Technical Fact Sheet – Tungsten

November 2017

At a Glance

- Tungsten is a naturally occurring element that exists in the form of minerals, but typically not as a pure metal.
- Typically used in welding, oil-drilling, electrical and aerospace industries.
- Introduced in the mid-1990s as a replacement for lead ammunitions.
- Under certain conditions, tungsten dissolves in water and is mobile in the environment, but little is known about its fate and transport in the environment.
- In 2002, elevated tungsten concentrations were found in drinking water and investigated for carcinogenic effects. No direct link was found, but tungsten was nominated for study under the National Toxicity Program.
- No federal drinking water standard established.
- 2017 EPA regional screening levels include soil and tapwater screening values for tungsten.
- 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.

Historically, tungsten was thought to be insoluble and have little or no mobility in the environment. However, the presence of tungsten in groundwater near background sources and anthropogenic sources suggests that under certain conditions, tungsten dissolves in water and is mobile in the environment. Currently, limited 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 historic use in the defense industry as a substitute for lead-based munitions.

What is tungsten?

- Tungsten is a naturally occurring element that exists in the form of minerals, but typically not as a pure metal (ATSDR 2005).
- The color of tungsten may range from white for the pure metal to steel-gray for the metal with impurities (NIOSH 2016).
- There are more than 20 known tungsten-bearing minerals (ATSDR 2005). Wolframite ([FeMn]WO4) and Scheelite (CaWO4) are two common, commercially-mined minerals that contain tungsten (ATSDR 2005; Koutsospyros and others 2006).
- Natural tungsten is composed of five stable isotopes. There are 28 artificial radioactive isotopes, which have short half-lives ranging from less than a second to 121 days (ATSDR 2005; Audi and others 2003).
- The most common formal oxidation state of tungsten is +6, but it exhibits all oxidation states from -2 to +6 (Lemus and Venezia 2015).
- The melting point of tungsten is the highest among metals. It is resistant to corrosion, is a good conductor of electricity and acts as a catalyst in chemical reactions (ATSDR 2005; Gbaruko and Igwe 2007).

- 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 2009; NIOSH 2016).

Exhibit 1: Physical and Chemical Properties of Elemental Tungsten
(ATSDR 2005; NIEHS 2003; NIOSH 2016)

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 (°C at 760 mm Hg)	5,900
Melting point (°C)	3,410
Vapor pressure at 2,327°C (mm Hg)	1.97×10^{-7}
Specific gravity/Density at 20°F /4°C	18.7 to 19.3

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

Existence of tungsten in the environment

- Tungsten-based products have been used in a wide range of applications ranging from common household products to highly specialized components of science and technology (Koutsospyros and others 2006).
- Tungsten/nylon "green" bullets were introduced as a replacement to lead bullets and other ammunition in the United States in the 1990s. In early 2003, the production of tungsten/nylon bullets was discontinued based on flight instability issues (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 (Kennedy and others 2012; USACE 2007).
- Tungsten 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 (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 mobilized through rain or other forms of precipitation (ATSDR 2005; NIEHS 2003).
- Principal transport and transformation mechanisms include deposition (wet and dry), advective transport, colloidal transport, chemical precipitation, oxidation/reduction, dissolution, complexation, adsorption and anion exchange (Koutsospyros and others 2006).
- Studies indicate that an elevated pH in soil may increase the solubility of tungsten and cause it to leach more readily into the groundwater table (ASTSWMO 2011).
- Laboratory studies found that the dissolution of tungsten into tungstate ions was accompanied by significant reductions in pH and dissolved oxygen concentrations (ASTSWMO 2011).
- Studies found large amounts of dissolved tungsten when tungsten powder or alloy pieces were exposed to aqueous solutions. Additionally, tungsten appears to undergo strong uptake by clay minerals and organic soils (Dermatas and others 2004).
- 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).
- Water soluble tungsten substances include sodium tungstate, ammonium metatungstate, sodium metatungstate and ammonium paratungstate. Insoluble tungsten substances include tungsten metal, tungsten carbide, ditungsten carbide, tungsten trioxide, tungsten oxides and tungsten disulfide (Lemus and Venezia 2015).
- Studies suggest that the tungsten powder used in the Army's tungsten/nylon bullets forms oxide coatings that dissolve in water and may be mobile under some environmental conditions. (Kennedy and others 2012; USACE 2007).
- Plants are known to take up and accumulate tungsten in substantial amounts and plant toxicity has been reported in the literature (Koutsospyros

and others 2006; Kennedy and others 2012; Adamakis and others 2008).

