Valzinco Mine Orphaned Land Project:
Mine Site Reclamation Reduces Impacts of Acid Mine Drainage
Knights Branch, VA

WATERBODY IMPROVED

This success story highlights the design and evaluation of the reclamation project administered by the Virginia Deparment of Mines, Minerals and Energy Orphaned Land Program and implemented to abate acid mine drainage (AMD) from the Valzinco sulfide mine in Spotsylvania County, Virginia (VA). Established to support the war efforts in World Wars I and II, the Valzinco mine, a zinc, lead, and copper mine, left behind a denuded landscape, open mine shafts, and a legacy of AMD. Although never formally listed on the U.S. Environmental Protection Agency's (USEPA) Clean Water Act § 303(d) List of Impaired Waters, the Knights Branch had ambient pH and dissolved metal concentrations far enough below natural regional conditions that native flora and fauna could not survive on the site. However, a collaborative group of participants from various state and federal agencies, as well as from the mineral mining industry, private contracting companies, and the public, were able to take advantage of multiple funding sources and greatly improve the ecological integrity of the historically degraded Valzinco mine site. Following reclamation, pH levels in Knights Branch rose back to conditions natural for the Virginia Piedmont (>5.0) and dissolved metal concentrations fell by 75-99.5%.

PROBLEM

Valzinco mine is situated at the headwaters of the Knights Branch watershed in VA, part of the York River basin that discharges into the Chesapeake Bay. The mine workings consisted of multiple levels extending as much as 450 feet deep, and 1,500 feet horizontally beneath the valley. Mine processing operations sent mine spoils and waste processing chemicals to a tailings pond created with a dam constructed across the incised channel and floodplain of the valley. Although the Valzinco Mine remained abandoned and unused for mining purposes from the 1940's until 2001, it was continuously used as a dumping site for trash. In addition, failure of the dam spillway enabled fluvial transport of mine wastes down the watershed, a substantial mass of previous mine spoils laden with crushed pyrite and heavy metals from the ore and chemical residue from the treatment process remained on the upstream side of the dam on the Valzinco Mine site. These sulfide-rich spoils from mining operations resulted in AMD that contaminated the soil and water of surrounding ecosystems through lowered ambient pH and increased levels of dissolved metals to the extent that the soil chemistry, water quality, vegetation, and animals of the Knights Branch watershed were severely adversely affected.

USEPA's compilation of national recommended water quality criteria for the protection of aquatic life and human health in surface water are published pursuant to Section 304(a) of the CWA and provide guidance for states and tribes in adopting water quality standards and setting remedial goals for contaminated sites. These criteria for 150 pollutants can be found at http://www.epa.gov/waterscience/criteria/wqctable/. Based on a pre-reclamation assessment of seasonal variations of acid and metal concentrations in Knight's Branch done by the U.S. Geological Survey (USGS), baseline data for evaluating the success of the reclamation project collected downstream of the mine site revealed that these USEPA acute and chronic water-quality criteria for aquatic ecosystem health were exceeded due to high dissolved levels of acids and metals (iron, aluminum, zinc, lead, copper, cobalt and sulfate)(Seal et al, 2002). In particular, the pH of the water in Knights Branch ranged from 2.6 to 3.9, well below the ambient pH typical for the VA Piedmont region, and mean concentrations of a number of metals in the stream were one or two orders of magnitude above USEPA criteria (**Table 1**). As a result of decreased pH and increased metal concentrations, approximately 11 acres of on-site land were almost completely denuded; vegetation was sparse to non-existent, and woody vascular plants rarely survived for more than a year on the spoils and were usually represented by only their standing-dead remains. The positive feedback between decreased pH / increased metal concentrations in soil and water and loss of vegetative cover, subsequently resulted in further release of the spoils, increased downstream drainage, and exacerbated water quality conditions (*i.e.*, pH and metal concentrations) up to several hundred feet downstream, due to the loss of stabilizing vegetative root systems.

PROJECT HIGHLIGHTS

Oxidation of pyrite or pyrrhotite in mine waste generates acid that can attack other sulfide and aluminosilicate minerals in the waste material and release base metals. Since the high levels of acids and dissolved metals in AMD are generated via geochemical and microbial reactions that occur in the presence of sulfur-containing minerals, free oxygen, and water, the main environmental goals for the reclamation project was to isolate the mine spoils from atmospheric oxygen and reduce or prevent fluvial transportation of spoils downstream in the Knights Branch watershed to depositional environments through the existing channel.

