EPRI

TECHNICAL BRIEF

Molybdenum At Coal Combustion Product Sites

KEY POINTS

- Molybdenum is a naturally occurring element that plays an important role as a micronutrient in humans, plants, and animals. It is a component in some fertilizers and over-the-counter multivitamins and supplements.
- The range of molybdenum concentrations in coal ash is enriched relative to the range of molybdenum concentrations in soil.
- If molybdenum is released to groundwater, its concentration can decrease with distance from the release point due to natural attenuation.
- If molybdenum is released to groundwater, the primary pathway by which people can be exposed to it is via drinking water. However, in order for exposure to occur, the drinking water well must be located downgradient of the coal ash management units and draw water from the specific aquifer contaminated with molybdenum.
- If molybdenum concentration in groundwater is higher than the groundwater protection standard (GWPS) established by EPA regulations for coal ash sites, then utilities are required to clean up the contaminated groundwater.
- The GWPS for molybdenum is based on a 1961 study in which increased uric acid levels were observed in humans who had been living in an area of Armenia with high molybdenum content in the soil and plants. The daily molybdenum dose at which these effects were observed is at least 27 times higher than the amount of molybdenum a resident would consume from drinking water with a molybdenum concentration equal to the GWPS. In fact, at the GWPS, a resident would have to drink at least 21 liters of water in a day to reach the dose at which these adverse health effects have been observed.

WHAT IS MOLYBDENUM?

Molybdenum is a naturally occurring element that is commonly found in the form of oxide or sulfide compounds.[1] Molybdenum plays an important role as a micronutrient in humans, plants, and animals. It is also found in fertilizers and over-the-counter multivitamins and supplements.[2,3] Legumes, grains, nuts, leafy vegetables, and dairy products are the main dietary sources of molybdenum.[4]

Molybdenum is commonly used in manufacturing processes because of its high melting temperature. It is used in the production of steel, superalloys, electronics, X-ray tubes, and filaments. Molybdenum compounds are also used as lubricants, catalysts, and pigments.[5,6]

MOLYBDENUM IN COAL ASH

Coal ash is generated from burning coal at coal-fired power plants. It can be beneficially used in concrete production and other applications. When not used, it is managed in landfills, and in the past, was also managed in surface impoundments.

Coal ash is composed of rocks and minerals in coal that do not burn, and while it contains many of the same chemicals that are present in rocks and minerals, these chemicals may

1 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.
2 *Chemical Constituents in Coal Combustion Products: The Chemical Profile Interactive Tool, V2.0*. EPRI, Palo Alto, CA: 2022. 3002023681.
3 National Institutes of Health (NIH), 2024. "Molybdenum: Fact Sheet for Health Professionals."
4 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.
5 *Chemical Constituents in Coal Combustion Products: The Chemical Profile Interactive Tool, V2.0*. EPRI, Palo Alto, CA: 2022. 3002023681.
6 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.

become enriched in coal ash compared to soil. In the case of molybdenum, the range of concentrations measured in coal ash overlaps the upper portion and extends above the range of molybdenum concentrations in natural soil, indicating that molybdenum in coal ash is enriched relative to soil (see Figure 1).[7,8]

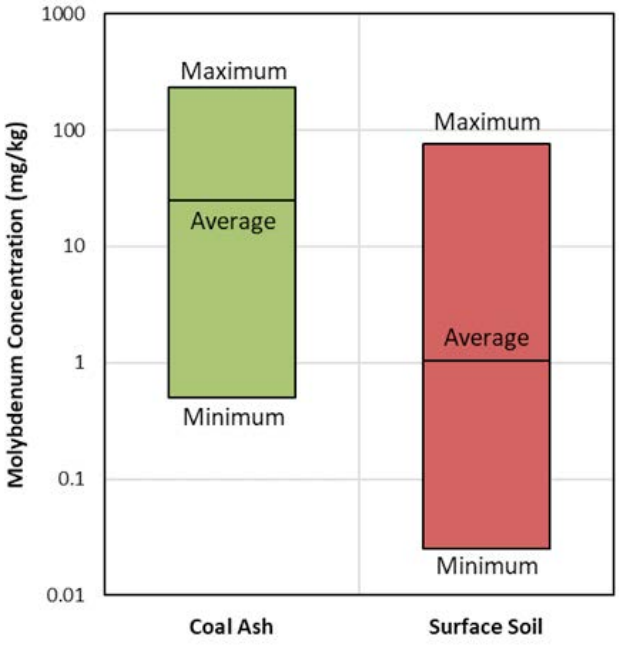

Figure 1. *A comparison of molybdenum concentrations found in coal ash and naturally occurring molybdenum concentrations in surface soils across the US.*

MOLYBDENUM MOVEMENT IN GROUNDWATER

When rainwater soaks into a coal ash management unit, it can dissolve the molybdenum in the coal ash. The rainwater containing the dissolved molybdenum is called "leachate." Modern coal ash management units are lined with clay and/or plastic to contain this leachate and have collection systems to remove it. If a management unit is not lined and does not have a leachate collection system, then, depending on geology, the leachate may be able to seep downward through the soil underneath the storage unit and into groundwater.

