Dangers Downstream:

Mercury contamination in water, soil, and sediment near Black Butte Mine

By Pamela Johnston
HC 441: Willamette River Health
Clark Honors College, University of Oregon
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Black Butte Mine, in operation intermittently between 1890 and 1967, was once the fourth largest producer of mercury in Oregon and one of the largest producers in the nation. It is located approximately 15 miles south of Cottage Grove Reservoir in Lane County, Oregon, which receives flow directly from the Coast Fork of the Willamette River. It has been suggested that historical mining and processing of cinnabar (mercury ore) at this site has been, and is still, a factor in mercury contamination of the Cottage Grove Reservoir and its surrounding watershed.

Historic Mining

Documents from the year 1938 proudly tell how Oregon's production of quicksilver, as mercury was then commonly called, had advanced to second largest of the nation's states. This natural resource was receiving special attention at the time due to its recent economic gain, limited international production, and possibilities as a "war mineral." Its uses in military operations included the mercuric fulminate for detonating explosives, calomel (mercurous chloride) used as a purgative for troops on the field, and a corrosive agent in camp and hospital sanitation (Schuette, 50). Of course, many industrial and consumer applications existed such as mercury dry-cell batteries during WWII, incandescent lamps as developed by Thomas Edison, agricultural fungicides, and paint manufacturing (Carpi, 2001).

Mercury deposits are found in only a handful of countries worldwide, making it a comparatively rare metal. The deposits appear to have been formed by relatively recent volcanic activity, and Schuette in 1921 theorized that because of the metal's wide distribution, it is likely a common rock component of deep-earth magma. Pressure from below creates fractures in the earth's crust that allow minerals to rise towards the surface. Rocks of various types and ages show these deposits, although they are usually associated with Quaternary and Tertiary structures (the last 65 million years) where little erosion has taken place. The metal is volatile and will escape into the atmosphere if conditions are not ideal (Schuette).

Black Butte mine was found to include three forms of sedimentary mercury: cinnabar, the ore of mercury, that exists with sulfide as HgS and can be identified by its bright red color; metacinnabar, the same chemical composition as cinnabar but a black sulfide instead of red; and native quicksilver, less frequent than the ore because of mercury's volatility. Cinnabar, a pure crystal of which contains 86.2% mercury, plays a prominent role in the mining process.

Black Butte itself reaches 2800 ft in elevation, and the mine was developed by various owners and operators over the years at differing levels over a vertical range of about 1300 ft. The steep side of the Butte where most mining activity occurred is composed of andesitic lavas and other geologic species of the Calapooya formation.

When the deposit was first discovered, a 40-ton Scott furnace was built at the mining site to roast the ore—the simplest and most efficient method of recovery (Brooks). Mercury's boiling temperature of 1,076˚ F is exceeded within the furnace in order to rend the substance volatile, then it is sent through a condensing system. Gases released here include sulfur dioxide (due to sulfide of HgS mixing with air), carbon dioxide, water vapor, nitrogen, oxygen, and mercury vapor that condenses to liquid upon cooling (Schuette). The Department of Geology and Mineral Industries' Bulletin No. 4 spoke of some concern towards health of the furnace operators in this part of the process, but it was argued that no danger existed if temperatures and equipment were properly regulated. Wages for these workers in 1938 ranged from 50 to 60 cents per hour.

The Scott furnace was updated to a 4 x 60 ft rotary kiln in 1927, followed by a second in 1929 to increase the mill's capacity to 150 tons/day (Brooks). U.S. Bureau of Mines data show that the mine was at its peak production in 1930, soon after this addition. Black Butte mine was said to have an average product grade of 3 lbs/ton on recovery at this point, which made it "the outstanding low-grade producer of the U.S. quicksilver industry."

The Nature of Hg

The native element (Hg^0), mercurous (Hg^+) and mercuric forms (Hg^{2+}) are all found in various stages of the global mercury cycle, as shown in Fig. 1.

