Printed from: Interstate Technology & Regulatory Council (ITRC). 2017. *Bioavailability of Contaminants in Soil: Considerations for Human Health Risk Assessment.* BCS-1. Washington, D.C.: Interstate Technology & Regulatory Council, Bioavailability in Contaminated Soil Team. http://bcs-1.itrcweb.org.

11.8 Bingham-Magna Ditch Site, Salt Lake Valley, Utah (2008)

Contact: Scott Everett
Organization: Utah Department of Environmental Quality
Email: severett@utah.gov

11.8.1 Site Description and Conceptual Site Model

The Bingham-Magna Ditch (BMD) is a gravity feed ditch that once conveyed excess tail water from copper precipitation plants located in Bingham Canyon (Bingham Mining District). The BMD was located on property deeded, by easements, to the Utah Copper Company. The BMD was historically approximately 12 to 15 feet wide and approximately 17 miles long (Copperton, UT to Magna, UT). The ditch was constructed around 1932 and used until about 1935, when excess waters were sent to the South Jordan Evaporation Ponds. By 1937 the land on which the BMD was located was deeded back to the original property owners when Utah Copper Company relinquished the easements it held. Utah Copper Company was the predecessor to Kennecott Utah Copper Company, which is now known as Rio Tinto Kennecott Copper (RTKC).

In the early 1900s, the process to recover copper at various precipitation launderers in Bingham Canyon resulted in high concentrations of dissolved iron in the resulting tail water waste streams. Arsenic, which is naturally found in the ores mined in Bingham Canyon, has an affinity to bind to iron. During the process to precipitate copper from leach water, arsenic would transfer into solution (following the iron) and be conveyed in the resulting tail water to the BMD. As the tail water flowed along the ditch, the sediments that precipitated from the solution contained an iron-arsenic compound which was simultaneously deposited along the bottom of the BMD.

▼*Read more*

The deposited sediments oxidized, becoming a rust colored, iron rich sediment with arsenic constrained (on average) within the first two to six inches of the bottom of the ditch. Site characterization samples determined that arsenic concentrations were as high as 3,500 mg/kg, which is well above the USEPA and UDEQ selected interim land use action level (100 mg/kg arsenic) for the BMD removal action initiated by RTKC in 2007 under an Administrative Order of Consent.

The BMD was aligned under properties which were once used for agricultural purposes but with population growth were more recently redeveloped for residential, school, commercial, and open space use. RTKC implemented an early response removal action that removed approximately 10 miles of the overall 17-mile length of the BMD alignment. Properties in use for residential, school commercial, industrial, open space still overlie the BMD. Where the BMD remains in place, it is generally covered with two to four feet of native clean soil and governed under institutional controls (ICs).

11.8.1.1 Arsenic on the Site

▼*Read more*

Soil along the BMD was sampled by excavating eight trenches that transected the width of the former ditch. The location of the former BMD was and is evident from the reddish-brown staining of soil at depth. Visual evidence of elevated arsenic is not possible, as deposits of arsenic vary along the length of the BMD. The trenches were excavated perpendicular to the BMD alignment on average three and half to seven feet below ground surface. Excavation and sampling below the BMD sediment horizon was typically extended two feet below. The in-situ soils were screened using a portable x-ray fluorescence (XRF) instrument to determine the concentration profile of arsenic in the vertical walls. Approximately 30 to 40 samples in each trench were screened in situ and marked with color coded flags to delineate the pattern of deposition of BMD sediment. On average, approximately eight samples were collected from each trench for laboratory analysis. The highest arsenic levels (1,000 ppm and above) were from samples in the uppermost reddish stained layer. Samples of soil at average depths of six inches or more below this layer contained less than 100 ppm arsenic, indicating little migration into underlying soil. The mean arsenic concentration in soil sampled was 655 mg/kg; the maximum concentration was 3,090 mg/kg. More information about the site characterization is included in the URS (2008) report.

11.8.1.2 Soil Type

▼*Read more*

Results of the mineralogic evaluation indicate that, for all BMD samples evaluated, arsenic occurs predominantly in association with iron oxyhydroxides (FeOOH). In three of the eight samples evaluated, this form accounts for all of the arsenic present in the samples. In four other BMD samples, while the FeOOH form dominates the arsenic mineralogy (95.3% to 99.8% of the arsenic mass), smaller amounts of the arsenic mass (0.2% to 4.7%) also occur in association with iron sulfate ($FeSO_4$). In these samples, arsenic was found only in these two forms. In the remaining sample, while nearly all of the arsenic was present in association with FeOOH, a trace (0.32%) was also found in association with iron phosphate.

