EPRI

TECHNICAL BRIEF

Cobalt at Coal Combustion Product Sites

KEY POINTS

- Cobalt is a naturally occurring element that can be found in small amounts in most rocks, soils, and water.
- The range of cobalt concentrations in coal ash is similar to natural soils, although cobalt's average concentration is higher in coal ash than in soil.
- If cobalt is released to groundwater, its concentration can decrease with distance from the release point due to natural attenuation.
- If cobalt is released to groundwater, the primary pathway by which people can be exposed is via drinking water. However, 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 cobalt.
- If cobalt 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 cobalt is based on a 2-week human study that found that the ingestion of high amounts of cobalt temporarily affected thyroid function. The daily cobalt dose at which these effects were observed was more than 3,000 times higher than the amount of cobalt a resident would consume from drinking water with a cobalt concentration equal to the GWPS, and a resident would have to drink 2,500 liters of water in a day to reach the dose at which these adverse health effects were observed.

WHAT IS COBALT?

Cobalt is a naturally occurring element that can be found in small amounts in most rocks, soils, and water. Cobalt is also found in vitamin B_{12}, which is essential to the maintenance of animal and human health and has been used as a treatment for anemia. It can also be found in certain dietary supplements.[1]

Cobalt also has a wide variety of consumer uses. It is an important component of lithium-ion batteries, which are critical for electric vehicles, computers, and smartphones. Additionally, cobalt is used in medical devices and prosthetics (for example, knee and hip replacements). Cobalt is also used to color glass and ceramics, and as a drier for porcelain enamel and paints.[2]

COBALT 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). 2004. "ToxFAQs for Cobalt." April.

2 Agency for Toxic Substances and Disease Registry (ATSDR). 2023. "Toxicological Profile for Cobalt." January.

become enriched in coal ash compared to soil. Cobalt is one of the chemicals present in coal ash. In the case of cobalt, the range of concentrations measured in natural soil and coal ash are similar (see Figure 1), although coal ash has a higher average concentration (41 mg/kg) than soil (8.9 mg/kg). [3,4]

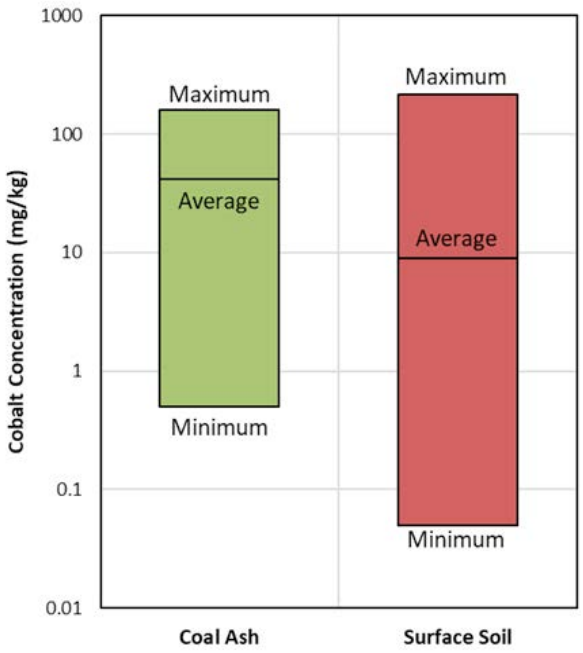

Figure 1. *A comparison of cobalt concentrations found in coal ash and naturally occurring cobalt concentrations in surface soils across the US.*

COBALT MOVEMENT IN GROUNDWATER

When rainwater soaks into a coal ash management unit, it can dissolve the cobalt in the coal ash. The rainwater containing the dissolved cobalt 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 cobalt, seep into groundwater, they can then 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 cobalt in groundwater decreases as groundwater flows away from the coal ash management unit due to dilution and reactions that cause the cobalt to attach to the soil.[5] Once cobalt 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 cobalt to attach to the sediment (see Figure 2).

