Understanding the Threat of Disaster from Mining Wastewater Entering the Water Table and how it will affect the Ecosystem of Butte, Montana

Submitted in fulfillment of the requirements for graduation with honors from the Department of Natural Sciences at Carroll College, Helena, MT

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April 12, 2011

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April 12, 2011

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Acknowledgements

I would like to thank Dr. Grant Hokit, my thesis adviser, for his dedication to his students, his unflappable patience with me, as well as his liberal policy toward deadlines. I would also like to thank my readers, Murphy Fox for his good humor and persistent encouragement, and Jeff Kuhn for infecting me with his genuine excitement for learning. Finally, I would like to thank my family for their faith in me and their sense of humor about the whole thing.

Abstract

Due to the immediate incentives for mining in Montana, specifically in Silver Bow County, there was little foresight into proper disposal of the mine waste. These problems were only exacerbated by the steep fall of copper prices which undercut the ability for these companies to provide proper cleanup measures to ensure safety for the future. The Berkeley Pit in Butte, Montana is potentially an ecological disaster; one that must be understood properly from an environmental and ecological position. The focus of this paper is to examine the potential effects on a variety of representative biota in the Silver Bow Valley, as well as to provide discussion as to how to deal with the problem proactively, citing specific examples, so as to avoid catastrophe in the coming years.

Introduction

Once dubbed “the richest hill on Earth,” Butte, Montana has long since passed its days of former luster. A literal goldmine, Butte’s hills have been mined for approximately one billion tons of copper, silver, and gold. The days of discovery having passed, all that are left are the remnants of a boisterous mining community: gallows frames, a scarred landscape, and a giant acid-water hole full of mine tailings. The Berkeley Pit is both a tourist site and a potentially serious problem for anyone or anything that uses the groundwater. As the water level rises in the pit, it comes closer and closer to flooding into the water table, which would spell disaster for the organisms of the Butte area, the Silver Bow Creek and the Clark Fork River basins. Estimates done in 2005 conclude that the rising water level of the acid mine drainage (AMD) water in the pit would reach “action level” in 2021 (Montana Bureau of Mines and Geology [MBMG]). It is important, therefore, to understand the effects of heavy metal toxicity preemptively, rather than waiting to see what happens to the ecosystem after the fact. By looking at the metallic and acidic contents of the pit, we can identify the effect each specific heavy metal will have on four types of impacted organisms: trees, terrestrial invertebrates, aquatic vertebrates and humans. Each heavy metal has a unique effect and the different organisms have specific sensitivities to some metals over others; the metals of most importance in the pit are: copper, lead, zinc, as well as compounds like arsenic. It is undeniable that these metals and compounds (among others) are particularly abundant in the pit and dangerous if allowed to escape from its closed system. We can predict the outcome of the disaster and hopefully raise awareness as to the severity of the problem and take appropriate measures to mitigate the outcome.

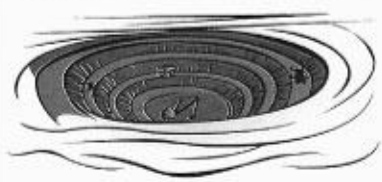
The Berkeley Pit

The pit itself is an impressive sight to behold: 1.5 by 1 miles in diameter and 1,780 feet deep as of 2007 ("MBMG"). The original Butte mines and the mines created after the coming of the greater railroads predominantly consisted of chalcocite (Cu_2S), a copper ore (Davis 251), which sparked the boom in mining. Because of the demand for and profitability of copper mining (pre-World War I), Butte had created an intricate system of underground drains and pumps to lower the groundwater level, which allowed for greater extraction of copper. It is also said that "water extracted from the mines was so rich in dissolved copper sulfate that it was also 'mined' by chemical precipitation for the copper it contained. In 1955, copper mining in the area expanded with the opening of the Berkeley Pit. The mine took advantage of the existing subterranean drainage and pump network to lower groundwater" (NASA). Water from the surrounding rock basin began seeping into the pit after the pumps were shut down and has continued to do so at an alarming rate, approximately 1,800 gallons per minute or 2.55 million gallons per day ("MBMG").

