Residents of Churchill, Lyon, Nye, and Pershing Counties recently learned that samples of their urine and blood contained levels of tungsten that were significantly higher than those normally observed elsewhere in the United States. Groundwater samples were also shown to contain high levels of this metal. This fact sheet presents information about tungsten, including a brief history of the element and its uses, potential sources in the environment, summary of experiments conducted to determine toxic effects, and interpretation of results of such research with respect to groundwater sampling results completed in Churchill County, Nevada.

IMPORTANCE IN NEVADA
A study conducted by the Centers for Disease Control in Churchill County found that local residents had an exposure to tungsten through drinking water far in excess of the national average. The finding caused concern about tungsten and about potential health effects associated with exposure through drinking water. EPA currently has no drinking water standard for tungsten and research on the possible toxicologic effects of tungsten in humans is very limited. Further studies are being carried out to assess exposure to tungsten in Nevada.

TUNGSTEN ORE AND USES
Tungsten along with molybdenum and chromium make up section VI of the periodic table and share many of the same chemical characteristics. Tungsten is a comparatively rare metal, being the 54th most abundant element in the earth’s crust (3). In its pure state, it is heavy with a silver grey color that has the highest melting point of all of the metals (about 6,200° F) (5), (10). It is 70% heavier than lead and about the same weight as gold. Many tungsten minerals glow under ultraviolet light. For example, scheelite (calcium tungstate) glows light blue when pure and the color changes to bright yellow or orange when molybdenum or thorium are present in the ore. In the natural environment, tungsten is most commonly found in the minerals scheelite, wolframite (iron manganese tungstate), ferberite (iron tungstate), and huebnerite (manganese tungstate) (5), (6).

The most common use for tungsten around the home is as incandescent light bulb filaments. It has recently found use as a nontoxic alternative to lead shot for waterfowl hunting and is being used to some extent as a substitute for lead in fishing weights because it is considered by the US Fish and Wildlife Service to be a nontoxic metal (7). Tungsten is also alloyed with nickel and cobalt to make hard steel alloys for metal cutting tools and balls for ballpoint pens.

Tungsten carbide is the most commonly encountered tungsten compound around the home. It is used extensively as a (continued inside)
surface coating in carbide saw blades and drill bits. Industrial uses for tungsten carbide include hard metal facing for excavation equipment, welding electrodes, and drill bits used in petroleum exploration and mining (11). In its crystalline form, it is just slightly less hard than diamonds. However, it is much more economical to use. When used as a coating on saw blades, dies, and drill bits it greatly prolongs the life of the tool because its hardness allows for working edges to remain sharp for a longer period of time. It is also used in a powdered form as an abrasive for metal and stone polishing (6).

HISTORY
Tungsten has an interesting early history. In the 1600’s, miners in what is now Austria and Germany were interested in producing bronze, an alloy of copper and tin. In order to get the tin necessary for their endeavors, they mined and smelted cassiterite, or tin dioxide. In the same deposits, however, there was also an unknown tungsten mineral that interfered with the smelting process by not allowing the tin to separate from the melt. The miners referred to this mineral in German as “wolf rahm” or wolf froth, as they believed that the mineral ate tin “like a wolf eats sheep.” (11). To this day tungsten is still known as wolfram in Germany, Austria, and Eastern Europe. The atomic symbol “W” reflects the first observations of how the metal reacted in the smelting process. In 1758, the same mineral was given the Swedish name “tungsten” or heavy stone (5). In 1781, two Swedish chemists produced tungstic acid from the ore and developed the first tungsten compounds. Two years later the Spanish d’Elhuyar brothers produced the first tungsten metal from the ore using charcoal to reduce the tungstic acid.

The commercial market for tungsten was limited until 1927, when it was discovered that tungsten could be alloyed with iron to produce high quality tool steels for metal working (11). In 1904, the first light bulb was produced using a tungsten filament in the place of carbon filaments. The new light bulbs using tungsten were seven times more energy efficient than the carbon filament light bulbs they replaced, and had a longer working life. By 1911 tungsten had completely replaced carbon for use as light bulb filaments.