If chemicals from coal ash, including molybdenum, seep into groundwater, then they can flow with the groundwater away from the storage unit in specific directions based on land and water features in the surrounding environment. Groundwater usually flows from areas of higher elevation toward large lakes and rivers in areas of lower elevation.

The concentration of molybdenum in groundwater decreases as groundwater flows away from the coal ash management unit due to dilution and reactions that cause the molybdenum to attach to the soil.[9] Once molybdenum in groundwater enters a large surface water body, its concentration is reduced to levels so low they usually cannot be detected because of dilution and reactions that cause molybdenum to attach to the sediment (see Figure 2).

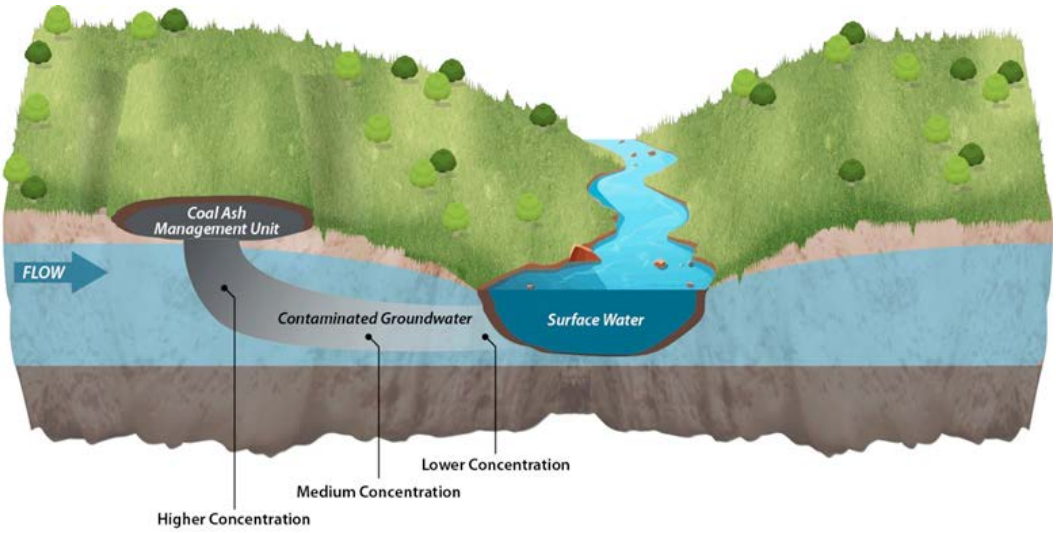

Figure 2. *Molybdenum concentrations in groundwater decrease with distance from the coal ash management unit.*

7 EPRI, 2024. CPInfo database. Unpublished.

8 United States Geological Survey (USGS). 2013. "Geochemical and Mineralogical Data for Soils of the Conterminous United States."

9 *Chemical Constituents in Coal Combustion Products: The Chemical Profile Interactive Tool, V2.0*. EPRI, Palo Alto, CA: 2022. 3002023681.

HOW CAN I BE EXPOSED TO MOLYBDENUM FROM COAL ASH STORAGE UNITS?

Exposure pathways for molybdenum and any other contaminants released to groundwater are site-specific. In general, if molybdenum from coal ash seeps into groundwater and is carried by the groundwater beyond the boundaries of the storage site, then there are several ways in which a person can be exposed. Households with water wells that use the contaminated groundwater as their source may be exposed via drinking water or from water used for other purposes (such as showering or cooking). Additionally, this water may be used for watering edible plants or filling a swimming pool. Drinking water usually carries the greatest risk for exposure to molybdenum released from coal ash; risk from the other possible types of exposure is lower (see Figure 3).

For exposure to occur, the well must be located in the path of the groundwater flow between the coal ash storage unit and the "groundwater discharge zone" (often a surface water body) and draw water from the same aquifer affected by chemicals from coal ash. If private wells are located outside the groundwater flow path or draw water from deeper aquifers that are not contaminated by the chemicals from coal ash, exposure will not occur. Similarly, households that receive water from a public water supply will not be exposed to chemicals from coal ash if their water is drawn from different aquifers that are not contaminated with these chemicals.

