Uneven Distribution of Heavy Metals in Shoreline Sediments of Spring Meadow Lake, Lewis and Clark County, Montana

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Uneven Distribution of Heavy Metals in Shoreline Sediments of Spring Meadow Lake, Lewis and Clark County, Montana

Submitted in partial fulfillment of the requirements for graduation with honors to the Department of Natural Sciences at Carroll College, Helena, Montana

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April 7, 2003
This thesis for honors recognition has been approved for the Department of Natural Sciences by:

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Abstract

The objective of this study was to determine the site-specific metal concentrations in the shoreline sediments of Spring Meadow Lake, Montana. A previous study had determined that there were elevated levels of manganese, lead, copper, iron, zinc, and cadmium in the sediment. In the present study, ten equally spaced areas were sampled around the lake to determine if a specific location of contamination existed. Samples were digested with nitric acid and analyzed by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES). After a preliminary analysis of the samples revealed that most of the metal contamination was located toward the east side of the lake, ten additional samples were collected and analyzed from that area. The results indicated that two sites with elevated levels of metals existed on the east side of the lake. During the early 1900’s Northwestern Metals Co. (also known as the New-York-Montana and Engineering Co.) operated an ore processing facility at this site. A connection between the elevated metal levels at the two sites and the operations of the ore processing facility is evaluated.
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Introduction

Recently, elevated concentrations of metals were found in the fine particulate sediment of Spring Meadow Lake, which lies approximately one mile due west of Helena, Montana. The previous study, conducted by Vannatta, 2002 (6) analyzed representative sediment samples from Spring Meadow Lake and found that lead and manganese were present in concentrations that were significantly higher than in uncontaminated locations. Since the samples from the lake in the previous study were composited, it was not possible to estimate the concentrations of metals at specific locations. The present study was designed to analyze discreet samples from specific sites around the lake in order to better define the location(s) of the highest concentrations of heavy metals previously observed in 2002. Sediment samples were prepared by acid bomb digestion and analyzed via a Perkin Elmer Optima 2000 Inductively Coupled Plasma Atomic Emission Spectrometer (ICP).
Materials and Methods

Site Selection

Spring Meadow Lake was selected because there was preliminary evidence that the lake sediment was impacted by heavy metals (6). The exact locations of the contamination were unknown. Initially in this study a starting point was selected and sites were defined on equal intervals around the lake; subsequently, ten equally spaced sites were sampled around the perimeter of the lake. Samples were collected at a depth of approximately 1.5 feet and 2 to 3 feet from shore. All sites are shown on the aerial photograph in Figure 1. The first ten samples, sites (A1-A10), were acquired between June 20 and July 3, 2002, while a second sampling, sites (B1-B10), took place on July 23, 2002. The second set of samples included some of the previous sites, but focused primarily on the east side of the lake.
Figure 1: Locations of Sites at Spring Meadow Lake

Sample Collection

A plastic spoon was used to scoop sediment samples from the top of the substrate. Between each site the spoon was washed with a solution of 1 percent (%) nitric acid for decontamination. A filtering device was constructed from an 8-inch Buchner funnel, which had the perforated bottom removed and replaced with the 63-micron nylon mesh. Several spoons of soil were taken from each site and washed with lake water through the filter until a gallon of water had been collected. This washing process gave a minimum of 1.5 grams of sediment for each sample.
Sample Preparation

Samples were kept at 4° Celsius (C) until the sediment settled, which took approximately three days. The lake water was decanted until about one inch remained. The sediment was resuspended and poured into an acid washed beaker, which was placed in a refrigerator where the sediment was allowed to settle again. After the sediment settled, water was decanted until about 1 centimeter (cm) remained; the sediment was re-suspended and transferred into a polyethylene weigh boat. Sediment samples were placed in a 65°C oven and allowed to dry, after which they were ground to a fine powder using acid washed mortars and pestles.

