Technical Fact Sheet – Tungsten

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TECHNICAL FACT SHEET– TUNGSTEN

At a Glance

- Hard, steel-gray to white solid.
- Highest melting point among metals and is a good conductor of electricity.
- Typically used in welding, oil-drilling, electrical and aerospace industries.
- Low solubility in water and high sorption (soil/water distribution) coefficients at low to neutral pH levels.
- Questions are being raised about tungsten's environmental stability.
- Exposure may cause eye and skin irritation, cough, nausea, diffuse interstitial pulmonary fibrosis and changes in blood.
- No federal drinking water standard established.
- Exposure limits set by the National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH).
- Treatment methods for tungsten in environmental media are currently under development. Methods under investigation include electrokinetic soil remediation and phytoremediation.

Introduction

This fact sheet, developed by the U. S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary for tungsten, 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 provides basic information on tungsten to site managers and other field personnel who may address tungsten contamination at cleanup sites.

Tungsten was originally considered a stable metal in soil that does not dissolve easily in water. However, tungsten-contaminated environmental media are now a growing concern to the EPA and the U.S. Department of Defense (DoD) because recent research indicates that tungsten may not be as stable as was indicated in earlier studies. Furthermore, varying soil properties such as pH may cause tungsten to dissolve and leach from soil into underlying aquifers (ATSDR 2005). Currently, little information is available about the fate and transport of tungsten in the environment and its effects on human health. Research about tungsten is ongoing and includes health effects and risks, degradation processes and an inventory of its use in the defense industry as a substitute for lead-based munitions.

What is tungsten?

- Tungsten (also known as Wolfram and represented by the letter W in the periodic table) is a naturally occurring element that exists in the form of minerals, but typically not as a pure metal (ATSDR 2005; NIOSH 2010).
- There are more than 20 known tungsten-bearing minerals. Wolframite ([FeMn]WO4) and Scheelite (CaWO4) are two common minerals that contain tungsten and that are mined commercially (ATSDR 2005; Koutsospyros and others 2006).
- Based on its purity, the color of tungsten may range from white for the pure metal to steel-gray for the metal with impurities. It is commercially available in a powdered or solid form (ATSDR 2005; NIEHS 2003; NIOSH 2010).
- The melting point of tungsten is the highest among metals and it resists corrosion. It is a good conductor of electricity and acts as a catalyst in chemical reactions (ATSDR 2005; Gbaruko and Igwe 2007; Koutsospyros and others 2006).

What is tungsten (continued)?

- Tungsten in the form of finely divided powder is highly flammable and may ignite spontaneously on contact with air. Powdered tungsten may also cause fire or explosion on contact with oxidants (HSDB 2009a; NIOSH 2010).
- Tungsten ore is used primarily to produce tungsten carbide and tungsten alloys, which are used in many general welding and metal-cutting applications, for operations within the aerospace industry and in sporting good products such as golf clubs. Tungsten metal is also used to produce lamp filaments, X-ray tubes, dyes and paints for fabrics (Koutsospyros and others 2006; NIEHS 2003).
- Tungsten/nylon "green" bullets were introduced as a replacement to lead bullets and other ammunition in the United States and other countries. DoD began using tungsten as a replacement for lead in bullets in 1999 for training. In early 2003, the production of tungsten/nylon bullets was discontinued based on flight instability issues (ATSDR 2005; USACE 2007).
- Recent reports of tungsten contamination in groundwater and soil at military sites have raised concerns about tungsten's stability in the environment and resulted in the suspension of tungsten/nylon bullets in some military applications. For example, the use of tungsten/nylon bullets at the Massachusetts Military Reservation was suspended in February 2006 based on concerns about tungsten's mobility in the environment (Kennedy and others 2012; USACE 2007).
- Under the U.S. Army's Green Ammunition program, at least 85 million rounds of tungsten/nylon bullets were produced. Currently, the Army Environmental Center evaluating the fate and transport properties of tungsten at training ranges (USACE 2007).