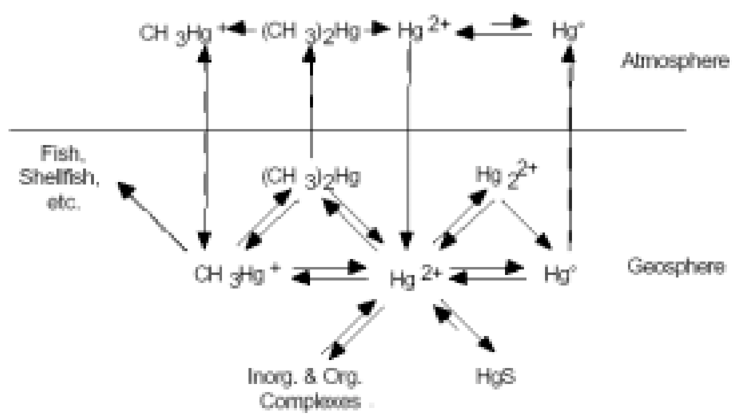

Figure 1. Major transformations of mercury in the environment [adapted from Beijer & Jernelöv (1979)].

Source: Carpi, Anthony. "The Toxicology of Mercury." 2001 <http://web.visionlearning.com/carpi/Hg%20Toxicology%20Brief.pdf>

Elemental mercury has an atmospheric half-life of 1 to 2 years and exerts a global effect, moving between the geosphere and atmosphere as a gas that can be ingested by living organisms. It is easily oxidized to Hg^{2+}, however, becoming chemically active and depositing as rainfall or dry particles as far away as 100 km from its source.

Although much inorganic mercury is present in the environment, the organic form is much more apparent in bodies of water. This is made clear by biological testing that shows predominantly methylmercury, the methylated version CH_3Hg^+, in the tissues of fish and other aquatic creatures. Certain microorganisms, molds, and enzymes in sediment have been found to cause this chemical change (Crompton). Inorganic Hg is not readily adsorbed into tissue compared to organic Hg, and for this reason is sometimes de-emphasized as a toxic component.

Toxicity and Health

There has been significant concern in recent years over the possibility of organomercury compounds causing serious illness in heavily polluted areas. Methylmercury is more mobile than the other forms, and therefore more toxic, because of its ability to transfer across biological membranes and solubility in lipid tissue. Fish that were exposed to 1 µg/L of methylmercury for 30 days showed weight reduction and decreased spawning. In another study, juvenile and adult fish were exposed to toxicologically-safe doses of an organomercury fungicide. After six months, multiple health conditions appeared such as liver abnormalities indicating carcinogenesis. Juveniles were especially affected (Crompton), probably owing to the fact that organic Hg interacts with proteins and therefore with the rapidly growing tissue of young organisms.

The majority of human exposure to methylmercury is clearly in the consumption of fish (Park). According to the World Health Organization's Permitted Limit, the organomercury in fish ingested by man is not to exceed 29 µg as a mean daily amount. The organic form is readily absorbed through the gastrointestinal tract into lipids, which is why mercury is a major player in bioaccumulation (Park). Central nervous system issues such as blindness, motor and mental impairment have been observed, along substantial liver and kidney toxicity and numerous other acute and chronic toxicity consequences.

The US Safe Drinking Water Act allows a maximum of 0.5 mcg/L total mercury including in potable water. Arsenic was found in moderately high doses in residential wells in the Black Butte mine area, but mercury levels were well below the set limit.

The Current Problem

Although the Black Butte Mine has been inactive for over 35 years, there is evidence of continued water and soil contamination even today. The Coast Fork of the Willamette provides a direct connection between the mine site and Cottage Grove Reservoir, located only miles downstream, which is of particular interest in studying mercury buildup from the mine. Methods in this investigation for determining mercury concentrations included tests of stream and reservoir sediment as well as tissue from fish and invertebrates. Largemouth bass, bluegill, and crappie in the reservoir, downstream from Black Butte Mine, were found to exceed the FDA's mercury limit.