For each of the samples, triplicate 0.5-gram (g) subsamples were digested individually using a Microwave Acid Digestion Bomb, (Parr model 4782). Accurately weighed 0.5g portions of sediment were placed into the Teflon cup of the bomb along with 20 millimeters (ml) of concentrated nitric acid (Fisher trace metals grade). The Teflon cups were placed into the digestion bomb, and were microwaved in a Hitachi 1000W kitchen microwave until the pressure reached 500 pounds per square inch (psi) or until 1 minute elapsed, whichever occurred first. The cooled digest was filtered using ashless filter paper into acid washed 100 ml volumetric flasks. A solution of 1% trace metals grade nitric acid was used to wash the cup and the filter paper to insure a complete transfer. After the initial analysis, the metal levels varied widely among the different samples, so dilutions of 10:100 and 1:100 were made because the ICP instrument gives the most accurate response up to about 10 parts per million (ppm).
Inductively Coupled Plasma Atomic Emission (ICP-AE) Analysis

The first 10 samples were analyzed, using an existing standard to obtain preliminary results and these samples were subsequently used to make three new standards. For the stock digested samples, a standard was made consisting of 1.0 ppm arsenic (As), cadmium (Cd), zinc (Zn), manganese (Mn), Copper (Cu), lead (Pb), and 30.0 ppm iron (Fe). The 10:100 dilutions were analyzed using a standard that was prepared consisting of 2.0 ppm As, 0.1 ppm Cd, 2.0 ppm Zn, 10 ppm Mn, 0.1 ppm Cu, 2.0 ppm Pb, and 20 ppm Fe. These analyses were done to more accurately determine the concentrations of samples with significantly elevated metals. Since Mn was in such high concentrations, a 1:100 dilution was made and a standard was prepared to contain 3 ppm Mn and 15 ppm Fe. This dilution was used to determine the concentrations of manganese in the sites with significantly elevated concentrations of this element.

These dilutions and standards were selected so linear calibration curves would be valid at the concentrations that were being analyzed. The mass of the sediment and the dilutions used were entered into a sample information file so that the ICP could calculate the concentrations of the metals in the original sediment samples. The ICP was programmed to look radially at the plasma and to take three replicates. This analytical approach required the ICP to look three separate times at the area of the emission peak for the first analyte and calculate an average, before moving on to the next sample. The concentrations of the triplicate analyzed samples were averaged and then plotted.
Results/Conclusions

The objective of this study was to determine the location of the elevated heavy metals in sediments at Spring Meadow Lake. Figure 1 shows the sample locations used in this study.

Preliminary Analysis Results

The graphs in Figure 2 show concentrations of each metal for all of the sites.

Figure 2: Levels of Metals Found in Sites A1-A10 in the Preliminary Analyses
The preliminary analytical results (sites A1-A10) for Pb, Zn, Mn, Fe, Cd, and Cu, are summarized in the graphs presented in the graphs Figure 2. The concentrations of the metals, especially Pb, Zn, Mn, and Cd are elevated most on the eastern side of the lake at sites A5 and A6.

Figures 2-A, B, C, and F show the trends of Pb, Zn, Mn, Cd and Cu, respectively. The concentrations of these metals are relatively consistent in all sites except A5 and A6. These two sites show significantly elevated metal concentrations relative to other sites around the lake. As shown in Figure 2-D, the levels of iron were somewhat elevated at sites A5 and A6 relative to the other locations.

The ten preliminary sample sites (A1-A10) were selected to be representative of shoreline sediments for the entire circumference of Spring Meadow Lake. From these analyses it was determined that the metal concentrations were mostly elevated in sediments on the east side of the lake. For this reason, additional sites (B1-B10) were sampled on the east side of the lake and the results from these samples are shown in Figure 3. As shown in Figure 1, B10 is at the north side of the lake. Proceeding clockwise from B10 around the east side of the lake the sites are encountered in this order: B1-B5, B9 B6-B8. It is important to note that since such high levels of metals were found at site A6, the site was re-sampled as site B9.
Secondary Analysis Results

Figure 3: Levels of Metals Found in Sites B1-B10 in the Secondary Analysis

In the preliminary analysis, site A6 was the site with the highest level of metals and this was corroborated in the secondary analysis with sample B9. In addition, site B2 showed significantly elevated metal concentrations. This is the first evidence that there are two sites at Spring Meadow Lake that have elevated levels of heavy metals. The initial analyses showed only one site (A6) that contained significantly elevated metal
concentrations. While the previous study conducted by Vannatta (2002) suggested high concentrations of metal in the shoreline sediments for all of Spring Meadow Lake, this study specifically identifies two sites (B2 and B9) as having high concentrations of heavy metals.

