Emerging Contaminants – 2,4,6-Trinitrotoluene (TNT)

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FACT SHEET

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 or the atmosphere because of transformation processes such as photolysis.
- Classified as a Group C contaminant (possible human carcinogens).
- Primarily damages the liver and blood systems, if inhaled or ingested.
- SW8515 is a field screening method used detect TNT in soil by colorimetric screening. The primary laboratory methods include liquid and gas chromatography.
- Treatment technologies include *in situ* chemical and biological remediation, composting, phytoremediation, ultrafiltration, and low-temperature thermal desorption.

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 2010). 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.

While TNT is not identified as an emerging contaminant by the Department of Defense (DoD), this compound 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. 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.

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).
- It is a highly explosive, single-ring nitroaromatic compound that is a crystalline solid at room temperature (CREEL 2006).
- 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 this 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).

What is TNT? (continued)

- Red water, the effluent from TNT manufacturing, was a major source of munitions constituent contamination in soils, groundwater, and occasionally surrounding surface water/sediment at Army ammunition plants. TNT production ended in the mid-1980s in the United States; however, contamination of soils and groundwater from red water remains in some areas (MMR 2001; EPA 2005).
- 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 (CREEL 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 25^{o}C)	130
Octanol-water partition coefficient (K_{OW})	1.6
Soil organic carbon-water coefficient (K_{OC})	300
Boiling point (oC)	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 – gram 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 open incineration and detonation 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).
- 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 (CREEL 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 groundwater (CREEL 2006).
- TNT has a high aqueous solubility and is mobile in surface water and groundwater. However, if TNT reaches the water table, it continues to be sorbed by the aquifer material and undergoes transformation processes that can limit its mobility (EPA 2005; CREEL 2006).
- Once released to surface water, TNT undergoes rapid photolysis to a number of degradation products. 1,3,5-TNB (1,3,5-Trinitrobenzene) is the primary photodegradation product of TNT in environmental systems (ATSDR 1995; CREEL 2006).
- 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 receiving limited rainfall (CREEL 2007a).
- TNT is broken down by biodegradation in water and surface soils but at rates much slower than photolysis. TNT photolysis is reportedly faster than biodegradation by a factor of 1,000 (ATSDR 1995; CREEL 2006).
- Biological degradation products of TNT in water, soil, or sediments include 2-amino-4,6-dinitrotoluene, 2,6-diamino-4-nitrotoluene, and 2,4-diamino-6-nitrotoluene (EPA 1999; CREEL 2007b).
- It is expected that TNT released to the atmosphere would undergo direct photolysis, as it does in surface water (ATSDR 1995).
- TNT does not seem to bioaccumulate in animals, but can be taken up by plants (CREEL 2006).

What are the health effects of TNT?

- For the general population, exposure to TNT is limited to 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; however, the most likely route of exposure at or near hazardous waste sites is ingestion of contaminated drinking water (MMR 2001).
- EPA has assigned TNT a weight-of-evidence carcinogenic classification of C (possible human carcinogen) (IRIS 1993; OSHA 1999).
- A Minimal Risk Level (MRL) of 0.0005 milligrams per kilograms per day (mg/kg/day) has been derived for intermediate oral exposure to TNT (ATSDR 1995).
- Animal study results indicated that inhalation or ingestion of high levels of TNT may cause liver, blood, immune system, and reproductive damage (MMR 2001; EPA 2005).
- When TNT reaches the liver, it breaks down into several different substances. Not all of these substances have been identified (ATSDR 1995).
- At high air levels, 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, respectively (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).
- Limited information is available regarding oral, respiratory, cardiovascular, dermal, and neurological effects in humans after exposure to TNT (ATSDR 1995).

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

- The EPA has established a lifetime Health Advisory guidance level of 2 parts per billion (ppb) for TNT in drinking water. The EPA has not established an ambient air level or a cleanup standard for TNT in soil (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 (ATSDR 1995).
- EPA assigned TNT an RfD of 5.00 $x10^{-4}$ mg/kg/day (IRIS 1993).
- The Drinking Water Equivalent Level (DWEL), a lifetime exposure at which adverse health effects would not be expected to occur, is 20 micrograms per liter (µg/L) for TNT. The Lifetime Health Advisory is 2 µg/L (ATSDR 1995).
- OSHA set a general industry permissible exposure limit (PEL) of 1.5 mg/m^3 (mg/m^3) of workplace air for an 8-hour workday for a 40-hour workweek (OSHA 2010).
- The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) for TNT during an 8-hour workday, 40-hour workweek 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/m3 (OSHA 2010).
- The Department of Transportation (DOT) specifies that when TNT is shipped, it must be wet with at least 10% water (by weight) and it must be clearly labeled as a flammable solid (ATSDR 1995).

What detection and site characterization methods are available for TNT?

- High performance liquid chromatography (HLPC) 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 HLPC 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 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?

- Biological treatment methods such as bioreactors, bioslurry treatment, and passive subsurface biobarriers have been proven successful in reducing TNT concentrations in soil (EPA 2005; CREEL 2006; ESTCP 2010).
- Composting has been proven in achieving cleanup goals for TNT at field demonstrations (EPA 2005).
- Low-temperature thermal desorption (LTTD) can be used on soil containing low concentrations of TNT (EPA 2005).
- Disposal of TNT has been accomplished by burning in an incinerator equipped with an afterburner and a scrubber (ATSDR 1995).
- Fenton oxidation and treatment with iron metal (Fe0) has been used to remediate TNT-contaminated soil and water (NCER 2010; EPA 2005).
- Other methods of treating waste waters include ultrafiltration, activated carbon, and resin adsorption (ATSDR 1995).

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
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