If the affected groundwater flows into a surface water body (for example, a lake or a river), a person can be exposed while swimming or boating, or by consuming fish caught from the water body. Molybdenum, however, is not readily absorbed through the skin, nor does it accumulate in fish. Furthermore, as previously mentioned, molybdenum concentrations in surface water tend to be too low to measure, and, thus, risk is also low.

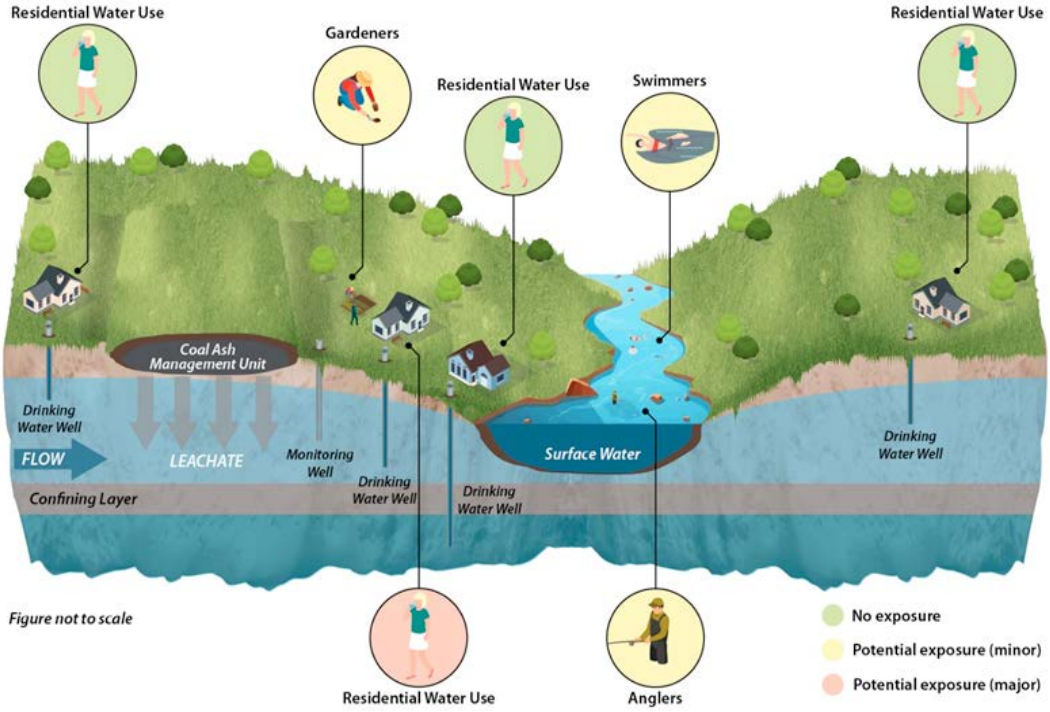

Figure 3. *This figure shows possible risk pathways and relative risk potential. The residential drinking water well on the opposite side of the river from the coal ash management unit, the residential water well uphill and upgradient of the coal ash management unit, and the residential water well in the uncontaminated deep aquifer (green circles) have no risk because the risk pathway is not complete. The yellow circles indicate complete exposure pathways, but where exposure and risk potential are lower. The highest potential risk pathway indicated by the red circle is for a residential drinking water well downgradient of the coal ash management unit (between the unit and surface water) that draws water from the contaminated aquifer.*

PUTTING RISKS IN PERSPECTIVE: MOLYBDENUM

US EPA's regulations for coal ash storage require electric utilities to measure groundwater concentrations of chemicals commonly found in coal ash. Concentrations measured in groundwater next to coal ash storage units are compared to regulatory standards (called groundwater protection standards, or GWPSs), set by US EPA. US EPA has set a GWPS of 100 parts per billion (ppb)[10] for molybdenum.[11] To be health-protective and account for any uncertainty regarding a chemical's toxicity, GWPSs are routinely set to be much lower than the levels at which adverse health effects have been observed.