Because of its history, the water is obviously highly acidic and contains high concentrations of both copper (140-190 mg/L) and zinc (540-620 mg/L), as well as arsenic, cadmium, cobalt, iron, manganese, and sulfate ("MBMG"). These heavy metals are very stable—hence they cannot be broken down and metabolized in the body—and cause biomagnification, which means that they are passed up the food chain to humans ("Heavy Metal Toxicity"). Constantly, more and more water is entering the pit, which because it is a terminal system, accumulates and increases the level of the pit, slowly rising to the termed "action level" where the wastewater runs the risk of leaving the

▼ Pit Facts at a Glance

Years of Operation:	1955 - 1982
Ore Mined from the Pit:	316 million tons (286 million metric tons)
Waste Rock Removed from the Pit:	700 million tons (635 million metric tons)
Pit Depth:	1,780 feet (543 meters)
Pit Lake Water Depth:	Over 1,000 feet (over 300 meters)
Pit Width:	1.25 miles (2 km) East-West, 1 mile (1.6 km) North-South
Pit Circumference:	4 miles (6.4 km)
Total Volume of Water in the Pit Lake:	Over 40 billion gallons (over 150 billion liters)
Current Water Level:	5,280.29 (1,609.43 meters)
Critical Water Level:	5,410 feet (1,649 meters)
Level at which Pit water would reach a surface outlet:	5,509 feet (1,679 meters)
Current Rate of Fill:	2.6 million gallons (10 million liters) per day
Rate of Fill, 1982-1996:	5.2 million gallons (20 million liters) per day
Rate of Fill, 1996: (after the diversion of Horseshoe Bend flows to the Yankee Doodle Tailings Pond, and, in 2003, to the Horseshoe Bend Water Treatment Plant)	3.1 million gallons (12 million liters) per day
Pit Water pH*:	2.5 to 3.0 (the pH of Cola is about 2.5)
Sludge Discharged to the Pit from the Horseshoe Bend Water Treatment Plant since 2003:	211,000 gallons (800,000 liters) per day, or 160 gallons (605 liters) per minute
Pit Water Pumped for Copper Extraction:	13.2 million gallons (50 million liters) per day
Metals & Minerals Present in Pit Water:	Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na), Iron (Fe), Manganese (Mn), Aluminum (Al), Cadmium (Cd), Copper (Cu), Zinc (Zn), Arsenic (As), Chloride (Cl), Fluoride (F), Sulfate (SO4)
Pit Water Metal Concentration Examples:	150 mg/L Copper, 600 mg/L Zinc, 1000 mg/L Iron



***What is the pH scale?**
pH is a measure of the acidity or alkalinity of a solution. Pure or neutral water has a pH of 7.0. Acids are defined as those solutions that have a pH less than 7; while bases are defined as those solutions that have a pH greater than 7. The pH scale is logarithmic. Unlike linear scales, which have a constant relationship between the item being measured and the value reported, each individual pH unit is a factor of 10 different than the next higher or lower unit. For example, a change in pH from 2 to 3 represents a 10-fold decrease in acidity, and a shift from 2 to 4 represents a 100-fold (10 × 10) decrease in acidity.

Figure 1. A quick reference-guide to the important details (image reprinted with permission, courtesy of "PitWatch").

system. The pit contains serious ecological hazards as well as detriments to human health if the water ever breaches its closed system.

The Potential Problem

The Berkeley Pit is a serious threat to ecological health of the community because of the potential damage it could cause to the water table. In order to prevent the pit water from leaving and entering into aquifers and surface waters, it must remain a "terminal pit", meaning that it is a sink for bedrock ground water. The Environmental Protection Agency (EPA) and the Montana Department of Environmental Quality (DEQ) have established 5,410 feet as the maximum elevation that the wastewater can reach before it leaves the terminal pit. The water level elevation as of December 2007 was 5,269 feet, which is only 141 feet below the critical water level (see Fig 2.). The problem is apparent and only getting closer and closer to the breaking point, flowing out from the pit, down gradient into the Silver Bow Valley.

