed skin irritation and cataracts (MMR 2001).
- There is no information indicating that TNT causes birth defects in humans. However, male animals treated with high doses of TNT have developed serious reproductive system effects (ATSDR 1995b; MMR 2001).

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

- A Minimal Risk Level (MRL) of 0.0005 mg/kg/day has been derived for intermediate oral exposure to TNT (ATSDR 1995).
- The EPA has established a Lifetime Health Advisory guidance level of 2 parts per billion (ppb) for TNT in drinking water. The health advisory for a cancer risk of 10-4 is 0.1 mg/L (ATSDR 1995; EPA 2011a).
- EPA has calculated a resident soil screening level of 19 milligrams per kilogram (mg/kg) and an industrial soil screening level of 79 mg/kg (EPA 2011b).
- The EPA has not established an ambient air level for TNT (MMR 2001).
- Since TNT is explosive, flammable, and toxic, EPA has designated it as a hazardous waste and EPA regulations for disposal must be followed (EPA 2012).

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

- The Occupational Safety and Health Administration (OSHA) set a general industry permissible exposure limit (PEL) of 1.5 milligrams per cubic meter (mg/m^3) of workplace air for an 8-hour workday for a 40-hour work week (OSHA 2010).
- The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for TNT during an 8-hour workday, 40-hour work week is 0.5 mg/m^3 (OSHA 2010).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has set a threshold limit value (TLV) of 0.1 mg/m^3 (OSHA 2010).
- TNT in bulk and in cased munitions is a United Nations Hazard Division 1.1 Explosive, not a flammable solid, and a Resource Conservation and Recovery Act ((RCRA) D003 (reactive) waste for waste military munitions containing TNT (DOT 1989).

What detection and site characterization methods are available for TNT?

- High performance liquid chromatography (HPLC) and high-resolution gas chromatography (HRGC) have been paired with several types of detectors, including mass spectrometry (MS), electrochemical detection (ED), electron capture detector (ECD), and ultraviolet detector (UV) (ATSDR 1995).
- Laboratory Method 8330 is the most widely used analytical approach for detecting TNT in soil. The method specifies using HPLC with a UV. It has been used to detect TNT and some of its breakdown products at levels in the low ppb range (EPA 2006).
- Another method commonly used is Method 8095, which employs the same sample-processing steps as Method 8330 but uses HRGC with an ECD for determination (EPA 2005).
- SW8515 is a specific field screening method used to detect TNT in soil by a colorimetric screening method (USACE 2005; Army 2009).
- Tested field-screening instruments for TNT include GC-IONSCAN, which uses ion mobility spectrometry (IMS), and the Spreeta Sensor, which uses surface plasma resonance (SPR) (EPA 2000; 2001).

What technologies are being used to treat TNT?

- In situ bioremediation is an emerging technology for the treatment of explosives (including TNT)-contaminated ground water. Biological treatment methods such as bioreactors, bioslurry treatment, and passive subsurface biobarriers have been proven successful in reducing TNT concentrations (EPA 2005; CRREL 2006; ESTCP 2010).
- Composting has been proven in achieving cleanup goals for TNT at field demonstrations (EPA 2005).
- Incineration can be used on soil containing low concentrations of TNT (EPA 2005).
- Granular activated carbon (GAC) is the primary method to treat explosives-contaminated ground water and waste waters. Ultrafiltration and resin adsorption have not been used at full scale to treat ground water contaminated with TNT or related explosives co-contaminants such as trinitrobenzene (TNB), dinitrotoluene (DNT), tetryl, RDX, or HMX (FRTR 2007).
- Fenton oxidation and treatment with iron metal (FeO) has been used to remediate TNT-contaminated soil and water but has not been used as standalone full-scale treatment technology (NCER 2010; EPA 2005).

Where can I find more information about TNT?

- Agency for Toxic Substances and Disease Registry (ATSDR). 1995. Toxicological Profile for TNT. www.atsdr.cdc.gov/toxprofiles/TP.asp?id=677&tid=125
- Bodeau, D. 1993. Occupational Health: The Soldier and the Industrial Base. Chapter 9. Military Energetic Materials: Explosives and Propellant.