Arsenic is a heavy metal that has impacted soils all across Montana in areas where mining has taken place. The ICP that was used to determine concentrations of metals for this study does not have the detection limit low enough for accurate determination of arsenic. Due to this limitation, the As values were obtained through Energy Laboratories of Billings, MT. Sites A1, A6, A8, B2, and B9 were selected for analysis. Sites A1 and A8 were selected on the basis that these sites showed relative low levels of metals and sites A6, B2, and B9 were selected because they showed elevated levels of metals in the previous analysis. Figure 4 shows elevated concentrations of As at sites A6, B2, and B9.

![Levels of Arsenic](image)

**Figure 4:** Levels of As Found in the Sediments of Selected Sites by Energy Laboratories

It is important to note that a different method was used by the independent lab for the determination of metal concentrations in sediments. They use a method that calls for the addition of hydrogen peroxide (H₂O₂) to destroy any organic compounds that may be
chelating metals. Second, the samples are digested with nitric acid using an open-air digestion, in which the sample is boiled in nitric acid on a hot plate rather than digested in a microwave acid digestion bomb.

Spring Meadow Wild Animal Center, which is owned and operated by the Montana Department of Fish, Wildlife and Parks (FWP), previously was The New-York-Montana Testing and Engineering Co. in the early 1900’s. This company processed mine ores and this processing is possibly the source for the elevated levels of metals that were found in the lake sediment. It is therefore not surprising that the southeast portion of the lake is impacted because it is located near the site of the previous ore processing facility, but it was a surprise that site B2 contained similar elevated levels of metals.

On Saturday February 3, 1917 the first carload of ore concentrates were shipped from the New York-Montana Testing and Engineering Company’s mill to the lead smelter located at East Helena, MT (1). This first shipment consisted of 50 tons of ore, from which lead was smelted. This evidence suggests a probable source for the lead contamination at Spring Meadow Lake.

The levels of Mn (Figure 3-I) were elevated in sites B2 and B9. In 1918, The New York-Montana Testing and Engineering Co. was also producing manganese concentrates at the mill. This mill was the largest custom plant in Montana at that time and during the month of January in 1918 it shipped 713 tons of manganese concentrates to Chicago (2). At that time the mill had government contracts to provide 1,000 tons of manganese concentrates per month to steel mills around the country (2).

It is interesting to hypothesize why the elevated metals are located in the sediments on the southeast side of the lake and not on the southwest side. Figure 1 shows
that the ore processing facility was located to the southwest of sites A6 and B9, which contain high levels of metals. This is a considerable distance from site B2. The waste tailings from the facility could have been dumped at site A6. After cessation of the ore processing, the area immediately north of the facility was operated as a sand and gravel mining operation. When this operation ended, Spring Meadow Lake was formed. The sand and gravel operation could have moved metal impacted soil from A6 to the site of B2.

A limited amount of information exists about the nature and source of the ore processed at the mill. According to an investment prospectus from 1909, one of the ores that the mill was processing was assayed at the time and it was determined that the ore contained 20% zinc, 1.5% copper, and 4% lead. This ore was called “zingocopsil” because of its zinc, gold, copper and silver content (4). This ore is a highly probable source for the zinc, copper, and lead contamination that was found in the sediments of Spring Meadow Lake. Arsenic, manganese and cadmium commonly accompany ores that contain gold, zinc, copper and silver, which makes this ore a probable source of contamination for the other metals, that were found in the sediments of Spring Meadow Lake.

