The Dangers of Acid Mine Drainage: An Experience and Solutions from Oakland, California

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Many people take their resources for granted and do not realize that the things they use daily are mined from the earth. Take matches, for example. On the tip of the match sulfur is used for ignition, and it is often mined from the earth. Companies that mine extract ores from the earth and turn them into various products. Many companies do not mine in a sustainable way, and destroy the surrounding environment. In Oakland, California there is an abandoned sulfur mine called the Leona Heights Mine that produces Acid Mine Drainage (AMD), which then flows into an urban watershed. Through our research and water monitoring we have found high levels of lead, arsenic, and iron in the surface waters around the abandoned mine and in the water downstream. The acid from the mine causes the metals to become more mobile, and they then easily enter the water. This abandoned mine is not sustainable because it poisons the surrounding water sources. Without mine remediation, mining can cause contamination of water and soil, negatively affecting the surrounding life. As we will show, there are ways to sustainably develop areas affected by mines, by layering compost over areas where AMD seeps out, and by installing wetlands so that microorganisms can help neutralize the AMD.

The creek which flows from the Leona Heights Mine in Oakland is called Leona Creek, and in the summer of 2008 we decided to test its waters because it runs through Mills College, and many people use the creek for recreation and relaxation. We took our samples to the Lawrence Hall of Science, UC Berkeley to test for heavy metals. We used standard Hach procedures to test for lead, arsenic and iron with a spectrophotometer and test kits *(1-3)*. The levels of lead collected from the creek on the Mills campus were 39.764, 33.283 and 41.20µg/liter (Figure 2). These readings were all higher than the US Environmental Protection Agency's legal limit for lead (15µg/l)*(4)*.

When we saw the readings we were surprised .We decided to go to the headwaters of the creek to find out what was causing such high levels of heavy metals. There we found the Leona Heights Mine and it was poorly contained. Through library research we found an old article describing how the mine was once a huge economical success, and that the company that owned the mine had sold sulfuric acid throughout the western United States *(5)*. After all the prime sulfur ore was gone, it became too expensive to mine for less valuable sulfur ore, so they abandoned the mine. In the 1910s when the mine was operating there were few laws that required mines to be cleaned up, which is why so many mine tailings still exist today. Because they made no attempt to cover or remediate the mine, it is now producing AMD, which causes heavy metals to leach into the water. Today the California Regional Water Quality Control Board regulates the water in Oakland and throughout the State, and has fined the current owner for not restoring the land. The owner would like to develop homes on the site *(6)*.

When we took water samples from the mine, the levels of lead were even higher than the levels found at Mills College. Some of the lead results were 55.260, 46.946, and 77µg/l (Figure 2). We also found arsenic at the mine at levels of and 15, 20 and 30µg/l (Figure 3), and iron levels were over 1.8mg/l (Figure 4). The EPA legal limits are 10µg/l for arsenic and 0.3mg/l for iron *(4)*. Exposure to high levels of arsenic and lead can cause birth defects, cancerous infections, mental illness, and even death *(7-9)*. Because there is limited information on the extent of mining in the area, we tested other surface water sources that the mining might have contaminated. We tested water from a nearby branch of Leona creek near Merritt College, which is one ridge to the north of the abandoned mine tailings (Figure 1). That branch also had intermittent heavy metal contamination. Some of the lead levels we measured were 26.119 and 15.779µg/l (Figure 2), and 1.8, 0.5, and 0.4mg/l of iron (Figure 4) indicating that mining could also affect water quality in this branch of Leona Creek.

Alongside the creek we also found a small toxic spring that many people had played with because of its vibrant colors. This spring also had high levels of all three heavy metals tested and could indicate past mining in the area (Figures 2-4). To prevent further exposure, we put up a sign to alert users of the creek and met with representatives from the City of Oakland who manage the land as a park. To confirm our results we found that other scientists had measured similar levels of heavy metals in the area using more advanced spectrometer equipment *(10)*. Because Leona Creek flows into the San Francisco Bay, the mine could be contaminating the San Francisco Bay ecosystem as well.

Beyond the Leona Heights mine, mining has had negative effects on the environment and human health throughout the world. In an article by Stephen D'Esposito, he discusses how mining produces a lot of waste and uses a lot of energy. He writes that, "too often, mining companies want to discuss sustainability only in terms of how to mine, not whether to mine. For any sustainability policy to be complete it must address the issues of where and when it is or is not appropriate to mine” *(11)*. 10,000 pounds of waste are left after one golden wedding band is made (*11)*. After gold is mined, water can become contaminated and degraded permanently. As long as money is being earned, some companies don’t care about these harmful issues. For example, in Honduras, people have been complaining about health problems such as respiratory, skin and gastro-intestinal disease that have been occurring because of the gold mine polluting their drinking water *(12)*. Many Hondurans who live near the gold mine have complained to the government and the government resists doing something about this issue.