TUNGSTEN MINING AND Smelting IN NEVADA
Most of the tungsten mines in Nevada have ceased production due to economic constraints. However, tungsten mines were once very active. One of the first commercial tungsten operations in the state was the Silver Dyke Mine west of Mina in the Excelsior Mountains. Prospectors looking for silver accidentally discovered a scheelite deposit. The Silver Dyke Mine was opened in 1916 to take advantage of high tungsten prices brought on by the demand for tool steel during World War I. The mining operation supported a 60-ton per day mill that produced a 66% tungsten oxide concentrate (14). The mill, owned by the Nevada-Massachusetts Corporation, also acted as a custom mill for other mines in the Excelsior and Pilot Mountains. The Nevada-Massachusetts Corporation also operated the Springer and Emerson Mines and an associated mill in Pershing County.
Union Carbide operated the Tempiute mine and mill in Lincoln County until the early 1960's. In addition, the Kennametal Corporation constructed the Nevada Scheelite Mine and mill east of Fallon in the 1950's. Other tungsten mines and mills operated at Tungsten Mountain in the Clan Alpine Mountains east of Fallon, Toulon, and the Victory Mine near Gabbs. Due to the low current price of tungsten concentrates, most if not all, of the tungsten mines in Nevada are inactive.

**TUNGSTEN IN THE ENVIRONMENT**

Most tungsten deposits are formed when hot geothermal fluids rising toward the surface cool and react with the surrounding rock. As the temperature of the geothermal fluids drops, tungsten dissolved in the water combines with calcium, iron or manganese present in the host rock and drops out of solution to form scheelite, wolframite, or other minerals. Since scheelite and wolframite are brittle minerals when they are exposed to erosional forces, they tend to produce fine-grained sediments that can be transported long distances by wind and flowing water. If the scheelite is ultimately transported to an alkaline desert playa, it will quickly dissolve to form tungstate. Formations that have high concentrations of tungsten may also have high concentrations of molybdenum, vanadium, uranium, and tin.

**TUNGSTEN IN WATER**

Tap water samples collected in a recent sampling survey in Churchill County had concentrations ranging from less than the detection limit of the instruments used for analysis to 810 parts per billion (ppb). Tungsten contained in scheelite is highly soluble in natural alkaline waters that contain significant amounts of carbonate (soda) such as those found in desert lakes and playas. It occurs naturally in hot springs and other geothermal sources at levels up to 240 ppb. Another natural source of tungsten is the brines and muds from desert playas in areas with significant geothermal activity. Brines produced from Searles Lake, located just southwest of Death Valley, contain up to 65 parts per million (ppm) tungsten.

In alkaline environments with high levels of carbonates dissolved in water, tungsten (like molybdenum, vanadium, and uranium) can form soluble compounds, in a process that is driven by the alkalinity and oxidation potential of the water. These metals can also be precipitated from water by changes in alkalinity or oxygen content. Tungsten in the form of tungstate can naturally be removed from ground and surface waters by coprecipitation with iron or by absorption by carbonaceous (plant) materials.

A study of the Truckee, Walker, and Carson Rivers to determine natural concentration of several elements including tungsten, showed that concentration increases as the rivers pick up tungsten from natural deposits and from geothermal areas. In all three rivers tungsten levels were low near the rivers’ sources and increased downstream as tungsten was added by erosion of naturally occurring deposits and from geothermal activity. In the Truckee River system, Steamboat Creek is a significant source of tungsten for the main stream. Most of the tungsten load in Steamboat Creek originates in the Steamboat geothermal area south of Reno. In the Walker River system, the major source of tungsten appears to be flows from the East Walker River. The East Walker River drains an area that includes the Pine Grove, Aurora and Lucky Boy mining districts in Nevada, as well as the Bridgeport Valley in California, a major geothermal area. Tungsten is added to the Carson River system from mineralized areas east of Carson City and north of Gardnerville and from geothermal sources in the lower basin. The Carson River system has the highest tungsten levels of the three rivers studied, followed by the Walker River system. As the rivers flow farther down into the Great Basin, evaporation further concentrates the tungsten.