Another ore came from the dump of the Valley Forge Mine located near Rimini, MT (4). This area includes the Upper Tenmile Creek Mining Area located in Lewis and Clark County, MT (5), which is a national Superfund site that covers 53 square miles. The superfund site contains 150 known mines near the Rimini Mining District in the Tenmile Creek watershed, which serves as the primary municipal water source for Helena, MT (5). This is interesting because the Rimini area also has elevated levels of
heavy metals that are consistent with the metals found in the sediments of Spring Meadow Lake. The graphs in Figure 5 show the relationship between the levels of metals in sediments of the lake, compared to the levels found near Rimini. The values reported for the Rimini site are the average metal concentrations in sediments in the Upper Tenmile creek near Rimini, MT. These values do not reflect direct analysis of waste rock taken from the dump at the Valley Forge Mine.

In the paragraphs to follow, the results from this study are compared to levels of metals found in other sites that were impacted by metal mining. It is important to note that the results of this study were for lake sediments and they are being compared to pond sediments, stream sediments, river sediments and soils. This comparison is only to give a reference point to begin to piece together what the results from Spring Meadow Lake really mean.
Figure 5: Levels of Metals Found in Sites B1-B10 Compared to Levels Found in the Upper Tenmile Creek Superfund Site Near Rimini, MT
The level of lead (Figure 5-M) at the Rimini site is higher than the sites at Spring Meadow Lake except for sites B2 and B9. The levels of lead at sites B2 and B9 could be cause for concern because the recreational cleanup level used by the Montana Department of Environmental Quality is 2300 ppm (7). The excavation level for residential yards for lead is 800 ppm in soil (5). The clean up level (risk level) for lead in residential yards is 1000 ppm (5). The reason for the difference in numbers to ensure that action is taken before the level of acceptable risk is met (clean up level). It is important to note that these clean up values are for soil while this study analyzed lake sediment, which is a related but different substance. Only two sites exceed these levels, sites B2 and B9. For comparison purposes only, the three sites that are elevated more closely match the values that were discovered in the sediments of the Warm Springs Ponds in the Upper Clark Fork River Basin, Montana (3). The upper Clark Fork River is also a national Superfund site monitored by the United States Environmental Protection Agency (3). The levels of cadmium found at the Warm Springs sites range from 22 ppm to 58 ppm. These are comparable to Spring Meadow Lake sites B2 and B3, but site B9 is in the range of 118 ppm (3).

The concentration of lead is also comparable to the levels found in the sediments of Warm Springs Ponds. The levels of lead were between 100-200 ppm for three of the ponds and between 400-600 ppm for the remaining two (3).

The level of manganese (Figure 5-O) in the Rimini area is surprising because it significantly lower than at the lake sites B2 and B9. This can possibly be explained by years of producing manganese concentrates from the Rimini ore (2). Also, the levels at the Rimini site are stream sediments and there is a certain amount of natural dilution from
source water concentrations. The recreational cleanup level set by the Mine Waste Cleanup Bureau (MWCB) is 7330 ppm for manganese (7). Sites B9 and B2 both exceed this value.

The levels of copper (Figure 5-R) were also interesting because the Rimini stream sediments are higher than all of the lake sites except sites B2 and B9. It does appear that sites B2 and B9 contain elevated levels of copper, but when they are compared to the Upper Clark Fork River, the values are not as high. Levels of copper between the values of 2,000 to 10,000 ppm have been found at the national Superfund site on the upper Clark Fork River (3). Also the recreational clean up level set by the MWCB is 54,200 ppm (7). This is substantially higher that the levels found in the sediments of Spring Meadow Lake.

This study identified specific locations for the elevated heavy metals previously determined to exist at Spring Meadow Lake, Montana. These metal concentrations have been compared to two metal mining Superfund sites also located in Montana. Results from the study suggest highly probable source for the elevated metals in lake sediments originated in 1917 by the operation of an ore-processing mill owned by York-Montana Ore Testing and Engineering Co, (formally Northwestern Metals Co., 1910-1914). It has also been documented that common practices at this mill included the waste tailings being allowed to accumulate on the ground outside of the mill. It is not known what happened to these tailings, but it is possible that some of these were left at that site and contributed to the elevated metals that are present today.
References


2. [Anonymous]. Helena Plant Works Ore Needed for War. The Helena Daily Independent 1918 February 17


