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

August 2021

FACT SHEET – TNT

At a Glance

- Synthetic chemical that does not occur naturally in the environment.
- Used extensively in munitions manufacturing and accounts for a large part of the explosives contamination at active and former U.S. military installations.
- Tends to remain in soils, limiting its migration to water.
- Degrades in the presence of light.
- Not expected to persist for a long period in surface water because of breakdown processes.
- Classified as a possible human carcinogen.
- Can damage the liver and blood systems if inhaled or ingested.
- Treatment technologies include composting, incineration, alkaline hydrolysis, solidification/ stabilization, DARAMEND® process, granular activated carbon treatment and ion exchange.

Introduction

This fact sheet, developed by EPA's Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of 2,4,6-trinitrotoluene (TNT). The fact sheet covers TNT's physical and chemical properties, environmental and health impacts, federal and state guidelines, detection and treatment methods, and additional sources of information. This fact sheet is for environmental professionals and the general public.

What is TNT?

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

- TNT is a yellow, odorless solid that does not occur naturally in the environment (ATSDR 1995; NCBI 2020). It is a single-ring nitroaromatic compound made by combining toluene with a mixture of nitric acid and sulfuric acid. Its Chemical Abstracts Service (CAS) number is 118-96-7 (ATSDR 1995; USACE CRREL 2006; NCBI 2020).
- TNT is one of the most widely used military 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 shells, bombs and grenades (U.S. Army 1984; ATSDR 1995; Cal/EPA 2010).
- It has been used both as a pure explosive and in binary mixtures. The most common binary mixtures of TNT are cyclotols (mixtures with RDX) and octols (mixtures with HMX) (ATSDR 1995; USACE CRREL 2006; NCBI 2020).
- Wastewater discharge from TNT manufacturing is a major source of TNT contamination in soil and groundwater at military ammunition plants (EPA 2005).
- TNT production in the United States occurs at military and commercial facilities (EPA 2020b). TNT may be imported into the United States for industrial applications (ATSDR 1995; Cal/EPA 2010; NCBI 2020).
- Small amounts of TNT are 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 (ATSDR 1995; NCBI 2020).

Table 1 presents physical and chemical properties for TNT. For additional information, see the EPA Chemicals Dashboard.

Table 1: Physical and Chemical Properties for TNT

Property	Value
Chemical Abstracts Service (CAS) number	118-96-7
Physical description (physical state at room temperature)	Yellow, odorless solid
Molecular weight	227.13 g/mol
Water solubility	5.67×10^{-4} mol/L (experimental average)
Octanol-water partition coefficient (log K_{ow})	1.6 (experimental average)
Soil adsorption coefficient (K_{oc})	300 L/kg (predicted average)
Boiling point	240°C (experimental average)
Melting point	80°C (experimental average)
Vapor pressure	8.02×10^{-6} mm Hg (experimental average)
Density	1.63 g/cm^3 (predicted average)
Henry's law constant	3.93×10^{-7} atm-m^3/mol (predicted average)
Notes: g/mol = grams per mole mol/L = moles per liter L/kg = liters per kilogram °C = degrees Celsius mm Hg = millimeters of mercury g/cm^3 = grams per cubic centimeter atm-m^3/mol = atmosphere-cubic meters per mole	

What are the potential health effects of TNT?

TNT is a possible human carcinogen, specifically, bladder cancer via oral exposure (EPA IRIS 2002). It can also damage the liver and blood cell systems (ATSDR 1995; NCBI 2020).

Cancer Effects (EPA IRIS 2002)
Level of confidence: possible human carcinogen

Urinary

Noncancer Effects (EPA IRIS 2002)

Liver

EPA considers risk to be the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor. For a risk to exist, the following three factors must be present: 1) contamination; 2) pathways for that contaminant to reach surrounding populations; and 3) populations that may be exposed to the contaminant. If any of these factors are missing, little or no risk is present.