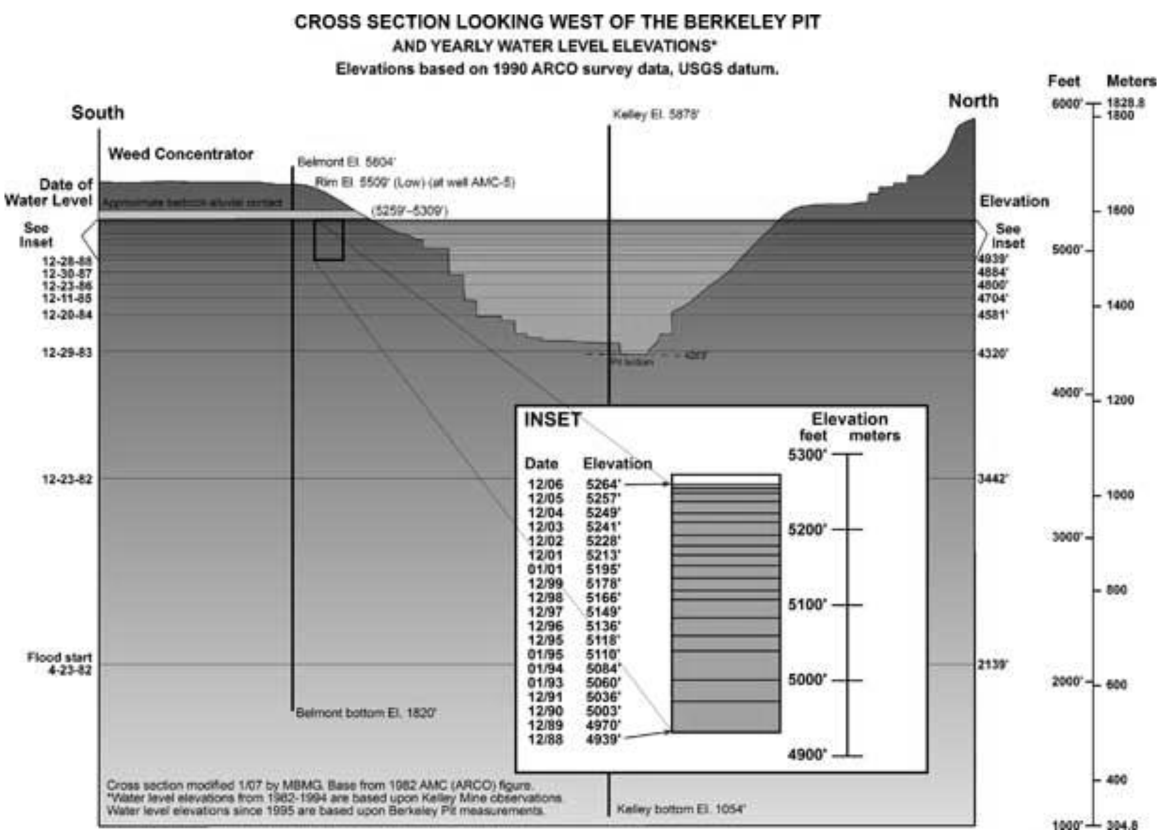


Figure 1. The cross-section view of the Berkeley Pit System (image reprinted with permission, courtesy of MBMG).

Heavy Metals

The Environmental Protection Agency has set standards of allowable contaminant levels for each individual contaminant, called a Maximum Contaminant Level (MCL), which are defined as "the highest level of a contaminant that is allowed in drinking water" ("EPA Index"). Along with establishing maximums for the contaminants, the EPA also sets a Maximum Contaminant Level Goal (MCLG), where the attempt is to determine "the level of a contaminant in drinking water below which there is no known or expected risk to health" ("EPA Index"). Though this is the standard for drinking water, and obviously the pit is not a source of potable water, these standards will set both a reference point and a goal for the AMD water. Though high acidity is also a problem, the biggest focus will be on the heavy metals, specifically copper and lead, which have significant effects to organisms' health.