In Black Mesa, Arizona the mining of coal has had a huge effect on the Navajo and Hopi way of life. The Navajo and Hopi have been removed from their native lands and the rivers have become acidic from AMD (*13*). Judith Nies writes that “sheep that drink from [polluted] ponds at noon are dead by suppertime.” The mining creates other problems besides AMD. When the coal is mined the it is pumped to power plants on a slurry. The coal is polluting the water and the pumping is draining the ground water that the Navajo and Hopi depend on. The coal is then burned to create electricity. Once it is burned, the coal releases sulfur into the air, which can cause the formation of acid rain, much like the AMD that is created in the streams at Black Mesa.

As the previous examples show, recent mining has immediate effects on the earth. A study of sulfur mining in Spain shows how mining from the Roman times through the 4^{th} century A.D. are still having large effects on the environment. The rivers near the mines became contaminated with AMD, and the heavy metals from that time are still found in ocean sediments today *(14)*. In Yellowstone National Park in Wyoming it has been shown that the percentage of survival for caddis flies was lower in streams affected by AMD than in the places where streams are unaffected *(15)*. This drop in biodiversity could affect the whole food chain, and it could contribute to heavy metal accumulation in many different species, including humans. People in Spain and across the world still eat shellfish and other animals that are from the contaminated areas of the rivers and oceans. Mining from the past was clearly unsustainable, so we should explore how to make mined lands sustainable again.

Other scientists have been investigating ways to reclaim mines to make the land safe. They have researched methods such as using limestone, sheep manure, phyto-remediation and constructed wetlands to reverse the effects of AMD. Limestone has a very basic pH level, which could reverse the acidity of AMD. Although limestone has a neutralizing effect, it is also mined and can be expensive (*16)*. In an experiment with a mixture of sheep manure and limestone, Gilbert *et al* found that the mixture neutralized pH and eliminated heavy metals, except for zinc, in AMD. However, there was no change in the amount of sulphate reducing bacteria which are important in neutralizing the sulfur *(17)*. Another study took AMD from the Leona Heights Mine and put it in a controlled environment of organic matter and dead cattail as a growth medium for sulphate reducing bacteria. This combination caused the pH of the water to increase and heavy metals to decrease, when the bacteria were present *(18)*.

These lab experiments have been done at a larger scale with AMD in Alabama. Scientists built constructed wetlands and found that they work more efficiently to reduce heavy metals than naturally occurring wetlands *(19)*. Since there is not an abundance of oxygen in anaerobic wetlands, sulfur is not oxidized; hence, the mineral does not become acidic. Thus, constructed anaerobic wetlands can be excellent ways to treat waste and prevent pollution *(16)*.