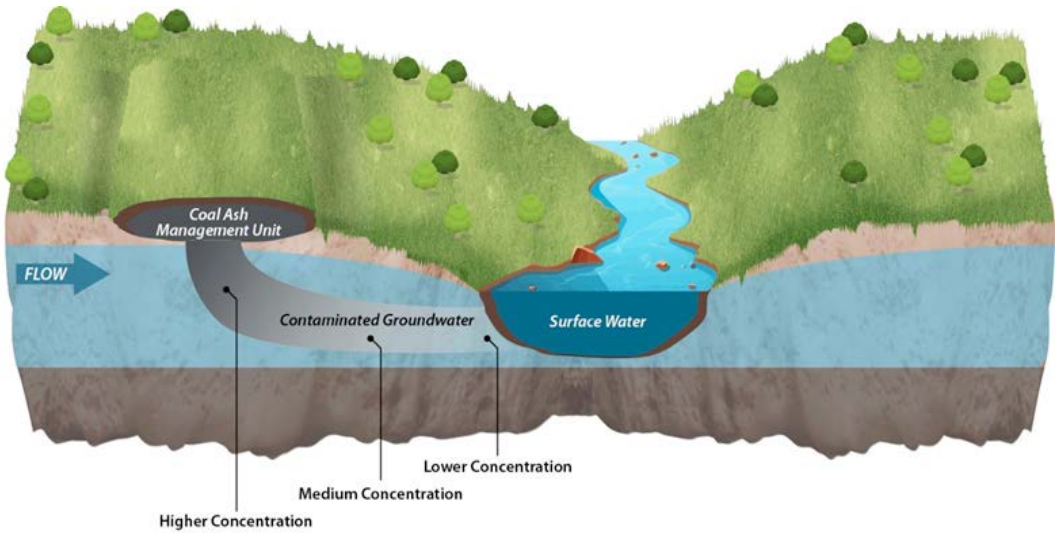

Figure 2. *Cobalt concentrations in groundwater decrease with distance from the coal ash management unit.*

3 EPRI, 2024. CPInfo database. Unpublished.

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

5 *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 COBALT FROM COAL ASH STORAGE UNITS?

Exposure pathways for cobalt and any other contaminants released to groundwater are site specific. In general, if cobalt 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 cobalt released from coal ash; risk from the other possible types of exposure is much 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 in the water body, or by consuming fish caught from the water body. Cobalt, however, is not readily absorbed through the skin, nor does it accumulate in fish. Furthermore, as previously mentioned, cobalt concentrations in surface water tend to be too low to measure, and risk is also low.

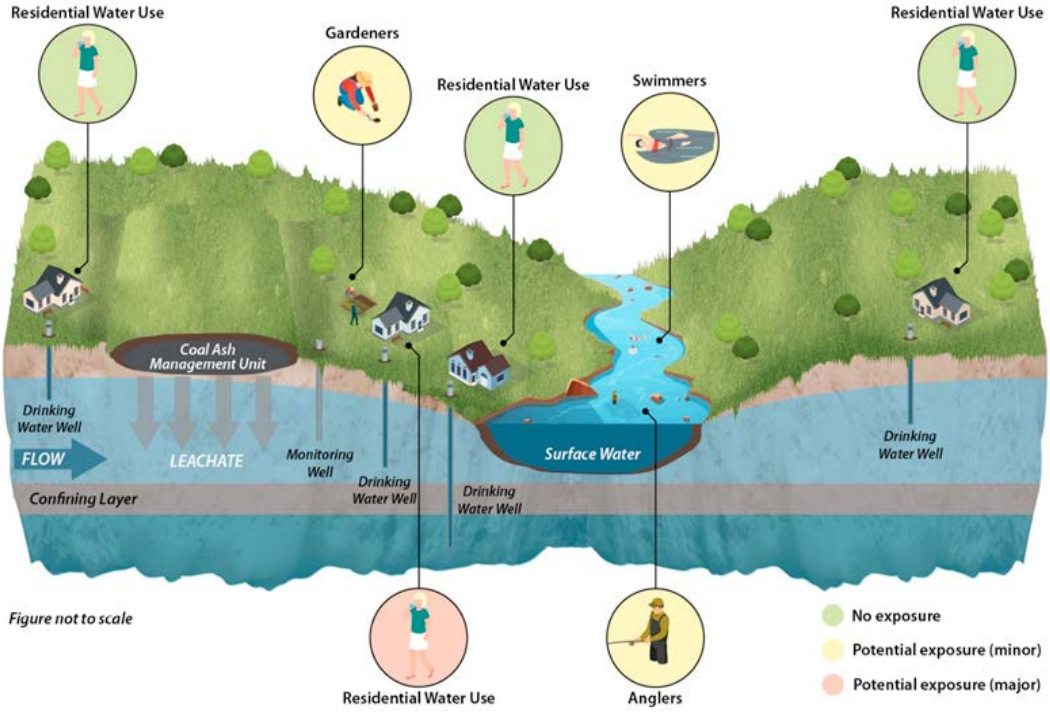

Figure 3. *This figure shows possible risk pathways and relative risk potential. The residential drinking water well on the opposite side of the river from the coal ash management unit, the residential water well uphill and upgradient of the coal ash management unit, and the residential water well in 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: COBALT