The reclamation activities began in 2001 and proceeded in two significant phases through 2007. During phase one, four acres of spoil were excavated, mixed with bactericide and lime to eliminate acid producing microbes and neutralize acid, respectively, and 'dry' land filled on site. The landfill was then covered with a two-foot thick cap of clean soil and native vegetation to reduce infiltration of precipitation and prevent erosion. Because submerged soil in wetlands is naturally anoxic, the establishment of wetlands was critical for effectively eliminating the oxidation chemical reactions that release acidity into the water column. Therefore, two acres of wetlands full of native vegetation were established in the former tailings pond following the excavation and land filling of the spoil. Alkalinity was added to the remaining spoil masses through the use of submerged, sacrificial, aggregate limestone beds, and a new spillway was built to allow for natural stream flow through the site. Below the dam, three step-pool structures were constructed out of dimension stone and riprap to create two additional acres of wetlands.

During the second phase of reclamation, an area of approximately one acre in size, where spoil had been fluvially transported downstream of the mine, was excavated and the spoil was 'dry' land filled, treated, and covered to support vegetation. Three hundred feet of spoil-laden streambed were also restored by establishing native vegetation on site. Reclamation ended with the planting of more diverse varieties of native plants in the wetland areas and the reseeding of the dam area. In particular, legumes, which fix nitrogen from the air and store it in their roots, were established to enhance the productivity of the disturbed soil on the site. Lastly, in December of 2007, approximately 400 wetland and riparian trees and shrubs were planted at the mine and along the restored stream.

RESULTS

The final products of this reclamation project included:

- Revegetation of 11 acres with indigenous plants.
- The creation of 4 acres of wetlands.
- The excavation and consolidation of mine spoils in onsite disposal/landfill cells capped with clean soil.
- Installation of anoxic limestone drains to add alkalinity to the system.
- The capping of three mine shafts with reinforced concrete caps and the demolition of hazardous structures remaining on the site.
- Restoration of 300 feet of stream channel.
- Abatement of AMD and associated heavy metal contamination including biocide treatment of selected areas to inhibit AMD development.

Notable evidence of improved ecological health and integrity at Valzinco as a result of the aforementioned remediation work are abundant. Water quality measurements recorded before and after reclamation showed an increase in average pH from 3.4 to 5.1, an increase in hardness of 37 %, and decreases in total dissolved solids (68 %), Fe (94 %), Al (98 %), Zn (77 %), Pb (99.5 %), Cu (97 %), Cd (94 %), and sulfate (81 %) relative to mean pre-reclamation values (**Table 1**). It should be noted that even though significant reductions in dissolved metals have been recorded, the concentrations of Cu and Zn remain above USEPA and VA hardness-based acute and chronic ecosystem toxicity criteria, and the concentration of Pb remains above USEPA hardness-based chronic ecosystem toxicity criteria. However, these elevated concentrations appear to be at least partly attributable to the natural lithology and pre-mining characteristics of the watershed.

Table 1. Pre- and post reclamation water quality for filtered (0.45 µm) samples at downstream site (VLZN-3) compared to USEPA aquatic ecosystem toxicity criteria and VA water quality standards for aquatic life when available. [1]

Parameter	Units	Pre-Reclamation				Post Reclamation		USEPA Acute Toxicity Criteria[2]	USEPA Chronic Toxicity Criteria[2]	VA Acute Toxicity Criteria[3]	VA Chronic Toxicity Criteria[3]
		Low	High	Mean	Standard Deviation	June 2007	Percent of Pre-Reclamation Mean				
pH	S.U.	2.6	4.0	3.4	0.5	5.1	151			6.0 – 9.0	
Hardness	mg/L $CaCO_3$	10.0	62.0	21.2	14.5	29.0	137				
Sulfate	mg/L	27.0	1,400	204	421	38.0	19				
Fe	mg/L	5.0	69.7	17.7	18.9	1.01	6		1.0		
Al	mg/L	0.6	19.5	3.1	5.8	0.051	2	0.75	0.087		
Mn	µg/L	410	2100	779	529	1,120	144				
Cd*	µg/L	3.2	88	15.2	25.6	0.91	6	1.0	0.4	1.0	0.4
Cu*	µg/L	49.0	2,200	311.6	664.6	9.7	3	5.7	4.2	5.7	3.2
Ni*	µg/L	2.0	37.0	8.5	10.2	2.3	27	512	57	512	7.3
Pb*	µg/L	170	1,300	349	340	1.6	0.5	17.6	0.7	17.6	2.9
Zn*	µg/L	1,900	27,000	5,750	7,548	1,320	23	42.2	3.2	42.2	42

[1] Data table borrowed and modified from Seal et al. 2008.
[2] USEPA toxicity limits are adjusted based on a hardness of 30 mg/L $CaCO_3$. For additional information please refer to http://www.epa.gov/waterscience/criteria/wqctable/.
[2] VA water quality standards for aquatic life are adjusted based on a hardness of 30 mg/L $CaCO_3$. For additional information please refer to http://www.deq.state.va.us/export/sites/default/wqs/documents/WQS_eff_9_11_07.pdf.

