Emerging Contaminants – Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)

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FACT SHEET

At a Glance

- Highly explosive, white crystalline 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.
- Not significantly retained by most soils and biodegrades very slowly under aerobic conditions. As a result, it can easily migrate to groundwater.
- 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 carcinogen).
- Can damage the nervous system if inhaled or ingested.
- EPA plans to update its toxicity benchmarks and health risk assessment.
- Three basic types of on-site analytical methods are widely used: colorimetric, immunoassay, and biosensor. The primary laboratory methods include liquid and gas chromatography.
- Treatment technologies include *in situ* chemical and biological remediation, composting, 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 the emerging contaminants Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), including its physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information.

RDX is a secondary explosive that is used extensively by the U.S. military in the manufacturing of explosives. With its manufacturing impurities and environmental transformation products, this compound accounts for a large part of the explosives contamination at active and former U.S. military installations (EPA 1999). This fact sheet is intended for use by site managers and field personnel who may address RDX contamination at cleanup sites or in drinking water supplies.

What is RDX?

- RDX, also known as Royal Demolition Explosive, cyclonite, hexogen, and T4, is a synthetic product that does not occur naturally in the environment and belongs to a class of compounds known as explosive nitramines (CREEL 2006; ATSDR 1995).
- It is a highly explosive, white crystalline solid (in its pure form) that is often mixed with other explosives, oils, or waxes to make military munitions and other products (DoD 2010).
- RDX is not produced commercially in the United States. Production in the United States is limited to Army ammunition plants. However, RDX is used both in military and commercial applications (ATSDR 1995).
- RDX is one of the most powerful high explosives available and was widely used during World War II. It is present in over 4,000 military items, from large bombs to very small igniters (DoD 2010).
- It is commonly used as an ingredient in plastic explosives and has been used as explosive "fill" in most types of munitions compounds. (MMR 2001; DoD 2010).
- Civilian applications of RDX include use in fireworks, demolition blocks, heating fuel for food rations, and as an occasional rodenticide (ATSDR 1995).

What is RDX? (continued)

- RDX can be used alone as a base charge for detonators or mixed with other explosives such as TNT to form Torpex, composition B, H6, and cyclotols, which produce a bursting charge for aerial bombs, mines, and torpedoes (1995a).
- RDX is commonly found at hand grenade ranges, antitank rocket ranges, bombing ranges, munitions testing sites, and open burn/open detonation (OB/OD) sites (CREEL 2006; CREEL 2007).

Exhibit 1: Physical and Chemical Properties of RDX
(Major et al. 2007; ATSDR 1995)

Property	Value
CAS Number	121-82-4
Physical Description (physical state at room temperature)	White Crystalline Solid
Molecular weight (g/mol)	222
Water solubility (mg/L at 20^{o}C)	42
Octanol-water partition coefficient (K_{ow})	0.87
Soil organic carbon-water coefficient (K_{oc})	1.80
Boiling point (^{o}C)	Decomposes
Melting point (^{o}C)	206
Vapor pressure at 25^{o}C (mm Hg)	4.0 x10^{-9}
Specific gravity	1.816
Henry's Law Constant at 25^{o}C (atm-m^3/mol)	1.96 x10^{-11}

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 mol

What are the environmental impacts of RDX?

- RDX can be released to the environment through spills, firing of munitions, disposal of ordnance, open incineration and detonation of ordnance, leaching from inadequately sealed impoundments, and demilitarization of munitions. The compounds can also be released from manufacturing and munitions processing facilities (ATSDR 1995).
- RDX has been identified in at least 16 of the 1,338 hazardous waste sites that have been proposed for inclusion on the National Priorities List (NPL) (1995a).
- In surface soils, RDX is biodegraded very slowly aerobically. It degrades most easily under anaerobic conditions (EPA 1999).
- Its biodegradation products include Hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine (MNX) Hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine (DNX) Hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX) (CREEL 2006; Army 2009).
- Low soil sorption coefficient (K_{OC}) values indicate that RDX is not significantly retained by most soils. However, the rate of migration depends on the soil composition with rapid migration occurring in finer-grained soils, whereas slow migration is noted in sandy soils (EPA 2005; ATSDR 1995a).
- RDX can migrate through the vadose zone and contaminate underlying groundwater aquifers, especially at source areas that have permeable soils, a shallow groundwater table, and abundant rainfall (CREEL 2006).
- RDX dissolves in and evaporates from water very slowly as evident by its low solubility in water (EPA 2005).
- Phototransformation of RDX in soil is not significant; however, it is the primary physical mechanism that degrades RDX in aqueous solutions. Consequently, RDX is not expected to persist for a long period of time in surface waters (CREEL 2006; ATSDR 1995).
- When released to the atmosphere, RDX is degraded by reacting with photochemically generated hydroxyl radicals. Photolysis of RDX is an important fate process in the atmosphere since RDX absorbs ultraviolet wavelengths between 240 and 350 nanometers (nm) (ATSDR 1995).
- Based on its low octanol-water partition coefficient (K_{OW}) and low experimental bioconcentration factor, RDX has a low bioconcentration potential in aquatic organisms (EPA 2005; ATSDR 1995).

