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Comparison of Sulfate Concentration with Mine Number and Proximity at Telegraph Creek, Lump Gulch and Ten Mile Creek Drainage Basins

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Comparison of Sulfate Concentration with Mine Number and Proximity at Telegraph Creek, Lump Gulch and Ten Mile Creek Drainage Basins

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

Amanda Reeves
April 9, 2001
Signature Page

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# Table of Contents

Acknowledgements ................................................................. i
List of Tables ................................................................. iii
List of Figures ................................................................. iii
Abstract ................................................................. iv
Introduction ................................................................. 1
Methods ................................................................. 4
Results ................................................................. 6
Discussion ................................................................. 7
Literature Cited ................................................................. 15
Acknowledgements

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List of Tables

Table 1. Sample data from the
Telegraph Creek Drainage Basin----------------------------- 12

Table 2. Sample data from the
Lump Gulch Drainage Basin---------------------------------- 12

Table 3. Sample data from the
Ten Mile Creek Drainage Basin------------------------------ 12

List of Figures

Figure 1. Map of the study sites in the
Helena National Forest, MT------------------------------- 10

Figure 2. The Relationship between Sulfate
Concentration and Number of Upstream Mines------------- 13

Figure 3. The Relationship between Sulfate
Concentration and Mine Proximity------------------------ 14
Abstract

Mining effluent is prevalent in Montana. Iron disulfide (FeS$_2$) is a major by-product of mining sites and prospect pits and oxidizes into sulfuric acid once it enters drainage streams. It is possible, therefore, that mining effluent determines a portion of the amount of sulfuric acid in a basin. However, no direct tests of this potential correlation have been conducted in the Helena area. If a cause (mining) and effect (high sulfate concentration) correlation is demonstrated, then a protocol for determining resulting sulfate concentration in other mined areas might be established. I hypothesize that streams in mined areas will have a higher concentration of sulfate than streams in un-mined areas. Eighteen samples taken from mined and un-mined areas of the Telegraph Creek, Lump Gulch and Ten Mile Creek Drainage Basins were tested for sulfate concentration using an ion chromatographer. Measurements were made to examine the effect of the number of upstream mines and mine proximity on sulfate concentration. The results were statically analyzed. No statistically significant correlations were established. Other factors affecting the results and possible further studies are discussed.
Introduction

Mining is a major source of revenue for Montana. In Jefferson, Powell and Lewis and Clark County, mining began in the early 1860s. Silver, gold and lead was extracted using placer and load mines (USGS 1963). During this time, few environmental ordinances existed and therefore most mining waste was discarded into nearby streams. Although new regulations prevent this type of destructive disposal, old abandoned mines have already caused extensive damage (Meis 1999).

Sulfate has been shown to be an excellent indicator of mining, whereas pH and acidity readings have proven to be insufficient (Rikard and Kunkle 1990). Since mining is prevalent in Montana, quantifying the abundance of acid generated by the mining process is crucial in determining water quality of a drainage basin. Acid generation typically occurs in mined areas and this leads to acid mining drainage (AMD). AMD occurs when metal sulfides are oxidized and sulfuric acid is produced (Canty 1999). When metal sulfides, notably FeS_2, react with oxygen and water they become oxidized. Acid generation occurs according to the following reaction:

\[
\text{FeS}_2 + \frac{15}{4} \text{O}_2 + \frac{7}{2} \text{H}_2\text{O} \leftrightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+ \quad \text{(Canty 1999)}
\]

This reaction increases the amount of sulfate and acidity of the water causing AMD. Therefore, testing for dissolved SO_4^{2-} in drainage basins may indicate mining presence. A comparison of sulfate concentration with mine number and with mine proximity in three drainage basins could indicate whether or not sulfate concentration is a good indicator of mining effluent.

Acid mine drainage causes a variety of consequences. An estimated 10,000 miles of streams and 29,000 hectares of impoundments are perilously affected by
AMD in the United States alone (Canty 1999). AMD can have adverse effects on the surrounding vegetation. In addition, AMD has been shown to decrease amphibian population sizes and macro-invertebrate populations. Changes in these populations and vegetation can alter habitat for other species. This in turn can effect other populations and even amplify the harm of AMD.