- TNT is considered a possible human carcinogen. EPA considers human evidence of carcinogenicity to be inadequate, but urinary bladder tumors were observed in female rats. TNT is mutagenic in the presence and absence of metabolic activation (EPA IRIS 2002).
- Potential symptoms of exposure may include irritation of the skin and mucous membrane, liver damage, jaundice, cyanosis, sneezing, cough,

sore throat, peripheral neuropathy, muscle pain, kidney damage, cataract, dermatitis, leukocytosis, anemia and cardiac irregularities (NIOSH 2016).

- ❖ At high levels in air, workers involved in the production of TNT experienced anemia and liver function abnormalities. After long-term exposure to skin and eyes, some people experienced skin irritation and developed cataracts (ATSDR 1995).

Where is TNT found in the environment?

TNT contamination can be found where munitions have been used, manufactured or disposed (ATSDR 1995).

- ❖ Due to its chemical properties, TNT tends to remain in most soils, limiting its potential to migrate to groundwater (Price et al. 1997; USACE 1997, USACE CRREL 2006).
- ❖ TNT in surface water breaks down rapidly in sunlight (photodegradation). Photodegradation can also occur in surface soils. 1,3,5-Trinitrobenzene (1,3,5-TNB) is a primary degradation product of TNT in environmental systems (ATSDR 1995; EPA 2012b).
- ❖ TNT can also break down by microorganisms (biodegradation), but at a much slower rate than photodegradation (ATSDR 1995; EPA 1999, 2006a; USACE CRREL 2006).
- ❖ Under low oxygen conditions, TNT degrades rapidly (Price et al. 1997; USACE 1997).
- ❖ Most TNT may be degraded in the surface soil at impact areas; however, small quantities can reach shallow groundwater (USACE CRREL 2006).
- ❖ TNT does not seem to bioaccumulate in animals, but may be taken up by plants from contaminated soil (USACE CRREL 2006; EPA 2005).
- ❖ As of 2020, TNT had been identified at 34 sites on the EPA National Priorities List (NPL) (EPA 2020a).

What are the routes of exposure of TNT?

The most likely routes of exposure to TNT at or near hazardous waste sites is drinking contaminated water or skin contact with contaminated surface water or soil. Potential exposure to TNT could also occur through inhalation, or by eating crops grown in contaminated soil (ATSDR 1995).

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

To determine potential risks of adverse health effects, the federal government has derived toxicity values based on available health studies, which can be used to calculate screening values and standards. When combined with exposure information, toxicity values can be used to establish screening values and standards. Table 2 includes federal toxicity values derived for TNT. Table 3 includes federal and state advisories, screening values and standards established for TNT.

Table 2: Federal Human Health Toxicity Values for TNT

Parameter	Value	Source
Chronic oral reference dose (RfD)	5 x10^{-4} milligrams per kilogram per day (mg/kg-day)	EPA IRIS 2002
Oral slope factor (OSF) for carcinogenic risk	3 x 10^{-2} per mg/kg-day	EPA IRIS 2002
Drinking water unit risk	9 x 10^{-7} per microgram per liter (µg/L)	EPA IRIS 2002
Minimal risk level (MRL) for oral exposure	0.0005 mg/kg-day for intermediate duration	ATSDR 1995