Exhibit 1: Physical and Chemical Properties of Elemental Tungsten
(ATSDR 2005; HSDB 2009a; NIEHS 2003; NIOSH 2010)

Property	Value
Chemical Abstracts Service (CAS) Number	7440-33-7
Physical Description (physical state at room temperature)	Hard, steel-gray to tin-white solid
Molecular weight (g/mol)	183.85
Water solubility	Insoluble
Boiling point (^oC at 760 mm Hg)	5,900
Melting point (^oC)	3,410
Vapor pressure at 2,327^oC (mm Hg)	1.97×10^{-7}
Specific gravity/Density at 20/4 ^oC	18.7 to 19.3

Abbreviations: g/mol – grams per mole; ^oC – degrees Celsius; mm Hg – millimeters of mercury.

What are the environmental impacts of tungsten?

- Tungsten is a common contaminant at mining sites, industrial sites that use the metal and at DoD sites involved in the manufacture, storage and use of tungsten-based ammunition. It is also found in detectable amounts in municipal solid waste and landfill leachate because of its use in common household products such as filaments in incandescent light bulbs (Koutsospyros and others 2006).
- Tungsten particles may be present in the environment as a result of mining, weathering of rocks, burning of coal and municipal solid waste, land application of fertilizers or industrial applications that involve tungsten (ATSDR 2005).
- In the ambient atmosphere, tungsten compounds exist in the particulate phase because of their low vapor pressures. These particles may settle on soil, water or other surfaces and can be deposited through rain or other forms of precipitation (ATSDR 2005; NIEHS 2003).
- Tungsten is considered a "lithophilic" element (preferring terrestrial over atmospheric or aquatic environments) based on its low vapor pressure and atmospheric interference factor. Tungsten compounds are expected to exist as ions or insoluble solids in the environment; therefore, volatilization from soil surfaces is not considered an important fate and transport process (Koutsospyros and others 2006; NIEHS 2003).
- The sorption coefficients for tungsten increase as pH decreases, indicating low to moderate mobility of tungsten in soil under low to neutral environmental conditions. Sorption coefficients for the tungstate ion range from 100 to 50,000 at about pH 5, 10 to 6,000 at about pH 6.5 and 5 to 90 at pH 8 to 9 (Meijer and others 1998).

What are the environmental impacts of tungsten? (continued)

- Studies indicate that an elevated pH in soil may increase the solubility of tungsten by decreasing its sorption coefficient, which may cause it to leach more readily into the groundwater table (ATSDR 2005; ASTSWMO 2011).
- Increased acidification and oxygen depletion of soils from dissolution of tungsten powder have been shown to trigger changes in the soil microbial community, causing an increase in fungal biomass and a decrease in the bacterial component (Dermatas and others 2004; Strigul and others 2005). In water, tungsten compounds are expected to adsorb to suspended solids and sediment based on their sorption coefficients (HSDB 2009b).
- In 2006, the assumed stability of tungsten in the environment was questioned when tungsten was detected in groundwater and in soil above baseline levels at a small arms range at the Massachusetts Military Reservation, where tungsten/nylon bullets were being used. The use of these bullets was then suspended in Massachusetts per a Governor's Office Cease and Desist Order (ASTSWMO 2011; EPA Region 1 2013; USACE 2007).
- Studies suggest that the tungsten powder used in the Army's tungsten/nylon bullets forms oxide coatings on the bullets that are soluble in water (Dermatas and others 2004; USACE 2007).
- Tungsten has been shown to accumulate in plants in substantial amounts. The extent of accumulation appears to be related to the tungsten content in soil and varies widely, depending on the plant genotype (Koutsospyros and others 2006).
- Results from an aged soil bioassay indicated that sodium tungstate-spiked soil impaired cabbage growth (Kennedy and others 2012).
- As of 2005, tungsten had been identified at more than six sites on the EPA National Priorities List (NPL) (HazDat 2005).