**HEALTH EFFECTS OF EXPOSURE TO TUNGSTEN**

Minimal strong scientific evidence exists on the metabolism of tungsten in humans. Tungsten primarily enters the body through the ingestion of food and water. Tungsten is primarily removed from the body through urine, with some being removed in the feces. Very little research has been conducted to determine if tungsten causes cancer in lab animals or humans. Lab animals that were exposed to very high levels of tungsten and cobalt metal dusts showed some early signs of lung cancer. Studies in industrial settings have not linked tungsten with cancer. One study, however, indicated a link between workplace exposure to dusts containing cobalt and tungsten and lung cancer.
Tungsten

According to information currently available from the Centers for Disease Control and Prevention (February, 2003) tungsten has not been tested for reproductive or developmental effects. No studies have been conducted of exposure to tungsten by the general public in non-industrial settings that revealed negative health effects (12).

In studies conducted in the mid 1960's, rabbits were fed varying levels of sodium tungstate to determine the lowest concentrations that produced any acute toxic effects. As a result of this study, it was found that rabbits that consumed 1241 milligrams sodium tungstate per kilogram of body weight displayed an inhibition of cholinesterase and phosphatase enzymes. To compare this with domestic water consumption in Churchill County, it would be necessary for a 132-pound adult to consume 15,600 gallons of water in a few days or less containing 80 ppb tungsten to receive an equivalent dose. It should be noted that the vast majority of wells in Churchill County contain tungsten at levels lower than the example above.

If present in mammals at extremely high levels, soluble tungsten can substitute for molybdenum on molybdenum specific enzymes (1), (15). This can result in the enzyme being deactivated or having highly reduced activity. In humans a major function of molybdenum enzymes is to oxidize sulphite, produced by the body's consumption of cysteine, to sulphate. At high levels sulphite can damage the nervous system. It should be noted that the concentration of tungsten necessary to deactivate the molybdenum enzymes is far in excess of those found in the domestic wells in Churchill County. In a scientific study conducted on rats in the 1950's, a dietary concentration of 94-ppm soluble tungsten did not reduce their rate of weight gain. Rats fed a diet containing 2,000-ppm sodium tungstate had a pronounced weight loss and rats that were fed a diet containing 9,000-ppm sodium tungstate died from the exposure (8). More recent research has investigated the short-term effects of injecting relatively large amounts of tungsten in the form of sodium tungstate.

In 2001, a team from the University of Barcelona published the results of a study in which Zucker diabetic fatty rats were fed a diet that included 2-ppm tungstate in their water supply. The rats displayed a decrease in elevated serum triglyceride levels for the two-month duration of the study (4). The rats were decapitated after the two-month study to thoroughly test their blood, liver, and to determine metabolite concentrations. A study with rats of lifetime exposure to 5-ppm tungstate in drinking water showed no discernable adverse effects (8). A study with rats given much higher concentrations (100-ppm tungsten in drinking water for 21 days) indicated a decrease in enzyme activities (7).

Chickens fed a balanced diet containing 250-ppm tungsten showed no adverse effects. However, a diet containing 1,000-ppm tungsten led to reduced egg production. A slight difference was found in the effects of tungsten consumption based upon the age of the chicken. Day old chicks were found to be more sensitive to tungsten. The consumption of chicken feed laced with 500-ppm tungsten led to adverse effects (7). As a point of comparison to levels of tungsten used in the above study, a teaspoon (10 grams) of common table salt (sodium chloride) ingested in a single dose will produce acute poisoning and may be lethal to a child (9). A 1956 study in which chickens were fed a diet low in molybdenum and high in tungsten (500-ppm soluble tungsten in feed) showed a decrease in molybdenum based enzyme activity. The effects were reversible when the chickens were fed a molybdenum supplement (10). Chickens that were fed 250-ppm tungsten had no noted adverse effect.