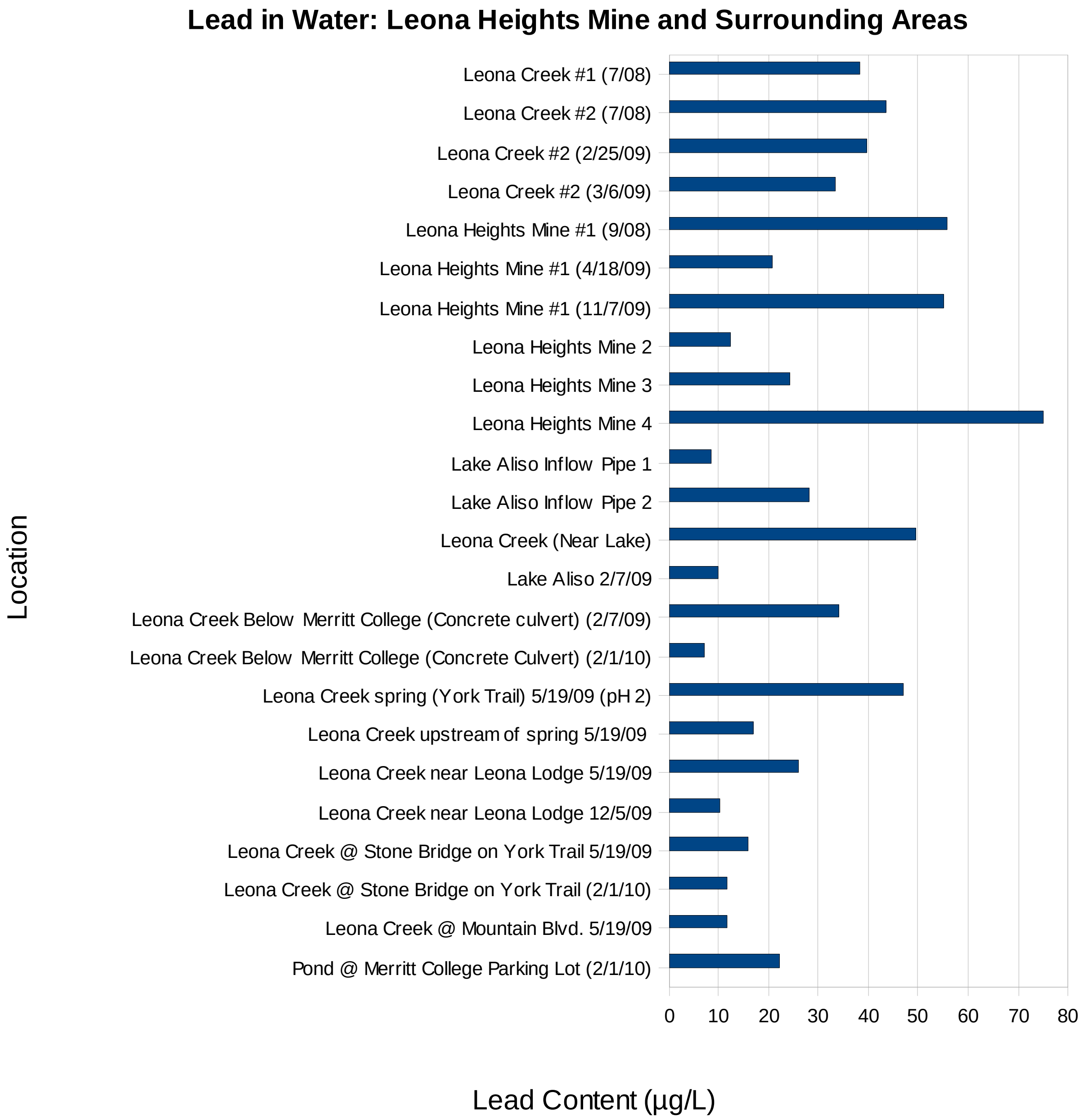
The process of plants take up heavy metals and other pollutants is called phyto-remediation. A plant called *Cistus ladanifer* grows on the acidic earth around the pyrite mining area in Portugal and Spain. The land has low pH, poor nutrients, and is high in toxics, but the plant is still able to survive in such extreme soil. *Cistus ladanifer* is able to uptake some heavy metals such as manganese but not lead *(20)*. *Cistus landanifer* and other plants could be used alongside other methods to clean areas with AMD, such as the Leona Heights Mine in Oakland, California.

As our research has shown us, mining is not sustainable. Mining throughout the world pollutes the water and air with heavy metals that cause brain disorders, learning disabilities and cancer and causes the death of surrounding plants and animals.. The water from mines flow into rivers and then past homes and schools, which could poison our water sources. We are harming ourselves and everything around us when we do not clean old mining areas. It is time for us to fix the dangerous environment we have created. We should continue to test different methods that neutralize AMD. At the Leona Heights Mine, for example, the land owner should install wetlands and coat layers of compost and manure over the acidic soil.

Instead of mining, companies should actually focus on developing alternatives. We don't have to completely stop the use of metals. To be sustainable we could reuse all the metals and elements that have already been mined, and try to develop new materials that have similar functions as the metals and elements we currently mine. For example, we can reuse iron and steel from old buildings that were abandoned and use them for new buildings. As for sulfur, it is used for many things such as explosives and batteries, but we could reduce the amount we produce for certain uses that are not necessities. In the long run we must make our resource use more sustainable so our communities do not continue to have such high rates of health problems attributed to mining pollution.

Figure 1: Map of Sample Locations in Oakland, California

Figure 2:



Lead in Water: Leona Heights Mine and Surrounding Areas
Leona Creek #1 (7/08)
Leona Creek #2 (7/08)
Leona Creek #2 (2/25/09)
Leona Creek #2 (3/6/09)
Leona Heights Mine #1 (9/08)
Leona Heights Mine #1 (4/18/09)
Leona Heights Mine #1 (11/7/09)
Leona Heights Mine 2
Leona Heights Mine 3
Leona Heights Mine 4
Lake Aliso Inflow Pipe 1
Lake Aliso Inflow Pipe 2
Leona Creek (Near Lake)
Lake Aliso 2/7/09
Leona Creek Below Merritt College (Concrete culvert) (2/7/09)
Leona Creek Below Merritt College (Concrete Culvert) (2/1/10)
Leona Creek spring (York Trail) 5/19/09 (pH 2)
Leona Creek upstream of spring 5/19/09
Leona Creek near Leona Lodge 5/19/09
Leona Creek near Leona Lodge 12/5/09
Leona Creek @ Stone Bridge on York Trail 5/19/09
Leona Creek @ Stone Bridge on York Trail (2/1/10)
Leona Creek @ Mountain Blvd. 5/19/09
Pond @ Merritt College Parking Lot (2/1/10)
Location
0
10
20
30
40
50
60
70
80
Lead Content (µg/L)