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 6 parts per billion (ppb)[6] for cobalt.[7] 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 cobalt is based on a 2-week human study that found that the ingestion of high amounts of cobalt affected thyroid function. However, the effects were not permanent and thyroid function returned to normal when the cobalt exposure stopped.[8] The daily cobalt dose at which these effects were observed is at least 3,000 times higher than the amount of cobalt a resident would consume from drinking water with a cobalt concentration equal to the GWPS. In fact, at the GWPS, a resident would have to drink at least 2,500 liters of water in a day to reach the dose at which these adverse health effects have been observed (see Table 1).[9]

Table 1. *Amount of drinking water a resident would need to consume to reach the adverse health effect documented for cobalt*

COBALT CONCENTRATION	WATER (LITERS PER DAY)
GWPS (6 ppb)	2,500
2 × GWPS (12 ppb)	1,250
5 × GWPS (30 ppb)	500
10 × GWPS (60 ppb)	250

For reference, the figure below shows the amount of cobalt in drinking water at the GWPS, compared to the amount of cobalt in the human body,[10] our daily diet,[11] and typical vitamin B_{12} supplements.[12]

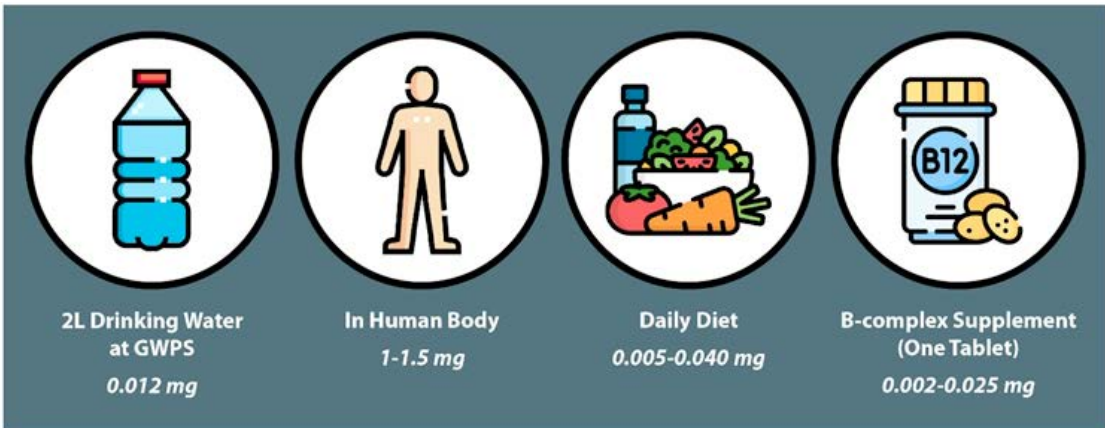

Figure 4. *Amount of cobalt in drinking water at GWPS compared to amount of cobalt in human body, daily diet, and a typical vitamin B_{12} supplement*

6 Equivalent to 6 micrograms of cobalt in 1 liter of water.

7 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.

8 US EPA, National Center for Environmental Assessment (NCEA), Superfund Health Risk Technical Support Center. 2008. "Provisional Peer Reviewed Toxicity Values for Cobalt (CAS No. 7440-48-4)." August.

9 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.

10 World Health Organization (WHO), 2006. "Cobalt and inorganic cobalt compounds." Concise International Chemical Assessment Document 69.

11 Agency for Toxic Substances and Disease Registry (ATSDR). 2023. "Toxicological Profile for Cobalt." January.

12 National Institutes of Health (NIH), 2024. "Vitamin B12: Fact Sheet for Health Professionals."

COBALT REMEDIATION

If cobalt 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 cobalt 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[13] to select the optimal remediation approach.

13 *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.

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

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