It is important to see how damaging lead and copper poisoning is in order to understand the severity of the danger. "Lead poisoning is… linked to cognitive and behavioral impairment… Recent research has indicated that significant neurologic damage to children occurs at very low levels of exposure" (Gould 1162). Gould's essay goes on to explain the cost-benefit of increased lead hazard control, concluding that every dollar spent on lead hazard control would return between $17 and $221, which translates to between $181-269 billion dollars of savings (on health-care costs, lifetime earnings, decreased special education and attention deficit-hyperactivity disorder, a decrease in crime, etc) (Gould). As if the argument for safeguarding the environment was not enough!

The human threshold for lead is indeed low; the EPA has established that the MCL is 0.015 mg/L (or ppm) and the MCLG is zero. Because of the severe effects in children and pregnant women and the ability to cause kidney problems and high blood pressure in adults, the EPA has taken a very serious stance on lead in drinking water. Fortunately, lead is not a relatively regular element in the toxic brew, so its effects are not as dangerous compared to the more prevalent metals.

As stated above, Butte gained its notoriety for the incredible amount of copper mined from the surrounding hills, so it is safe to say that copper presents a severe risk as a major contaminant in the AMD water. The MCL and MCLG of copper are a bit more modest than that of lead, at approximately 1.3 mg/L. As stated above, however, estimated concentrations of dissolved copper in the pit are approximately 140 mg/L in the epilimnion (the upper-stratified layer of liquid) and 190 mg/L in the hypolimnion (the lower-stratified layer of liquid).

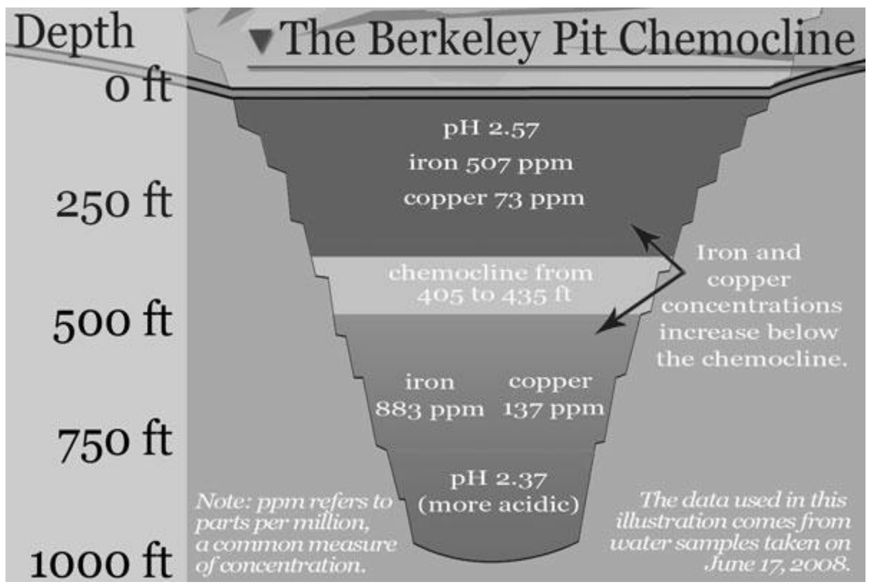


Figure 2. An animation of the epilimnion and hypolimnion of the Berkeley Pit. The chemocline, a zone of rapid chemical and physical change, separates stratified layers of the Berkeley Pit, allowing for two different pH levels and metal concentrations (image reprinted with permission, courtesy of "PitWatch").

There is a vast array of metals in the pit that have concentrations which are harder to estimate than the more significant metals. The EPA created what are called "secondary regulations", which are "non-enforceable guidelines regulating contaminants that may cause cosmetic effects or aesthetic effects in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply" ("EPA Index"). This secondary standard is more lenient and idealistic, and it can be adopted as state law on a state-by-state basis. This list is also more inclusive; zinc, iron, manganese, and sulfate are accounted for as contaminants (Table 1). This secondary list, though non-enforceable under federal law, provides researchers with a tentative guide to the effects of specific heavy metals and their toxicity and danger relative to each other.