Geochemically these results may be difficult to replicate in the real world because tungsten and molybdenum are generally found in the same environment and as a result, the overwhelming dominance of one element over the other is not likely to occur.
SUMMARY

The occurrence of tungsten in Northern Nevada has been well recognized for over 100 years. Locally, tungsten was originally first produced in 1916 at the Silver Dyke Mine located just northwest of Mina. Ore from this project was shipped to San Francisco to be processed into tungsten metal for use in the original versions of the electric incandescent light bulb. A major increase was noted in tungsten production from the local mines after WWII when it was in demand to produce high strength tool steels. Production of tungsten ores and concentrates in Nevada ceased upon the widespread importation of low cost tungsten concentrates from China. Even though tungsten is commonly found around the household in the form of light bulb filaments and carbide saw blades, little research has been conducted recently on the long term effects of tungsten exposure. What is fairly well known is that tungsten appears to have a very low acute toxicity. That is, it is relatively nontoxic when consumed in large amounts orally. Very few long term studies have been conducted on humans who have been exposed to soluble tungsten in the environment either through employment or by other sources of exposure.

References


(4) Munoz, Maria Carmen; Barbera, Albert; Dominguez, Jorge; Fernandez-Alvarez, Josefa; Gomis, Ramon; Guinovart, Joan J. “Effects of Tungstate, a New Potential Oral Antidiabetic Agent, in Zucker Diabetic Fatty Rats Diabetes.” 2001.


(6) “Mineral Resources of Cornwall.” Cornwall County Council, Truro, Cornwall, United Kingdom. 2001.


Glossary

Alloy: The mixture of two or more metals.

Carbide: A hard material made of compacted binary compounds of carbon and heavy metals, used to make tools that cut metal.

Cassiterite: A light yellow, red-brown, or black mineral, \((\text{tin oxide } \text{SnO}_2)\), that is an important tin ore.

Chromium: A lustrous, hard, steel-gray metallic element, resistant to tarnish and corrosion and found primarily in chromite. It is used in the hardening of steel alloys and the production of stainless steels, in corrosion-resistant decorative plating, and as a pigment in glass.

Cysteine: An amino acid, \(\text{C}_3\text{H}_7\text{O}_2\text{NS}\), derived from cystine and found in most proteins.

Enzymes: Any of numerous proteins or conjugated proteins produced by living organisms and functioning as biochemical catalysts.

Ferberite: An extremely heavy, black, grainy mineral that is comprised of at least 80% iron tungstate, belonging to the Wolframite family.

Filament: A fine wire heated electrically to incandescence in an electric lamp.

Geothermal: Of or relating to the internal heat of the earth.

Huebnerite: An extremely heavy, light to deep red, crystalline mineral that is composed of at least 80% manganese tungstate, belonging to the Wolframite family.

Incandescent: Emitting visible light as a result of being heated.

Ion: An atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons.

Molybdenum: A hard, silvery-white metallic element used to toughen alloy steels and soften tungsten alloy. An essential trace element in plant nutrition, it is used in fertilizers, dyes, enamels, and reagents.

Oxidation: The combination of a substance with oxygen.

Playa: A nearly level area at the bottom of an internally drained desert valley sometimes temporarily covered with water.

Precipitate: To cause a solid substance to be separated from a solution.

Scheelrite: A variously colored mineral, \(\text{CaWO}_4\), found in igneous rocks and used as an ore of tungsten.

Thorium: A radioactive silvery-white metallic element that is recovered commercially from monazite.

Toxic: Capable of causing injury or death, especially by chemical means; poisonous.

Toxicology: The study of the nature, effects, and detection of poisons and the treatment of poisoning.

Uranium: A heavy silvery-white metallic element, radioactive and toxic, easily oxidized, and having 14 known isotopes of which \(^{238}\text{U}\) is the most abundant in nature. The element occurs in several minerals, including uraninite and carnottite, from which it is extracted and processed for use in research, nuclear fuels, and nuclear weapons.

Vanadium: A bright white, soft, ductile metallic element found in several minerals, notably vanadinite and carnottite, having good structural strength and used in rust-resistant high-speed tools, as a carbon stabilizer in some steels, as a titanium-steel bonding agent, and as a catalyst.

Wolframite: Any of several red-brown to black minerals with the general formula \((\text{Fe,Mn})\text{WO}_4\), which constitute a major source of tungsten.

References for Glossary


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