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

- Toxicological information on tungsten and its compounds is limited (Koutsospyros and others 2006).
- Occupational exposure is considered the most common scenario for human exposure to tungsten and its compounds. Inhalation, ingestion and dermal and eye contact are the possible exposure pathways (ATSDR 2005).
- Occupational exposure to tungsten is known to affect the eyes, skin, respiratory system and blood. Tungsten may cause irritation to eyes and skin; diffuse interstitial pulmonary fibrosis; loss of appetite; nausea; cough; and changes in the blood (Gbaruko and Igwe 2007; NIOSH 2010).
- Studies on female rats have shown that oral exposure to tungsten caused post-implantation deaths and developmental abnormalities in the musculoskeletal system. Exposure of pregnant rats to sodium tungstate resulted in fetal death (NIEHS 2003).
- Studies on rats also found that tungsten primarily accumulated in bones and in the spleen after oral exposure (NIEHS 2003).
- Tungsten has not been classified for carcinogenic effects by the Department of Health and Human Services, the International Agency for Research on Cancer or the EPA.
- The EPA's Toxic Substances Control Act (TSCA) Interagency Testing Committee has included tungsten compounds in the Priority Testing List, which is a list of chemicals regulated by TSCA for which there are suspicions of toxicity or exposure and for which there are few, if any, ecological effects, environmental fate or health effects testing data (EPA 2006).

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

- A federal drinking water standard has not been established for tungsten. In addition, the EPA has not derived a chronic inhalation reference concentration (RfC) or a chronic oral reference dose (RfD) for tungsten or tungsten compounds (EPA 2013).
- The American Council of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value of 5 milligrams per cubic meter (mg/m^3) as the time-weighted average (TWA) over an 8-hour work exposure and 10 mg/m^3 as the 15-minute short-term exposure limit (STEL) for airborne exposure to tungsten metal and for insoluble tungsten compounds (ACGIH 2008).

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

- Tungsten and related compounds were included as part of EPA's 2012 Integrated Risk Information System (IRIS) agenda. The current projected start date for conducting the literature search for the chemical is fiscal year 2014 (EPA 2012).
- The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit of 5 mg/m^3 as the time-weighted average (TWA) over a 10-hour work exposure and 10 mg/m^3 as the 15-minute short-term exposure limit (STEL) for airborne exposure to tungsten and insoluble tungsten compounds (NIOSH 2010).
- The Occupational Safety and Health Administration (OSHA) recommends a permissible exposure limit of 5 mg/m^3 for insoluble compounds of tungsten and a PEL of 1 mg/m^3 limit for soluble compounds in the construction and shipyard industries as a TWA over an 8-hour work exposure. OSHA also established a PEL of 10 mg/m^3 as the 15-minute STEL for airborne exposure to insoluble compounds of tungsten and 3 mg/m^3 as the 15-minute STEL for airborne exposure to soluble tungsten compounds (OSHA 2013).

What detection and site characterization methods are available for tungsten?

- Tungsten is commonly deposited in the environment as discrete particles with strongly heterogeneous spatial distributions. Unless precautions are taken, this distribution causes highly variable soil data that can lead to confusing or contradictory conclusions about the location and degree of contamination. 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 2003).
- NIOSH Method 7074 uses flame atomic absorption to detect tungsten in air. It has a detection limit of 0.125 mg/m^3 for insoluble forms of tungsten and 0.05 mg/m^3 for soluble forms of tungsten (NIOSH 1994).
- Other NIOSH methods for the detection of tungsten in air are Methods 7300 and 7301, involving inductively coupled argon plasma-atomic emission spectroscopy. The working range for these methods is 0.005 to 2.0 mg/m^3 for each element in a 500-liter sample. Special sample treatment may be required for some tungsten compounds (NIOSH 2003a, b).
- OSHA Method ID-213 is also used for the detection of tungsten in air. The method uses inductively coupled plasma (ICP)-atomic emission spectroscopy (AES) and has a quantitative detection limit of 0.34 mg/m^3 (OSHA 2013).
- Tungsten in soil and water can be measured using the ICP-AES, ICP-mass spectrometry (ICP-MS) and ultraviolet/visible spectroscopy (UV/VIS) methods (ATSDR 2005).
- Tungsten is not currently included on the list of analytes under EPA SW-846 Methods 6010, ICP-AES, and 6020, ICP-MS; however, these methods may be modified for the detection of tungsten in soil and water (ASTSWMO 2011; EPA 2007b, c).
- Tungsten is also not currently included on the list of recoverable metals using SW-846 Method 3051A, a microwave-assisted acid digestion method. Therefore, the digestion method is being modified to enhance tungsten recovery from soils (EPA 2007a; Griggs and others 2009).
- Trace concentrations of tungsten in water and air can also be estimated by instrumental neutron activation analysis (Gbaruko and Igwe 2007; NIEHS 2003).