Table 1: Secondary Maximum Contaminant Levels ("Government Printing Office")

Contaminant	Level
Aluminum………………	0.05 to 0.2 mg/L
Chloride…………………	250 mg/L
Color……………………..	15 color units
Copper…………………..	1.0 mg/L
Corosivity……………….	Non-corrosive
Fluoride………………….	2.0 mg/L
Foaming agents…………..	0.5 mg/L
Iron………………………	0.3 mg/L
Manganese………………	0.05 mg/L
Odor……………………..	3 threshold odor number
pH……………………….	6.5-8.5
Silver……………………..	0.1 mg/L
Sulfate……………………	250 mg/L
Total dissolved solids……	500 mg/L
Zinc………………………	5 mg/L

The Affected Organisms

It has been well established that water containing high concentrations of heavy metals can be very harmful to organisms that either encounter it directly by consumption or indirectly by secondary effects such as consuming contaminated organisms. Unfortunately little to no data exists on the ecosystem of the Butte watershed specifically with respect to wastewater. Using other sample species, assumptions can be made for similar species found in Silver Bow County.

Flora

Plants are a very visible victim of wastewater damage as well as strong indicators of community health. Drawing their water from the soil, most wetland plants would be devastated if the mine water were to invade the groundwater. However, a buffer does exist: “higher plants are capable of accumulating heavy metals without any toxic symptoms to such levels that can be hazardous for human health” (Bielińska 895). Plants, specifically trees and woody shrubs, are not defenseless against heavy metal toxicity and have several mechanistic techniques to survive in an inhospitable system, such as the ability to bind heavy metals into “non-bio-active” forms and chelating them into complexes (Mleczek 1609), or simply a tolerance for the metals. Plants are able to accumulate heavy metals, but this ability depends on many interrelated factors. “The most important of these include the plant genotype, its biomass increment, soil conditions, adaptability to new environmental conditions and interactions between metals as well as their availability” (Mleczek 1609), as well as heavy metal type itself and plant species. In the case of high (not necessarily lethal) concentrations, which affect the plant's metabolism, the metal's concentration has the most significant effect (the level of toxicity of the respective metal is not significant). As stated, plants have several defenses to survive a high level of heavy metal concentrations in the soil, but when the metal concentration is greater than the plant's maximum level tolerable, the above mechanisms are not sufficiently effective to defend the plant, which ends with its slow atrophy (Mleczek 1609). In Mleczek's research on *Salix* (willow) species, he collected sample specimens based on different heavy metal contents to determine the absorption of respective heavy metals in the plants (e.g. shoots, roots, bark, leaf and petioles) (Tables 2 and 3). The data concludes that heavy metal absorption in *Salix* species is significant in both the structure of the plant and the soil factors.

Table 2. Absorption of heavy metals in different tissues in Salix (Mleczek 1613)

Tissue	***Metal Accumulation Abilities of Tissues***						
Root	Zn	Cd	Pb	Cu	Co	Cr	Ni
Bark	Cu	Cd	Zn	Co	Pb	Cr	Ni
Leaf	Ni	Cr	Co	Zn	Pb	Cu	Cd
Petioles	Cd	Cr	Zn	Cu	Pb	Ni	Co
Shoot (0.1 m)	Cu	Cr	Zn	Cd	Pb	Ni	Co
Shoot (1 m)	Cd	Cr	Cu	Pb	Ni	Zn	Co

Table 1. Correlation coefficients of the metal contents in the soil and in Salix tissues. A positive coefficient details the extent of a metal's concentration in the soil and its effect on individual tissues (Mleczek 1611)

Tissue	***Cd***	***Co***	***Cr***	***Cu***	***Ni***	***Pb***	***Zn***
Root	0.558	0.497	0.380	0.786	-0.114	0.630	-0.145
Bark	0.697	0.923	0.545	0.751	-0.048	-0.157	-0.070
Leaf	0.413	-0.483	0.737	-0.166	0.069	-0.421	0.608
Petioles	0.787	-0.344	0.831	-0.166	-0.452	-0.548	0.391
Shoot (0.1 m)	0.657	0.342	-0.007	0.745	-0.147	-0.343	-0.197
Shoot (1 m)	0.740	-0.041	0.276	0.971	-0.184	-0.668	-0.125