The results of the in vitro extraction indicate that the samples with higher bioaccessibility are the ones that contain small amounts of arsenic in association with $FeSO_4$. However, the association with $FeSO_4$ does not fully explain the higher bioaccessibility, because one of the sulfate-containing samples demonstrated very low bioaccessibility.

11.8.1.3 Source of Arsenic

▼Read more

The arsenic in the tail waters originated from the copper ore. The tail water that flowed in the BMD also contained high concentrations of dissolved iron as a result of the process used to recover copper at the precipitation plants. Because of the high affinity between arsenic and iron, iron and arsenic coprecipitated out of the water as it flowed along the ditch and were deposited as a two- to six-inch thick layer of rust-colored sediments in the bottom of the ditch.

11.8.1.4 Land Use/ Exposure Scenarios/Soil Management Strategies

▼Read more

Land uses (in 2007) in areas underlain by the BMD included residential, school, industrial, limited agricultural, recreational, and open space uses. The early response action to remove the BMD was performed in areas where the BMD was readily accessible. Areas where the BMD was left in place, at a depth on average two to four feet below current surface, remain in use for residential, school, commercial, recreational and open space, and to a limited degree agriculture.

The interim cleanup action level for arsenic was established at 100 mg/kg based on conservative risk management decisions from other operable units at RTKC sites. Part of the characterization efforts implemented concurrent to the early response removal action included a risk assessment using site specific samples. Cleanup levels were not developed for agricultural areas due to (1) lack of an exposure pathway during routine agricultural use because the material is at depth and (2) anticipated near-future conversion of agricultural use to residential use. Cleanup levels were also not developed for the recreational scenario because less exposure is likely from recreational use, as compared to residential or industrial scenarios, for which frequent daily exposure may occur over much of a day.

For residential use, cleanup levels that are protective of residential exposure to surface soil are based on integrated exposure to soil concentrations throughout the major areas of a yard. Cleanup levels were not calculated for subsurface soils in the BMD, because the elevated arsenic concentrations in the BMD exist at depths that are below the soil horizon of potential contact. Institutional controls will be implemented to ensure that when excavated, soils and sediment with elevated arsenic are appropriately managed. The soil concentration (cleanup level) equivalent to a target risk-based level was determined using the USEPA equation for calculating risk associated with arsenic in residential soil. Standard default input values were used for many of the parameters. For relative oral bioavailability of arsenic from soils (RBA), which depends on specific soil characteristics, site-specific and other relevant information was considered as part of a weight-of-evidence evaluation to determine a site-specific RBA value for application to site soils. In addition, because the soil that a person incidentally ingests is composed of both outdoor soil and indoor dust, differences in arsenic concentrations between outdoor soil and indoor dust were also considered in calculating the performance goals.

Performance standards for industrial areas assume exposure to soil at the surface that are potentially encountered on a chronic basis over time. Cleanup levels for industrial exposure were calculated using an equation similar to that for the residential scenario, except that the parameter values were based largely on USEPA default worker exposure assumptions.

Where the BMD was left in place, ICs are or will be implemented. ICs are intended to assist with the management (upon excavation) of BMD sediments/soils with elevated concentrations of arsenic above the applicable land use action levels (310 mg/kg – residential and 1,380 mg/kg – industrial). A technical memorandum dated January 2009 from the Agencies notes that no ICs are necessary where the BMD sediments/soils with elevated arsenic are located 10 feet or more below the current surface grade.

11.8.2 Methodology Used for Evaluating Bioavailability

11.8.2.1 In Vitro Analysis

▼*Read more*

Samples were submitted for in vitro bioaccessibility and mineralogic analysis by Dr. Drexler at the Laboratory for Environmental and Geological Studies (LEGS), which is administered by the Department of Geological Sciences at the University of Colorado, Boulder. Samples were selected based on representation of the full length of the ditch, pH, potential interactions with other metal concentrations, and arsenic concentrations with bias toward those higher than 100 ppm. The soil samples (<250 µm size fraction) were subjected to bioaccessibility testing according to the Standard Operating Procedure (SOP) developed by Dr. Drexler and others (Exponent 2008b). Extraction fluids and solids were analyzed for arsenic by inductively coupled plasma/mass spectrometry (ICP/MS, USEPA Method 200.8). Solids were digested using USEPA Method 3050B. At the time of this evaluation, no in vitro methods had regulatory approval for predicting the RBA of arsenic from soil. Therefore, results from the in vitro bioaccessibility testing and mineralogic evaluation of site samples were used in a weight-of-evidence evaluation.