What technologies are being used to treat tungsten?

- Treatment technologies to address tungsten contamination in environmental media are currently under development.
- Preliminary studies indicate that phytoremediation may be a potential treatment method for tungsten contaminated sites based on the reported accumulation of tungsten in plant tissue (Strigul and others 2005; Tuna and others 2012).
- Electrokinetic soil remediation is an emerging in situ technology for removal of tungsten from low-permeability soils in the presence of heavy metals such as copper and lead. A direct current is applied to contaminated soils using electrodes inserted into the ground (Braida and others 2007).

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

- Studies have reported the efficient removal (98 to 99 percent) of tungsten from industrial wastewater by precipitation, coagulation and flocculation processes using ferric chloride under acidic conditions (pH below 6) (Plattes and others 2007).
- A recent study demonstrated the efficient recovery of tungsten (over 90 percent) in aqueous solutions using a water-soluble polymer (polyquaternium-6) for complexing anion forms of tungsten prior to ultrafiltration (Zeng and others 2012).

Where can I find more information about tungsten?

- Agency for Toxic Substances and Disease Registry (ATSDR). 2005. “Toxicological Profile for Tungsten.” www.atsdr.cdc.gov/toxprofiles/tp186.pdf
- American Conference of Governmental Industrial Hygienists (ACGIH). 2008. Tungsten. “Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.” Cincinnati, Ohio.
- Association of State and Territorial Solid Waste Management Officials (ASTSWMO). 2011. “Tungsten Issues Paper.” www.astswmo.org/Files/Policies_and_Publications/Federal_Facilities/2011-02_FINAL_Tungsten_Issues_2-0.pdf
- Braida, W., Christodoulatos, C., Ogundipe, A., Dermatas, D., and G. O’Connor. 2007. “Electrokinetic Treatment of Firing Ranges Containing Tungsten-Contaminated Soils.” Journal of Hazardous Materials. Volume 149. Pages 562 to 567.
- Dermatas, D., Braida, W., Christodoulatos, C., Strigul, N., Panikov, N., Los, M., and S. Larson. 2004. “Solubility, Sorption, and Soil Respiration Effects of Tungsten and Tungsten Alloys.” Environmental Forensic. Volume 5. Pages 5 to 13.
- Gbaruko, B.C. and J.C. Igwe. 2007. “Tungsten: Occurrence, Chemistry, Environmental and Health Exposure Issues.” Global Journal of Environmental Research. Volume 1 (1). Pages 27 to 32.
- Griggs C., Larson, S., Nestler, C., and M. Thompson. 2009. “Coupling of Oxygen and pH Requirements for Effective Microwave-Assisted Digestion of Soils for Tungsten Analysis.” Land Contamination & Reclamation. Volume 17. Pages 121 to 128.
- Hazardous Substances Data Bank (HSDB). 2009a. Elemental Tungsten. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
- HSDB. 2009b. Tungsten Compounds. http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
- HazDat. 2005. HazDat Database: ATSDR’s Hazardous Substance Release and Health Effects Database. Atlanta, GA.
- Kennedy, A.J., Johnson, D.R., Seiter, J.M, Lindsay, J.H., Boyd, R.E., Bednar, A.J., and P.G. Allison. 2012. “Tungsten Toxicity, Bioaccumulation, and Compartmentalization into Organisms Representing Two Trophic Levels.” Environmental Science and Technology. Volume 46 (17). Pages 9646 to 9652.
- Koutsospyros, A., Braida, W., Christodoulatos, C., Dermatas, D., and N. Strigul. 2006. “A Review of Tungsten: From Environmental Obscurity to Scrutiny.” Journal of Hazardous Materials*.* Volume 136. Pages 1 to 19.
- Meijer, A., Wroblicky, G., Thuring, S., and M.W. Marcell. 1998. “Environmental Effects of Tungsten and Tantalum Alloys.” Elgin Air Force Base, Florida: Air Force Research Laboratory. AFRL-MN-EG-TR-2000-7017.
- National Institute of Environmental Health Sciences (NIEHS). 2003. “Tungsten and Selected Tungsten Compounds – Review of Toxicological Literature.” http://ntp.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/tungsten_508.pdf
- National Institute for Occupational Safety and Health (NIOSH). 1994. “Tungsten (Soluble and Insoluble) – Method 7074.” NIOSH Manual of Analytical Methods (NMAM), Fourth Edition. www.cdc.gov/niosh/docs/2003-154/pdfs/7074.pdf
- NIOSH. 2003a. “Elements by ICP (Nitric/Perchloric Acid Ashing) – Method 7300.” NIOSH Manual of Analytical Methods (NMAM), Fourth Edition. www.cdc.gov/niosh/docs/2003-154/pdfs/7300.pdf
- NIOSH. 2003b. “Elements by ICP (Aqua Regia Ashing) – Method 7301.” NIOSH Manual of Analytical Methods (NMAM), Fourth Edition. www.cdc.gov/niosh/docs/2003-154/pdfs/7301.pdf
- NIOSH. 2010. NIOSH Pocket Guide to Chemical Hazards: Tungsten. www.cdc.gov/niosh/npg/npgd0645.html