In the past, several methods have been used to measure the effects of mining effluent. Acidity and pH have been commonly used to test for mine drainage, however, Rikard and Kunkle (1990) found that acidity was only a moderate indicator and pH was a rather poor detector. The amount of metals can be a very good indicator but requires extensive and time-consuming analyses involving expensive equipment. Some studies monitored the populations of amphibians or macro-invertebrates (Meis 1999). While these studies have been useful, changes in population of these animals can come from a variety of other sources such as drought, colder than normal weather or decreased habitat size. Sulfate presence, however, typically only results from two factors- acid production during mining or dissolved gypsum. In addition, Rikard and Kunkle (1990) found that sulfate has been an excellent and consistent indicator of mining effluent.

I sampled streams in the Telegraph Creek, Lump Gulch and Ten Mile Creek drainage basins that varied in the number of historical mine sites. I analyzed each sample, quantifying the amount of sulfate in each using an ion chromatographer. Since there was no gypsum present in any of the basins (USGS 1963), the sulfate present should be solely from mining effluent and thus be an excellent indicator of
AMD. I then compared the sulfate concentrations with the number of mines in the drainage basin and mine proximity.
Materials and Methods

Study Area:

I selected three drainage basins in the Helena National Forest that differ in the number of historic mine sites (Fig. 1). Telegraph Creek, located in Powell county has a total of 73 mines that drain into it. Lump Gulch, in Jefferson county, includes Frohner Meadows and 23 mines. Ten-Mile Creek, in Lewis and Clark county, has 135 mines draining into the basin.

Within these basins, a total of 18 sites was selected based on mine proximity and number of upstream mines.

Collection:

At each site, I submerged a 100-ml collection tube into the stream with the lid still on. Then, I removed the lid to fill the container and reattached it before removing it from underneath the water surface. This is to preserve the purity of the sample. I placed the samples on ice while transporting them from the field. All samples were stored in a 15° C refrigerator and analyzed within 48 hr of collection.

Ion Chromatography:

I determined the amount of sulfate in each sample using an ion chromatographer following the methods detailed in Pfaff (1993) for analysis of anions. A 5-ml sample was loaded into the chromatographer where a small amount was injected into the instrument. Anions separate based on their affinity for the material in the packing column. Concentrations are computed based on the peak area of the anion (Pfaff 1993). Reference standards, duplicates and blanks were analyzed with each batch of samples.
Data Analysis:

I used USGS 7.5 minute topographical maps and UTM coordinates to plot the location of mines and sampled sites. I then measured the distance between the collection site to the nearest mine and tabulated the number of upstream mines (Tables 1-3). I tested for an association between number of mines and sulfate concentration by using linear regression analysis. The association between mine proximity and sulfate concentration was also examined. I used SPSS to conduct linear regression analyses and to determine p-values.
Results

Analysis of samples from 18 sites within the Telegraph Creek, Lump Gulch and Ten Mile Creek Drainage Basins indicated no statically significant correlation between sulfate concentration with mine number or with mine proximity (Fig. 2,3).
Discussion

The data suggests that there was no correlation between sulfate concentration and mining. However, further testing should be more inclusive when considering sulfate as an indication of mining. For instance, monitoring flow rate, pH, dissolved metals, reduction potentials, biochemical oxygen demand and other characteristics of water composition would be useful. Flow rate may play an important role as water becomes increasingly neutral as it flows from mine-waste piles (Swayze et al. 2000) and could explain the lack of correlation between sulfate concentration and mine proximity. A drainage having a faster, heavier flow rate should logically have a lower sulfate concentration compared to one of a slow flow.

Although pH and acidity readings have been insensitive in other studies (Rikard and Kunkle 1990) they may help in understanding the overall conditions and reactions in the drainage basin. Other ions present in the tailings may influence the oxidation of sulfide minerals and their presence should be considered. Testing the conductivity of the stream would reveal if other ions were present. Although conductivity readings will not reveal which ion are present, Rikard and Kunkle (1990) showed that conductivity could be a good indication of mining. In addition, heavy metal sulfates, particularly barium, lead, mercury and silver, do not dissociate readily in water and thus would reduce the amount of sulfate present. The reduction in amount of sulfate in some areas could be due to prior precipitation especially in streams with high concentrations of these heavy metals.