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

- Cold Regions Research and Engineering Laboratory (CRREL). 2006. Conceptual Model for the Transport of Energetic Residues from Surface Soil to Groundwater by Range Activities. ERDC/CRREL TR-06-18. www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA472270
- CRREL. 2007a. Photochemical Degradation of Composition B and Its Components. ERDC/EL TR-07-16. www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA472238
- CRREL. 2007b. Protocols for Collection of Surface Soil Samples at Military Training and Testing Ranges for the Characterization of Energetic Munitions Constituents. ERDC/CRREL TR-07-10. www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA471045.
- Environmental Security Technology Certification Program (ESTCP). 2010. Passive Biobarrier for Treating Comingled Perchlorate and RDX in Groundwater at an Active Range (ER-1028).
- Federal Remediation Technologies Roundtable (FRTR). 2007. Remediation Technologies Screening Matrix and Reference Guide, Version 4.0. Section 2.10.2 Common Treatment Technologies for Explosives in Ground Water, Surface Water, and Leachate.
- Massachusetts Military Reservation (MMR) 2001. Impact Area Groundwater Study Program. Chemical Fact Sheet – TNT. Fact Sheet 2001-05. http://imc2.army.mil/wastewater/community/facts/tnt.pdf
- Occupational Safety & Health Administration (OSHA). 1999. 2,4,6-Trinitrotoluene. http://www.osha.gov/dts/chemicalsampling/data/CH_274100.html
- Spalding, R. and J. Fulton. 1988. Groundwater Munition Residues and Nitrate near Grand Island, Nebraska, USA. Journal of Contaminant Hydrology. Volume 2 (2), Pages 139-153.
- Steen, K. 2007. Technical Expertise and U.S. Mobilization, 1917-18: High Explosives and War Gases. Frontline and Factory: Comparative Perspectives on the Chemical Industry at War, 1914-1924. Pages 103 –122.
- U.S. Army. 2009. Military Munitions Response Program. Munitions Response Remedial Investigation/Feasibility Study Guidance.
- U.S. Army Corps of Engineers (USACE). 1997. Review of Fate and Transport Processes of Explosives. Installation Restoration Research Program. Technical Report IRRP-92-2. March 1997. http://el.erdc.usace.army.mil/elpubs/pdf/trirrp97-2.pdf
- USACE. 2005. Military Munitions Center of Expertise. Technical Update. Munitions Constituent (MC) Sampling.
- U.S. Department of Transportation (DOT). 1989. Hazardous materials table and hazardous materials communications regulations. Code of Federal Regulations. 49 CFR 172.101.
- U.S. Environmental Protection Agency (EPA). 1999. Office of Research and Development. Federal Facilities Forum Issue. Field Sampling and Selecting On-site Analytical Methods for Explosives in Water. EPA 600-S-99-002.
- EPA. 2000. Office of Research and Development. Barringer Instruments. GC-IONSCAN. Environmental Technology Verification Report. EPA 600-R-00-046.
- EPA. 2001. Office of Research and Development. Research International, Inc. TNT Detection Technology. Texas Instruments Spreeta Sensor. Environmental Technology Verification Report. EPA/600/R-01/064. August 2001.
- EPA. 2005. EPA Handbook on the Management of Munitions Response Actions. EPA 505-B-01-001 http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100304J.txt
- EPA. 2006. 8330b. Nitroaromatics, Nitramines, and Nitrate esters by High Performance Liquid Chromatography (HPLC) Revision 2.
- EPA. 2011a. 2011 Edition of the Drinking Water Standards and Health Advisories. http://water.epa.gov/action/advisories/drinking/upload/dwstandards2011.pdf
- EPA. 2011b. Regions 3, 6, and 9. Regional Screening Levels Table. www.epa.gov/reg3hwmd/risk/human/index.htm
- EPA. 2012. Listed Wastes- Hazardous Wastes. www.epa.gov/osw/hazard/wastetypes/listed.htm

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

- EPA. Integrated Risk Information System (IRIS). 1993. 2,4,6-Trinitrotoluene (TNT) (CASRN 118-96-7). Last Revised 1993. www.epa.gov/iris/subst/0269.htm
- EPA. National Center for Environmental Research (NCER). 2010. Final Report: Fate and Transport of Munitions Residues in Contaminated Soil. Website accessed on July 2, 2010.

Contact Information

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