The most elevated mercury concentrations were found at and near the mine. Concentrations in sediments downstream of the mine in Dennis and Garoutte Creeks, tributaries of the Coast Fork of the Willamette, were found to be greater than those upstream of the site.

Results suggest that there exists a strong concentration gradient from the mine to the headwaters of the Coast Fork, with an additional surge in mercury concentration near the far end of the reservoir as water flow slows greatly (Curtis). Additionally, the Coast Fork branch leading into Cottage Grove Reservoir tested for ten times more mercury in sediment than other regional tributaries with no evidence of mining (Park).

Atmospheric deposition during crushing and roasting of cinnabar, leaching and runoff into stream water, and stockpiling of ore waste tailings all appear to be contributors of the current mercury contamination in the surrounding environment (Park). Thirty-five to fifty tons of mercury were likely lost in processing during the mine's active life due to both atmospheric deposition from furnace/condenser issues and piling of mine tailings (Ambers & Hygelund). A large amount of contaminated waste-rock is still stockpiled at the site.

As the research findings show, mercury contamination of several different types has been, and is currently being discharged from the mine. Distribution of the metal is therefore far and wide, and there are most likely impacts on the human population that have not even been realized.

Current Regulation

In August of 2002, Black Butte Mine was declared an Orphan Site by Department of Environmental Quality. This label is given to abandoned sites, often mines, than are releasing hazardous substances with no one taking responsibility for them. This may be because a responsible party is not available or can't be found, or because that party is unwilling or unable to pay for the cleanup.

In assigning Orphan Sites and priorities, Oregon uses the following approach:

- Emergency situations and immediate threats to public health and the environment should be addressed first
- Polluters should pay
- If the polluter and others who have owned or operated the property since the release are not able, the state will clean up the site.

DEQ's Orphan Site proposal for the Black Butte Mine lists several former owners of the site. The parties that were contacted insisted that the mine was not in operation under their ownership; however, the Department did find the Land and Timber Company to be a responsible party based on property transaction policies. The company also denied operation of the mine and was unwilling to participate in cleanup of the site.

DEQ is the leading agency for this investigation, but numerous state and federal agencies (Oregon State University, US Environmental Protection Agency, US Geological Survey, US Army Corps of Engineers, and others) are involved in the planning, past studies, or current research that is scheduled to begin within the next 12-18 months.

Black Butte Mine has been listed as a High Priority Site, and at this time DEQ has allotted $50,000 from the state-funded Orphan Site program towards the mine's investigation. DEQ will continue to look into possible responsible parties.

Future Actions

Mercury discharge has now been distributed as long as the mine has existed. Steps should be taken to control whatever contaminants have not yet been released from the site, and hopefully this is what DEQ's cleanup program will focus on first. However, in regard to the mercury that is already in the environment, there is research with evidence that the concentration may at least be lessened. These possibilities include sulfur coated cotton meshwork nets or polyvinyl alcohol gels that can remove inorganic mercury from contaminated water and sediments (Suggs, et al.). Even more recently is the research being done with bioremediation for the cause of methylmercury and other organic compounds. Various mechanisms have been recommended, some especially promising ones being mercury precipitation as HgS due to a bacterium's production of H_2S or volatile thiols (Essa, et al). This process may even be applicable in such cases as mercury-containing wastewater treatment.

The Black Butte Mine situation is not unique—there are numerous abandoned mine sites in Oregon alone. However, its vicinity to Cottage Grove Reservoir that is such a prominent resource for environmental systems and public recreation makes this site high on the list of priorities. Hopefully someday we will be able to look back on this situation not with anxiety for human health and that of the environment, but simply as a lesson learned in our state's history that will not be repeated.

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