Another key factor in sulfate abundance is the presence of sulfate-reducing bacteria, particularly Thiobacillus ferrooxidans. This bacterium is a naturally
occurring acidophilic (pH < 3.5) anaerobe that uses carbon and sulfate to produce hydrogen sulfide and bicarbonate (Das and Mishra 1996). Oxidation of sulfide is accelerated by the presence of *T. ferrooxidans* and may account for unpredicted sulfate readings within the drainage basins. My study did not look for or examine the presence of sulfate-reducing bacteria in the drainage basins.

Although other studies have revealed a significant association between sulfates and mining (Rikard and Kunkle 1990), my hypothesis that streams in mined areas would have a higher sulfate concentration than those in un-mined areas was unsupported. However, there are several plausible explanations for the unexpected results. Further studies may be more successful if they address such factors as flow rate, dissolved metals and sulfate reducing bacteria. With these refinements, sulfate measurements may be an accurate, quick and useful tool for assessing the impacts of mining.
Table 1. Data from the Telegraph Creek Drainage Basin.

<table>
<thead>
<tr>
<th>Area</th>
<th>Sulfate Concentration, mg/l</th>
<th>Number of Upstream Mines</th>
<th>Distance to Closest Mine, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sally Ann Marsh</td>
<td>3.3</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>O'Keefe, upper</td>
<td>10.1</td>
<td>5</td>
<td>0.45</td>
</tr>
<tr>
<td>O'Keefe, lower</td>
<td>12.4</td>
<td>10</td>
<td>0.65</td>
</tr>
<tr>
<td>Telegraph, upper</td>
<td>19.9</td>
<td>8</td>
<td>0.3</td>
</tr>
<tr>
<td>Telegraph, middle</td>
<td>8.3</td>
<td>31</td>
<td>1.25</td>
</tr>
<tr>
<td>Telegraph, lower</td>
<td>14.5</td>
<td>73</td>
<td>1.7</td>
</tr>
<tr>
<td>Hahn Creek</td>
<td>40.5</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Flume Gulch</td>
<td>10.8</td>
<td>2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 2. Data from the Lump Gulch Drainage Basin.

<table>
<thead>
<tr>
<th>Area</th>
<th>Sulfate Concentration, mg/l</th>
<th>Number of Upstream Mines</th>
<th>Distance to Closest Mine, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frohner, upper</td>
<td>58</td>
<td>12</td>
<td>0.5</td>
</tr>
<tr>
<td>Frohner, middle</td>
<td>37.1</td>
<td>14</td>
<td>1.1</td>
</tr>
<tr>
<td>Lump, upper</td>
<td>4.7</td>
<td>9</td>
<td>1.85</td>
</tr>
<tr>
<td>Lump Lake</td>
<td>12.6</td>
<td>23</td>
<td>2.4</td>
</tr>
<tr>
<td>Corrall Gulch</td>
<td>14.6</td>
<td>23</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Table 3. Data from the Ten Mile Creek Drainage Basin.

<table>
<thead>
<tr>
<th>Area</th>
<th>Sulfate Concentration, mg/l</th>
<th>Number of Upstream Mines</th>
<th>Distance to Closest Mine, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rimini, above</td>
<td>13.1</td>
<td>52</td>
<td>0.4</td>
</tr>
<tr>
<td>Rimini, below</td>
<td>85.1</td>
<td>107</td>
<td>0.8</td>
</tr>
<tr>
<td>Beaver Creek, above</td>
<td>8.2</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Beaver Creek, below</td>
<td>7.8</td>
<td>4</td>
<td>1.4</td>
</tr>
<tr>
<td>Moose Creek</td>
<td>31.9</td>
<td>135</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Figure 2. The relationship between sulfate concentration and number of upstream mines in the three drainage basins.
Figure 3. The relationship between sulfate concentration and mine proximity in the three drainage basins.
Literature Cited