It is assumed that the plants will only begin to die if the water surpasses the critical mark, however, if the system could be breached before this, it would be difficult to notice a problem before the chemicals started affecting wildlife. However, it is possible to tell if the plants are in danger before they begin to show atrophy. Changes in enzymatic processes in the soil are the early warning signs, "many chemical compounds assume a toxic or mutagenic character following metabolic transformations occurring in living organisms" (Bielińska 896). There is a chance that the mine water could get out of the system before it reaches the 5,410 ft critical mark, and enzymatic processes could be the first clue scientists have that a problem exists.

Terrestrial Invertebrates

If the Berkeley Pit system invades the watershed, it would most likely cause a bottom-up ecological cascade effect, starting with the primary producers like plants and the bottom of the food chain, notably arthropods and annelids (terrestrial invertebrates). Garg et al. tested the effects of heavy metal concentrations on the survival (reproduction and metal accumulation) for two species of earthworms. He specifically chose a local and an exotic species, the exotic species in the experiment is representative of Montana species (it is assumed that all annelids/arthropods, save extreme examples, are intolerant to heavy metals at a high enough concentration). The data concluded that the two species of earthworms in this study (*Alloloboraphora parva* and *Eisenia fetida*) were more tolerant to heavy metal intake than control species, especially the local species (*A. parva*). However, both species were unable to survive any dosage of copper (Table 4), and the other metals (Cr, Cd, Pb, and Zn) all produced significant mortality rates for the two species. Sub lethal doses of the heavy metals also are known to cause a decrease in reproductive rates by reducing the number and hatchability of egg capsules and by increasing the time in the embryonic state (Garg 1029). It must be said that this data is specific to the two tested species of earthworm mentioned above, and that it may not be a perfect indicator of how earthworms or annelids in general are affected by heavy metals in the soil. Earthworms were chosen for this paper because of their tolerance to the

Table 3. Concentrations of heavy metals in the two species of earthworm. Note especially the mortality rate of Cu, an important heavy metal of the Berkeley Pit (Garg 1027).

Metal	***Species***	***Background concentration of heavy metals in earthworms (mg/kg)***	***Spiked heavy metal (mg/kg)***		
			Heavy metal concentration in earthworms after 45 days		
			500	*1500*	*2500*
Cu	*Allolobophora parva*	0.62 ± 0.05	x	x	x
	Eisenia fetida	0.57 ± 0.90	x	x	x
Cr*	*Allolobophora parva*	0.30 ± 0.25	416 ± 2.0	728 ± 5.8	757± 4.5
	Eisenia fetida	0.28 ± 0.13	323 ± 3.0	617 ± 2.5	658 ± 4.0
Pb*	*Allolobophora parva*	0.47 ± 0.04	352 ± 0.5	490 ± 5.0	611 ± 3.0
	Eisenia fetida	0.62 ± 0.03	195 ± 1.7	246 ± 2.9	415 ± 8.0
Zn	*Allolobophora parva*	23 ± 1.65	168 ± 2.4	x	x
	Eisenia fetida	34 ± 0.52	155 ± 0.3	x	x
Cd	*Allolobophora parva*	0.60 ± 0.05	368 ± 2.5	790 ± 10	x
	Eisenia fetida	0.56 ± 0.24	216 ± 2.1	660 ± 3.2	x

* Shows significant difference ($P < 0.05$) in metal concentrations between species
x Shows mortality

impact of heavy metals. However, if they are the extreme end of the tolerance spectrum and they were susceptible to mortality due to metal toxicity, then it is likely that other terrestrial invertebrates would succumb to poisoning similarly or even more significantly than earthworms. Regardless, this study shows that terrestrial annelids and arthropods are at risk in the event of disaster.