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

- Occupational Safety and Health Administration (OSHA). 2013. "Tungsten and Cobalt in Workplace Atmospheres (ICP Analysis)." www.osha.gov/dts/sltc/methods/inorganic/id213/id213.html
- Plattes, M., Bertrand, A., Schmitt, B., Sinner, J., Verstraeten, F., and J. Welfring. 2007. "Removal of Tungsten Oxyanions from Industrial Wastewater by Precipitation, Coagulation and Flocculation Processes." Journal of Hazardous Materials. Volume 148 (3). Pages 613 to 615.
- Strigul, N., Koutsospyros, A., Arienti, P., Christodoulatos, C., Dermatas, D., and W. Braida. 2005. "Effects of Tungsten on Environmental Systems." Chemosphere. Volume 61. Pages 248 to 258.
- Tuna, G.S., Braida, W., Ogundipe, A., and D. Strickland. 2012. "Assessing Tungsten Transport in the Vadose Zone: From Dissolution Studies to Soil Columns." Chemosphere. Volume 86 (12). Pages 1001 to 1007.
- U.S. Army Corps of Engineers (USACE). 2007. "Fate and Transport of Tungsten at Camp Edwards Small Arms Ranges." ERDC TR-07-5. www.crrel.usace.army.mil/library/technicalreports/TR-07-5.pdf
- U. S. Environmental Protection Agency (EPA). 2003. "Guidance for Obtaining Representative Laboratory Analytical Subsamples from Particulate Laboratory Samples." EPA/600/R-03/027.
- EPA. 2006. "Fifty-Eighth Report of the TSCA Interagency Testing Committee to the Administrator of the Environmental Protection Agency; Receipt of Report and Request for Comments; Notice." Federal Register. Volume 71 (132). Page 39187.
- EPA. 2007a. "Method 3051A. Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils." SW-846 On-line. www.epa.gov/osw/hazard/testmethods/sw846/pdfs/3051a.pdf
- EPA. 2007b. "Method 6010C. Inductively Coupled Plasma-Atomic Emission Spectrometry." SW-846 On-line. www.epa.gov/osw/hazard/testmethods/sw846/pdfs/6010c.pdf
- EPA. 2007c. "Method 6020A: Inductively Coupled Plasma-Mass Spectrometry." SW-846 On-line. www.epa.gov/osw/hazard/testmethods/sw846/pdfs/6020a.pdf
- EPA. 2012. Integrated Risk Information System (IRIS); Announcement of 2012 Program. Federal Register. Volume 77 (88). Pages 26751 to 26755. www.gpo.gov/fdsys/pkg/FR-2012-05-07/html/2012-10935.htm
- EPA. 2013. Drinking Water Contaminants. water.epa.gov/drink/contaminants/index.cfm#List
- EPA. Region 1. 2013. Massachusetts Military Reservation. www.epa.gov/region01/mmr/.
- Zeng, J., Sun, X., Zheng, L, He, Q. and S. Li. 2012. "Recovery of Tungsten (VI) from Aqueous Solutions by Complexation-Ultrafiltration Process with the Help of Polyquaternium." Chinese Journal of Chemical Engineering. Volume 20 (5). Pages 831 to 836.

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, by phone at (703) 603-8712 or by email at cooke.maryt@epa.gov.