Beyond improvements in the abiotic conditions at the Valzinco site, positive biological indicators of ecosystem health are also present. Initial wetland vegetation, both planted and naturally occurring, quickly re-colonized the site with an average ground cover of >74% after five years. Aquatic vegetation cover averaged >50% after two years and many plots had coverage >100%. In addition to increases in the overall abundance of re-established vegetation, the composition, species richness, and abundance of vegetation communities were similar among the restored and near-by reference (un-affected by mine activities) wetlands (>75%, 6.0 spp. m^{-2} vs. 5.5 spp. m^{-2}, average cover 74% vs. 67%, respectively).

Accompanying the re-establishment and abundance of native wetland and aquatic vegetation within the site are observations of terrestrial wildlife, including bobwhite quail and wild turkey. In addition, an improvement in the aquatic ecosystems at Valzinco and return of herpetofauna to the wetland and aquatic communities at Valzinco are supported by the fact that two amphibians (southern leopard frog, pickerel frog) and two aquatic reptiles (brown water snake and northern water snake) were captured on the site during the fifth year.

PARTNERS AND FUNDING

The success of the Valzinco Mine Reclamation Project was built upon technical expertise, monitoring, and assistance stemming from a collaborative group of participants from the Virginia Institute of Marine Science, the USGS, the Virginia Department of Conservation and Recreation (VA DCR), the Virginia Department of Environmental Quality, the Virginia Department of Game and Inland Fisheries, the U.S. Army Corps of Engineers, the Virginia Department of Mines, Minerals and Energy, the mineral mining industry, private contracting companies, and the public. The total cost of the project, $500,000, was funded using $95,000 in grants from the USEPA's 319 Non Point-Source Implementation Grant Program and administered by the VA DCR, and $75,000 from Virginia's Water Quality Improvement Fund, also administered by VA DCR. The remainder of the balance came from the Virginia Department of Mines, Minerals and Energy – Division of Mineral Mining Orphaned Land Program.

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INFORMATION SOURCES

Hammarstrom, J.M., A.N. Johnson, R.R. Seal, II, A.L. Meier, P.L. Briggs, and N.M. Piatak. 2006. Geochemical and mineralogical characterization of the abandoned Valzinco (lead-zinc) and Mitchell (gold) mine sites prior to reclamation, Spotsylvania County, Virginia. U.S. Geol. Surv. Sci. Invest. Rep. 2006-05085. http://pubs.usgs.gov/sir/2006/5085/sir2006-5085.pdf

Seal, R.R., II, A.N. Johnson, J.M. Hammarstrom, and A.L. Meier. 2002. Geochemical characterization of drainage prior to reclamation at the abandoned Valzinco mine, Spotsylvania County, Virginia. U.S. Geological Survey. Open-File Rep. 02-360. http://pubs.usgs.gov/of/2002/of02-360/

Seal, R.R., II, J.M. Hammarstrom, A. Bishop, N.M. Piatak, D.M. Levitan, E. Epp, and R. Sobeck. 2008. Water Quality Before and After Reclamation at the Abandoned Valzinco Zn-Pb Mine Site, Spotsylvania County, Virginia. U.S. Geological Survey, Reston, VA. Technical Presentation given at the 25th Annual Meeting of the American Society of Mining and Reclamation, Richmond, VA, June 14-19, 2008.

Sobeck, R.G., Jr., J.E. Perry, A. Bishop and E. Epp. 2008. Acid Mine Reclamation in Spotsylvania County, Virginia, USA: Using Water Chemistry and Vegetation Re-Establishment as a Measure of Success. Metcalf & Eddy IAECOM, Washington, D.C. Technical Presentation given at the 25th Annual Meeting of the American Society of Mining and Reclamation, Richmond, VA, June 14-19, 2008.

PHOTOS

Before Reclamation

After Reclamation