Aquatic Vertebrates

The chemical composition of the water directly and indirectly affects aquatic organisms. Heavy metals are critically important with respect to aquatic vertebrates. Fish, because of their susceptibility to encountering concentrations in the sediments and in the water itself are quite vulnerable to the effects of heavy metal contamination. “Aquatic systems reflect perturbations in the environment; hence fish can often be used to indicate the health of an aquatic system because chemicals can be accumulated in fish and can cause harmful effects [to the fish]" (Ebrahimpour 361). Fish behaviors are sensitive to even sublethal exposure to heavy metals. Fish have few defenses against heavy metal influx; they are not particularly tolerant of some metals. However, rainbow trout (more so than the other species tested) are able to detect smaller concentrations of certain heavy metals and avoid them (Svecevičius). This adaptation is limited, however, for avoidance leads to a decrease in species habitat range. Obviously, because fish cannot leave their aqueous environment and because they have few defenses against heavy metal toxicity, they are particularly vulnerable to mine water damage (Tabari 650).

Humans

The threat of heavy metal contamination is not only one of toxicity, but also of bioaccumulation. Even though some of these metals are necessary for metabolic processes at low concentrations, they are dangerous once they surpass a threshold. Other metals are not metabolically involved in humans and gradually accumulate with age. People who live in historic mining areas, such as Butte and much of Montana, are at a high risk of poisoning. Heavy metals contaminate the water and get taken up into higher trophic levels of the food chain without being diluted; so even affected earthworms can indirectly harm humans who consume the predators of the earthworms (i.e. fish and birds). As previously discussed, fish can also accumulate heavy metals through encountering them in river sediment. In addition to exposure via soil and groundwater, heavy metals can also be emitted into the air and can directly impact humans. "Increased content of some elements including copper, cobalt, and arsenic…can cause some inflammatory diseases and cardiac functional disorders" (Tabari 650). All of these—bioaccumulation and biomagnification, groundwater infiltration, and airborne particles—all have the potential to affect human health.

Though no studies were available with respect to how humans are affected by mine water. In Jairo Zocche's study regarding the heavy metal content and the DNA damage of the blood cells of insectivore bats in Brazil, he stated that, "In coal mining areas, insectivorous bats can be used as bio-indicators of human health risks, because these animals are at the same trophic level in the food chains as humans. Furthermore, bats use the space above streams, ponds or riparian vegetation as feeding sites and frequently forage on emerging adult aquatic insects" (Zocche 685). In some of these Brazilian bats, the concentrations of copper, chromium, nickel, iron and lead in their livers were higher and their DNA also showed a significant amount of damage than the controls (Zocche). The health effects of heavy metal toxicity are vast and far-reaching, even having the potential of causing cancer in humans.

Remediation Possibilities and Prevention Measures

Though this paper is not meant to provide the means to solve the crisis in Butte, it is important to touch on why wastewater cleanup is relevant ecologically. The reason to treat wastewater is to "protect human and ecological health in cases where people or ecological receptors may come in contact with the impacted mine water through indirect or direct use" (Verburg 309). Several measures have been investigated as means to eliminate the problem (liming, magnetizing the metals, precipitation, etc.). The two problems that need to be overcome are: 1) the removal of the metals from the water, and 2) the acidity of the water. There have been tests, including those described in Petritz et al. 2009 which attempt to both use chemical lime or NaOH to raise the pH and to eliminate the chemical precipitate remaining in the solution. Ideally, the remediated mine water would be suitable for many potential uses including, but not limited to, irrigation, industry, or even for consumption. However, even though the mine water metal levels were lowered to drinking water standards by a combination of aeration and pH adjustments, the economic practicality for a larger-scale operation are dramatic and compounded as the scale increases (Petritz).