- Tungsten anions polymerize in environmental systems and under physiological conditions in living organisms. These reactions result in the development of several types of polyoxoanions that differ from monotungstates in certain chemical properties (Strigul 2010).
- Recent studies indicate that tungsten speciation may be important to ecotoxicology. Polytungstates develop and persist in environmental systems and are much more toxic than monotungstates. For example, sodium metatungstate, a polytungstate, is significantly more toxic to fish than sodium tungstate, a monotungstate (Strigul 2010).
- As of 2016, tungsten has been identified at one site on the EPA National Priorities List (NPL) (EPA 2016a).

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

- Tungsten bioaccumulates in the liver of mammals (Kennedy and others 2012).
- Recent studies found evidence for bioaccumulation of tungsten in plants from soil, implying the potential for trophic transfer into the terrestrial food web (Kennedy and others 2012).
- Results from a bioaccumulation study conducted using cabbage and snails showed tungsten compartmentalized first in the hepatopancreas, following by the body and foot. The results also suggested snails consuming contaminated cabbage accumulated higher tungsten concentrations relative to the concentrations directly bioaccumulated from dermal exposure to soil (Kennedy and others 2012).
- A study conducted using male mice exposure to sodium tungstate in tapwater reported dose-dependent increases in tungsten concentration in bone and bone marrow (ATSDR 2015).
- Studies on mice have shown that exposure to sodium tungstate resulted in effects on the immune system and tungsten-related immune suppression (ATSDR 2015).
- Studies on female rats have shown that exposure to tungsten caused post-implantation deaths and developmental abnormalities in the musculoskeletal system (NIEHS 2003); pre and postnatal exposure to sodium tungstate may produce subtle neurobehavioral effects related to motor activity and emotionality in offspring (McInturf and others 2011); and tungsten primarily accumulated in bones and in the spleen after oral exposure (NIEHS 2003).
- Exposure to tungsten in large amounts may cause breathing problems and changes in behavior (ATSDR 2005, 2015; Lemus and Venezia 2015).
- Symptoms of tungsten exposure can include irritation of the eyes, skin and respiratory system, diffuse pulmonary fibrosis, loss of appetite, nausea, cough and blood changes (NIOSH 2016).
- 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).
- The occurrence of a cluster of childhood leukemia cases in Fallon, Nevada prompted a wide investigation that included several local, state and federal agencies led by the Centers for Disease Control and Prevention (CDC). Groundwater was a source of drinking water and was found to have naturally elevated tungsten concentrations. Although no direct link was found, in 2002, tungsten was nominated for study under the National Toxicology Program (NIEHS 2003). In 2011 it was nominated for human health risk assessment under the EPA's Integrated Risk Information System (IRIS) agenda (EPA 2016b).
- In 2005, the ATDSR issued its toxicological profile for tungsten, identifying several data gaps in toxicity and exposure pathways. In 2015, ATSDR published an addendum to the toxicological profile for tungsten (ATSDR 2015). Additional laboratory studies were described for tungsten and its related substances in the addendum, but the conclusion did not change from 2005 to 2015. Available data are insufficient for derivation of a Minimum Risk Level (ATSDR 2015).

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, EPA has not derived a chronic inhalation reference concentration (RfC) or a chronic oral reference dose (RfD) for tungsten or tungsten compounds (EPA 2016c, d).
- EPA's regional screening levels include soil and tapwater screening values for tungsten due to Provisional Peer Reviewed Toxicity Values for Superfund (EPA 2017).
- Three states have standards for tungsten. Indiana is the only state that has soil and groundwater screening levels (IDEM 2016). North Carolina has preliminary soil remediation goals for tungsten (NCDEQ 2016). Texas has soil and groundwater protective concentration levels for sodium tungstate dihydride (TCEQ 2016).

What detection and site characterization methods are available for tungsten?

- Tungsten analysis is still in the development and optimization stage. For screening purposes, x-ray fluorescence seems to be the most common type of equipment used (ASTSWMO 2011).
- NIOSH Method 7074 is the preferred method for analysis (ASTSWMO 2011). It uses flame atomic absorption to detect tungsten in air. It has a detection limit of 0.25 mg (milligrams) for insoluble forms of tungsten and 0.1 mg 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 air 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 1994).
- Tungsten in soil and water can be measured using the ICP-AES, ICP-mass spectrometry (ICP-MS), neutron activation analysis (NAA), ultraviolet/visible spectroscopy (UV/VIS) methods (ATSDR 2005). EPA SW-846 Methods 6010 and 6020 may be modified for the detection of tungsten in soil and water (ASTSWMO 2011).
- The microwave-assisted acid digestion SW-846 Method 3051A can be modified to enhance tungsten recovery from soils (Griggs and others 2009).
- Tungstate can be measured and mapped in waters, soils and sediments using the low-disturbance diffusive gradient in thin-films passive sampling technique (Guan and others 2016).

What technologies are being used to treat tungsten?

- 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; Erdemir and others 2016).
- 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).
- 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 reported 98 percent removal of tungsten from industrial wastewater using acid- and heat-treated sepiolite (Wang and others 2015).
- 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?

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

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