Figure 3:

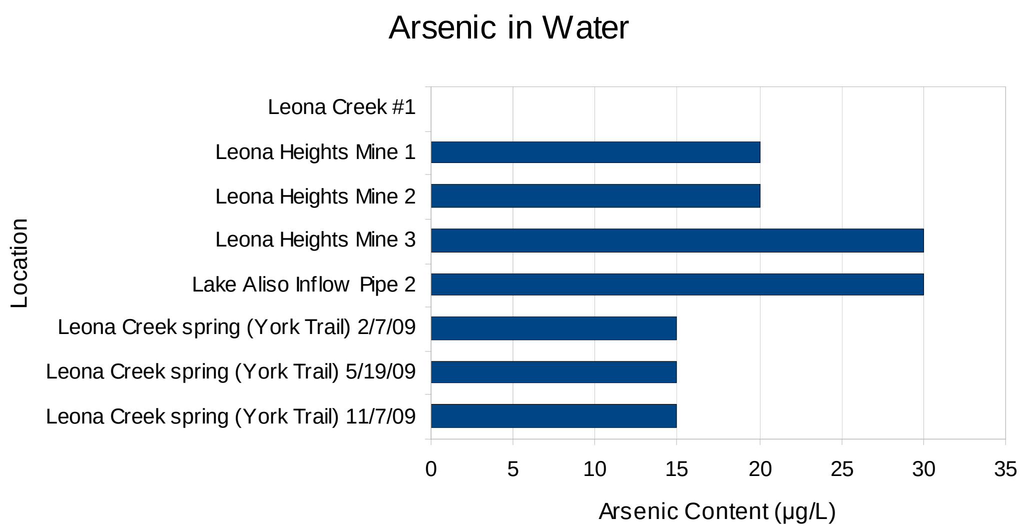
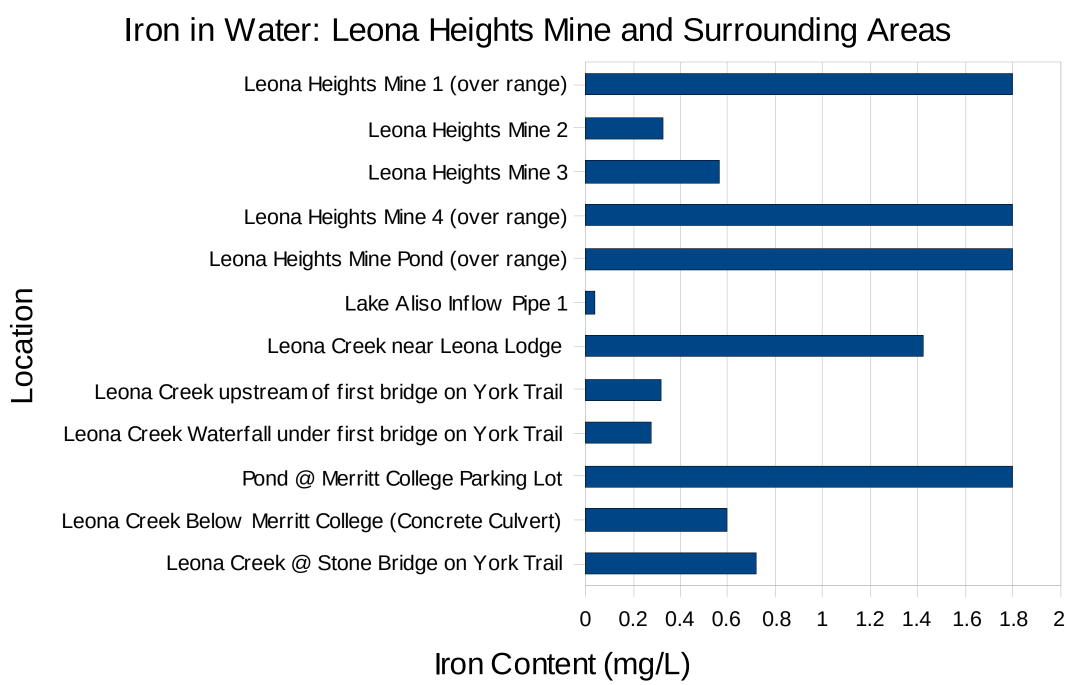


Figure 4:



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