What are the health effects of RDX?

- For the general population, exposure to RDX 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 RDX 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 RDX a weight-of-evidence carcinogenic classification of C (possible human carcinogen) (IRIS 1993; OSHA 2010).
- A Minimal Risk Level (MRL) of 0.06 mg/kg/day has been derived for acute-duration oral exposure (14 days or less) to RDX (ATSDR 1995).
- RDX targets the nervous system and can cause seizures in humans and animals when large amounts are inhaled or ingested. Human studies also revealed nausea and vomiting following inhalation or oral exposure to unknown levels of RDX. (ATSDR 1995; EPA 2005).
- EPA is looking to update its toxicity benchmarks and health risk assessment for RDX in its database of chemical risk values, the Integrated Risk Information System (IRIS) (DoD 2010).
- Limited information is available regarding respiratory, reproductive, cardiovascular, or dermal exposure in humans after any route or duration of exposure to RDX (ATSDR 1995).

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

- The EPA has established a lifetime Health Advisory guidance level of 2 parts per billion (ppb) for RDX in drinking water. The EPA has not established an ambient air level or a cleanup standard for RDX in soil (EPA 2009).
- EPA assigned RDX a reference dose (RfD) of 3 x 10^{-3} milligram per kilogram day (mg/kg-day) (IRIS 1993).
- RDX is on the EPA's Drinking Water Contaminant Candidate List (CCL) (DoD 2010).
- OSHA set a construction industry permissible exposure limit (PEL) of 1.5 mg/m^3 of workplace air (mg/m3) 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 RDX during an 8-hour workday, 40-hour workweek is 1.5 mg/m^3 (OSHA 2010).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has set a threshold limit value (TLV) is 0.5 mg/m^3 (OSHA 2010).
- Numerous states have established regulations on explosives for air quality control, solid waste disposal, storage, manufacture, and use. Massachusetts and Tennessee are developing new regulatory standards for RDX (DoD 2010).
- RDX is classified as a Class A explosive and domestic transportation is limited to road and water (ATSDR 1995).

What detection and site characterization methods are available for RDX?

- 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 RDX in soil. The method specifies using HLPC with a UV. It has been used to detect RDX 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 detection (EPA 2005).
- Specific field screening methods for RDX include SW4051 to detect RDX in soil by immunoassay and SW8510 to detect both RDX and HMX using a colorimetric screening procedure (USACE 2005; Army 2009).
- Colorimetric methods generally detect broad classes of compounds such as nitroaromatics or nitramines. As a result, these methods are able to detect the presence of the target analytes and also respond to many other similar compounds. Immunoassay methods are more compound specific (EPA 2005).
- Prototype biosensor methods for RDX have been field tested and are emerging methods for explosives analysis in water (EPA 1999).
- Tested field-screening instruments for RDX include FAST 2000, which uses antibodies and fluorescence, and GC-IONSCAN, which uses ion mobility spectrometry (IMS) (EPA 2000a, b).

What technologies are being used to treat RDX?

- Bioreactors, bioslurry treatments, and passive subsurface biobarriers have been proven successful in reducing RDX concentrations in soil (EPA 2005; CREEL 2006; ESTCP 2010).
- Composting has been proven in achieving cleanup goals for RDX at field demonstrations (EPA 2005).
- In situ chemical remediation can also be used to treat RDX. Fenton oxidation and treatment with iron metal (FeO) has been used to remediate RDX-contaminated soil and water (NCER 2010; EPA 2005).
- Other methods of treating waste waters contaminated with RDX include ultrafiltration, activated carbon, and resin adsorption (ATSDR 1995).

Where can I find more information about RDX?

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- EPA. 2000b. Office of Research and Development. Research International, Inc. FAST 2000. Environmental Technology Verification Report. EPA/600/R-00/045.
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Contact Information

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