Because AMD runoff is such a drastic issue, there have been several different attempts to find solutions, including natural systems such as vertical wetlands. The problem with this is that the sulfate-reducing bacteria are typically limited by nitrogen in these environments. In Daubert and Brennan's research, they used chitin from crab shells not only as a source of nitrogen to aid in the ability of the bacteria to reduce sulfate, but they also found that chitin can effectively remove heavy metals, including copper, iron,

Table 4. Chemical analysis of AMD water after chitin treatments (Daubert 1477)

	Raw Water (t = 0)	***Control (no chitin)*** (t = 9 days)	***Experimental (Chitin)*** (t = 9 days)
pH	3.2	3.3	6.8
Hot acidity (mg/ as $CaCO_3$)	192.3	164.4	114.1
Alkalinity (mg/L as $CaCO_3$)	0	0	235.1
Aluminum (mg/L)	14	16	<0.05*
Manganese (mg/L)	21	5.2	<0.05*
Iron (mg/L)	12	12.5	2.3
Chloride (mg/L)	5.17	6.21	23.9
Nitrate (mg/L)	1.58	0.8	0.66
Sulfate (mg/L)	489.3	471.1	303.2

Values are duplicate averages; *below detection limit

nickel, zinc, and aluminum from solution. Over their nine day experiment, they found that the metals were removed due to “physical sorption at low pH early in the experiment followed by precipitation at higher pH later in the experiment” (Daubert 1478). Overall, due to chitin treatments, pH was increased from 3.21 to 6.79 and iron and aluminum concentrations were reduced by over 99% (Daubert). Though the authors do warn that additional tests would be necessary in different microcosms, their results indicate the potential remediation ability of chitin holds promise.

Though few of the proposed solutions so far seem very economically feasible, it is important that we continue to investigate potential remediation techniques in the immediate future. While the potential risk for humans is difficult to accurately predict, the residents and biota of the Silver Bow drainage should not have to determine the risk through direct exposure to heavy metal contaminants.

The Horseshoe Bend Water Treatment Plant

The pit is constantly being filled by several streams and by storm water flow, but one drainage in particular stands out: the Horseshoe Bend drainage. This drainage was especially dangerous, being extremely sediment-laden and discharging over 2.6 million gallons per day ("PitWatch"). Completed in 2003, the Horseshoe Bend Water Treatment Plant has rerouted drainage in order to treat the AMD. The plant uses a High Density Solid (HDS) process, which is a process that produces a dense sludge that, as wastewater is cycled and recycled through, becomes more and more dense, allowing treated water to flow out. It uses a two-part lime precipitation process with the HDS, which removes metals from the water. The advantage of this system is that it produces much less sludge than conventional lime treatments, and the relatively low amount of sludge is then deposited in the pit (the ultimate goal being to slow the fill-rate of the pit until it can be treated later, more cost efficiently). The plant underwent a performance review in 2007, where it was determined that the water discharged from the plant met all the EPA standards for contaminants, though modifications need to be made to account for pH. Remediation alternatives such as those practiced for the Horseshoe Bend Drainage offer viable short-term solutions for minimizing flow into the pit and for treating highly contaminated water.

Conclusion

The people in Butte who once sat on "the richest hill on Earth" are now facing being drowned by the historical effects of mining the hill. The Berkeley Pit is a serious problem, not only for humans, but for the entire ecosystem at large; trees, annelids, rainbow trout and humans at the very least will be affected. We know that everything is related in the ecosystem and affecting one trophic level affects all the others. But the pit has the potential to sweep across all levels in contaminating life's necessary element, water. Those who know the pit see a long list of problems that cloud any hope of saving Silver Bow County from catastrophe. If groundwater flow changes directions, the pit water would flow into tributaries and into larger systems, such as the already threatened Clark Fork River. More research needs to be done with respect to the ecology of the pit. As of now most research focuses on extremophile life in the pit and its potential cure for cancer. It seems ironic that scientists are looking into the pit for cancer cures as the poisonous waters rise. The Berkeley Pit is a Superfund site, and remediation processes are being researched and implemented on smaller scales, but there needs to be a sense of urgency. Even the Horseshoe Bend plant is not scheduled to take on the pit water until 2023. The health and survival of this ecosystem is too important to jeopardize; there is still time before the wastewater reaches a critical level and drastic measures need to be taken.

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