Bioaccessibility results ranged from less than 1% to a high of 26%. Of the 21 samples tested, only two had bioaccessibility values greater than 10%, and most samples (86%) reflected arsenic bioaccessibility values of less than 6%. The mineralogic analysis of a subset of eight representative samples indicated that arsenic occurs nearly exclusively in association with iron oxyhydroxides. Two samples were selected for bioaccessibility testing specifically due to the presence of other metals in the sample. These two samples with higher concentrations of chromium, copper, manganese, and zinc are among the samples with the highest observed arsenic bioaccessibility, suggesting the possibility of metal-metal interaction influencing the arsenic solubility.

11.8.3 Calculated Bioavailability of Arsenic in Soils

▼*Read more*

Bioavailability using the in vitro bioaccessibility results was not calculated into a mean for use at this site. Rather, the range of RBA values used in the assessment were selected based on a weight-of-evidence evaluation that combined information about the in vitro bioaccessibility and mineralogy results for site samples, and evaluation of those data in the larger context of soil samples for which RBA testing had been completed in animal models. The assessment indicated that the soil samples from this site were most similar (based on bioaccessibility and mineralogy) to soils from sites in New York and Hawaii, as described next.

11.8.4 Application of Bioavailability to Risk Assessment

▼*Read more*

Based on mineralogy and in vitro bioaccessibility results, similarities were noted between soils from the BMD site and soil samples from two other sites, one in Hawaii and one in New York, which have in vivo relative bioavailability data in monkeys, mineralogy data, and in vitro bioaccessibility data using the same extraction method as applied to the BMD site soils. USEPA Region 8 and UDEQ toxicologists reviewed the results of the bioaccessibility testing and mineralogic analysis and concluded that the BMD samples were most similar in mineralogy to the New York site. Based on this similarity, the toxicologists recommended relative bioavailability values of 20% to 25% as health protective values for use at the BMD. These values were therefore used in the cleanup-level calculations.

11.8.5 How Did Bioavailability Results Affect Site Decisions?

▼*Read more*

The relative bioavailability factor was selected based on similarity in bioaccessibility and arsenic mineralogy with a site in New York (with input from regulatory agencies), even though the range selected based on the in vivo bioavailability data from the New York site was considerably above the in vitro bioaccessibility results for the BMD soils. The calculations therefore may overestimate bioavailability of arsenic in soil at the BMD site. Using 20% and 25% relative bioavailability in the risk calculations resulted in calculated arsenic cleanup levels for residential land use of 3 to 4 ppm (1×10^{-6} risk) to 310 to 380 ppm (1×10^{-5} risk). Calculated arsenic cleanup levels (both cancer and noncancer risks were considered) for commercial land uses range from 14 to 17 ppm (1×10^{-6} risk) to 1,380 to 1,730 ppm (1×10^{-5} risk), as shown in Table 11-5, (Exponent 2008a).

Table 11-5. Arsenic soil cleanup levels associated with the USEPA target risk range

Target Risk	Cleanup Level (ppm)[a]	
	Residential	Industrial
1×10^{-6}	3-4	14-17
1×10^{-5}	31-38	138-173
1×10^{-4}	310-380	1,380-1,730

[a]A range of cleanup levels is presented representing 20% to 25% bioavailability.

As a result of the bioaccessibility study and risk evaluation for BMD sediments/soils with elevated arsenic concentrations, site-specific, risk-based action levels for residential and industrial land use were selected. Further efforts combined to determine the BMD sediments/soils with elevated concentrations of arsenic were appropriate to leave in place if they were either (1) left undisturbed at depth, or (2) were located at depths 10 feet or greater below current surface grades. Combined, the early response removal action and the institutional controls by the local jurisdictions for soil management during excavation have helped to protect public health and the environment (USEPA 2008; 2009a).