The GWPS for molybdenum is based on a 1961 study in humans who had been living in an area of Armenia with high molybdenum content in the soil and plants. In this study, increased uric acid levels were directly correlated with dietary intake of molybdenum.[12] The daily molybdenum dose at which these effects were observed is at least 27 times higher than the amount of molybdenum a resident would consume from drinking water with a molybdenum concentration equal to the GWPS. In fact, at the GWPS, a resident would have to drink at least 21 liters of water in a day to reach the dose at which these adverse health effects have been observed.[13] Note that studies performed after 1961 have suggested a higher dose would be needed for adverse health effects to occur.[14]

Table 1. *Amount of drinking water a resident would need to consume to reach the adverse health effects documented for molybdenum (based on the 1961 study)*

MOLYBDENUM CONCENTRATION	WATER (LITERS PER DAY)
GWPS (100 ppb)	21
2 × GWPS (200 ppb)	11
5 × GWPS (500 ppb)	4
10 × GWPS (1,000 ppb)	2

For reference, the figure below shows the amount of molybdenum in drinking water at the GWPS, compared to the amount of molybdenum in our daily diet,[15] a molybdenum supplement or multi-vitamin,[16] and 3.5 oz legumes.[17]

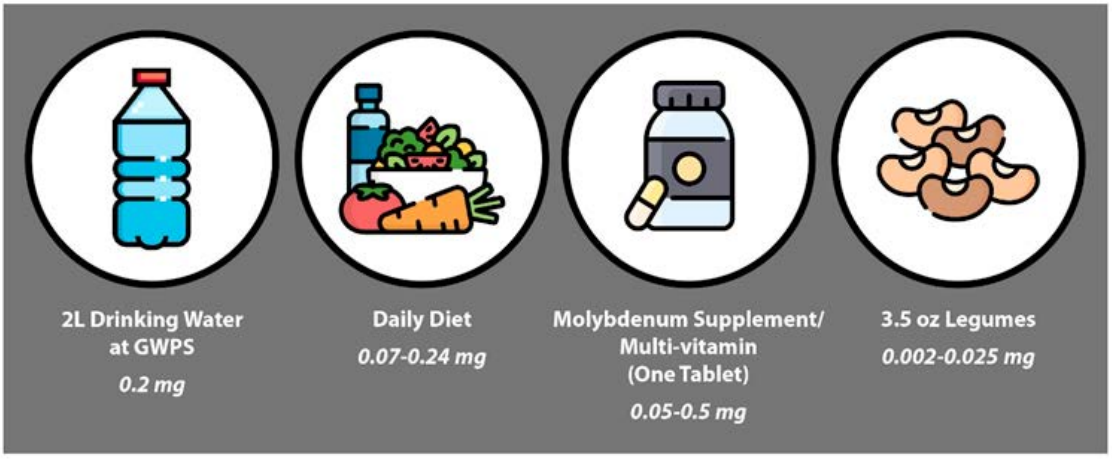

Figure 4. *Amount of molybdenum in drinking water at GWPS compared to the amount of molybdenum in daily diet, a molybdenum supplement/multi-vitamin, and 3.5 oz legumes.*

10 Equivalent to 100 micrograms of molybdenum in 1 liter of water.

11 US EPA. 2018. "Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals From Electric Utilities; Amendments to the National Minimum Criteria (Phase One, Part One)." Fed. Reg. 83(146): 36435-36456. 40 CFR Part 257. July

12 US EPA. 1992. "Integrated Risk Information System (IRIS) Chemical Assessment Summary for Molybdenum (CASRN 7439-98-7)". November.

13 These calculations assume a child resident who weighs 15 kg and drinks 0.78 liters of water per day. An adult resident (who weighs 80 kg and drinks 2.5 liters of water per day) would have to drink more water than a child to reach the dose at which adverse health effects have been observed.

14 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.

15 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.

16 National Institutes of Health (NIH), 2024. "Molybdenum: Fact Sheet for Health Professionals."

17 Agency for Toxic Substances and Disease Registry (ATSDR). 2020. "Toxicological Profile for Molybdenum." May.

MOLYBDENUM REMEDIATION

If molybdenum is detected at concentrations higher than its GWPS in groundwater near coal ash management units, electric utilities are required by federal rules to take action to clean-up (remediate) the groundwater contamination. There are a variety of remediation methods that can be used to reduce groundwater molybdenum concentrations, and the methods have different strengths and weaknesses. A method can work well at one site, poorly at another site, and may not even be feasible at yet another site. Geologists and engineers will consider a site's geology, depth to contaminated groundwater, chemicals requiring remediation, and other factors[18] to select the optimal remediation approach.

18 *A Holistic Decision Support Tool for Selecting Sustainable Corrective Actions at Coal Combustion Product Sites: Resource Documentation and User's Guide*. EPRI, Palo Alto, CA: 2023. 3002024223.

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3002030080 **December 2024**

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