Table 3: Federal and State Guidelines for TNT

Organization	Value	Medium[a]	Source
EPA	• 0.002 milligrams per liter (mg/L): lifetime health advisory • 0.1 mg/L: health advisory level (cancer risk of 10^{-4}) • 0.02 mg/L: 1-day and 10-day health advisory level for children	drinking water	EPA 2018
EPA	2.5 µg/L: tap water screening level	drinking water	EPA 2020c
EPA	• 21 mg/kg: residential screening level • 96 mg/kg: industrial screening level • 0.015 mg/kg: soil-to-groundwater screening level	soil	EPA 2020c
EPA Region 3 Biological Technical Assistance Group (BTAG)	100 µg/L: ecological screening benchmark	surface water	EPA Region 3 2006
Indiana	9.8 µg/L: residential screening level	drinking water	IDEM 2020
Mississippi	2.23 µg/L: target remediation goal	groundwater	MDEQ 2002
Missouri	7.63 µg/L: residential target level	groundwater	MDNR 2006
Nebraska	2.5 µg/L: residential remediation goal	groundwater	NDEQ 2018
New Jersey	1 µg/L groundwater quality	groundwater	NJ DEP 2020
New Mexico	9.8 µg/L: screening level	drinking water	NMED 2019
Pennsylvania	2 µg/L: residential standard	groundwater	PADEP 2016
Texas	0.012 µg/L: default residential cleanup standard	groundwater	TCEQ 2019
West Virginia	2.5 µg/L: remediation standard	groundwater	WVDEP 2020

Notes:
a) Drinking water is generally what comes out of the tap. Groundwater can be a source of drinking water. When groundwater is a source of drinking water, standards for groundwater and drinking water are often the same.

- Some states have adopted screening values or cleanup goals for TNT in soil. The states' soil values, which are not included in Table 3, are wide-ranging in value, including 7.3 mg/kg to 110 mg/kg for residential areas (NCDENR 2019; PADEP 2016) and 96 mg/kg to 1,600 mg/kg for industrial areas (NCDENR 2019; PADEP 2016).
- Since TNT is explosive, flammable and toxic, EPA has designated it as a characteristic hazardous waste once it becomes a solid waste, and EPA regulations for disposal must be followed (EPA 2012a).

What detection and site characterization methods are available for TNT?

- EPA SW-846 Method 8330 is the most widely used analytical approach for detecting TNT in water, soil and sediment. It has been used to detect TNT and some of its breakdown products at levels in the low parts per billion (ppb) range in water, soil and sediment (EPA 2006b, 2012b).
- TNT is commonly deposited unevenly in the environment. As described in SW-846 Method 8330B, proper sample collection and processing are required to obtain reliable soil data (EPA 2006b, 2012b).
- Another method commonly used is EPA SW-846 Method 8095 for detection of explosives in water and soil (EPA 2007, 2012b).
- Specific field screening methods for TNT include EPA SW-846 Method 8515 to detect TNT in soil by a colorimetric screening method (USACE 2005; EPA 2006a, 2012b).

- The Expray test is a common simple colorimetric screening kit that can support qualitative tests for TNT in soils. It is also useful for screening surfaces (EPA 2005, 2006a, 2006b).
- Use of gold nanoparticles and Raman spectroscopy is an emerging method for ultra-sensitive and rapid TNT detection in the field (Lin et al. 2012; Yang et al. 2014; and Jamil et al. 2015).

What technologies are being used to treat TNT?

As described by Craig (2020), a review of 24 remediation projects at 22 facilities indicates that the most common treatment technologies for explosives in soil is composting (46.5%), followed by incineration (32.1%). Groundwater contamination has been primarily treated by groundwater extraction and ex situ granular activated carbon (GAC) treatment. Based on promising results in pilot-scale treatability studies, in situ bioremediation could be employed more frequently in the future (Craig 2020). It is important to consider co-contaminants, such as metals and perchlorate, when selecting a treatment technology (EPA 1993). Table 4 summarizes treatment technologies for TNT.

Table 4: Cleanup Technologies for TNT

Cleanup Technology	Water	Soil
Composting		✓
Incineration (emissions may require treatment)		✓
Alkaline hydrolysis		✓
Solidification/stabilization (metals co-contaminants)		✓
DARAMEND® process of biological and chemical reduction		✓
Granular activated carbon (ex situ)	✓	
Ion exchange (ex situ) (perchlorate co-contaminant)	✓	
In situ bioremediation	Potential	Potential

Where can I find more information about TNT?

General

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Health Effects

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Contact Information

If you have any questions or comments on this fact sheet, please contact FFRRO, at www.epa.gov/fedfac/forms/contact-us-about-federal-facility-cleanups.