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THE EFFECTIVENESS OF A VERTICAL FLOW TREATMENT SYSTEM ON ACID MINE DRAINAGE

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ABSTRACT

I determined the effectiveness of a vertical flow acid mine drainage treatment system on water quality in Joller, Pennsylvania. High school students collected data on pH, dissolved oxygen and iron concentration over a 4-year period from input and output wetlands that are part of the treatment system. The pH of the input wetland (2.99) was significantly lower than that of the output wetland (4.38) (t = 3.51; df = 6; P = 0.006). Dissolved oxygen was also significantly lower in the input wetland (8.50 mg/L) than the output wetland (9.70 mg/L) (t = 2.16; df = 6; P = 0.037). The concentration of iron in the input wetland (36.5 ppm) was significantly higher then the output wetland (5.79 ppm) (W = 28.0; df = 6; P = 0.011). My results indicate that the treatment system was treating the acid mine drainage and improving water quality.

Keywords: acid mine drainage, anaerobic wetland, anoxic drained wetland, iron, limestone, pH, vertical flow wetland

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INTRODUCTION

Acid mine drainage (AMD) is a prevalent environmental problem that originates from active or abandoned mines (Ziemkiewicz 1997). AMD forms when pyrite (FeS_2) or other metal sulfides associated with mineral deposits are subject to oxygen and water (Wieder 1989). This exposure to oxygen and water causes a combination of oxidation and microbial catalyzing reactions, which produce large amounts of dissolved sulfate, iron and other metals (Wieder 1989). AMD is characterized by high acidity and low pH values and when it enters a stream; it consumes alkalinity and introduces metal ions, which can have negative impacts on the biological productivity of the stream (Ziemkiewicz, 1997). Macroinvertebrates may decrease in diversity and change in species composition in areas impacted by AMD (Cherry 2001).

Acid mine drainage affects over 2,500 miles of stream in Pennsylvania (Milavec 2002). In the past, alkaline chemicals were the prevalent treatment for acid mine drainage, but they are expensive, dangerous and can cause excessively alkaline water conditions (Hedin 1994). The Pennsylvania Department of Environmental Protection is now using a variety of passive systems to treat AMD because they are inexpensive and require relatively low amounts of maintenance (Milavec 2002, Ziemkiewicz 1997).

In October of 1998, the Pennsylvania Department of Environmental Protection completed a passive vertical flow treatment system in Joller. This system treats the water from two acid deep mine discharges, and a surface mine site before it enters the Roaring Run watershed (Milavec 2002). Vertical flow treatment systems use a perforated under drain pipe collection system, overlain with three to four feet of limestone, overlain with mushroom compost that ranges in depths from six inches to two feet and with approximately two feet of standing water at the surface (Milavec 2002). These systems operate on the principle that the organic material deoxygenates the water containing oxygen and ferric iron (Milavec 2002). This allows the ferrous form of iron to pass through the limestone without armoring (Milavec 2002). In addition, sulfate reduces within the compost layer, which adds some alkalinity to the water and the limestone adds bicarbonate alkalinity to the acid mine drainage (Milavec 2002, Hedin 1994). These systems also employ a flushing method to put any aluminum or other retained metal into a sedimentation facility (Milavec 2002).

There were numerous problems encountered in this treatment system, which included leaks in the ponds and vertical flow wetlands (Milavec 2002). Leaks prevented water from making it through the entire system (Milavec 2002). The Department of Environmental Protection repaired the leaks in April of 2000 (Milavec 2002).

The goal of this study was to confirm if the treatment system is now working effectively. I tested the hypotheses that pH and dissolved oxygen would increase from the input wetland to the output wetland. I also hypothesized that iron concentration would decrease from the input to the output wetland.

FIELD SITE

The study site is located in Joller, Pennsylvania on route 994 in the Saltillo quadrangle. The vertical flow wetland treatment system (Fig. 1) is on Pennsylvania State Game Land in a clearing from the abandoned mining town.

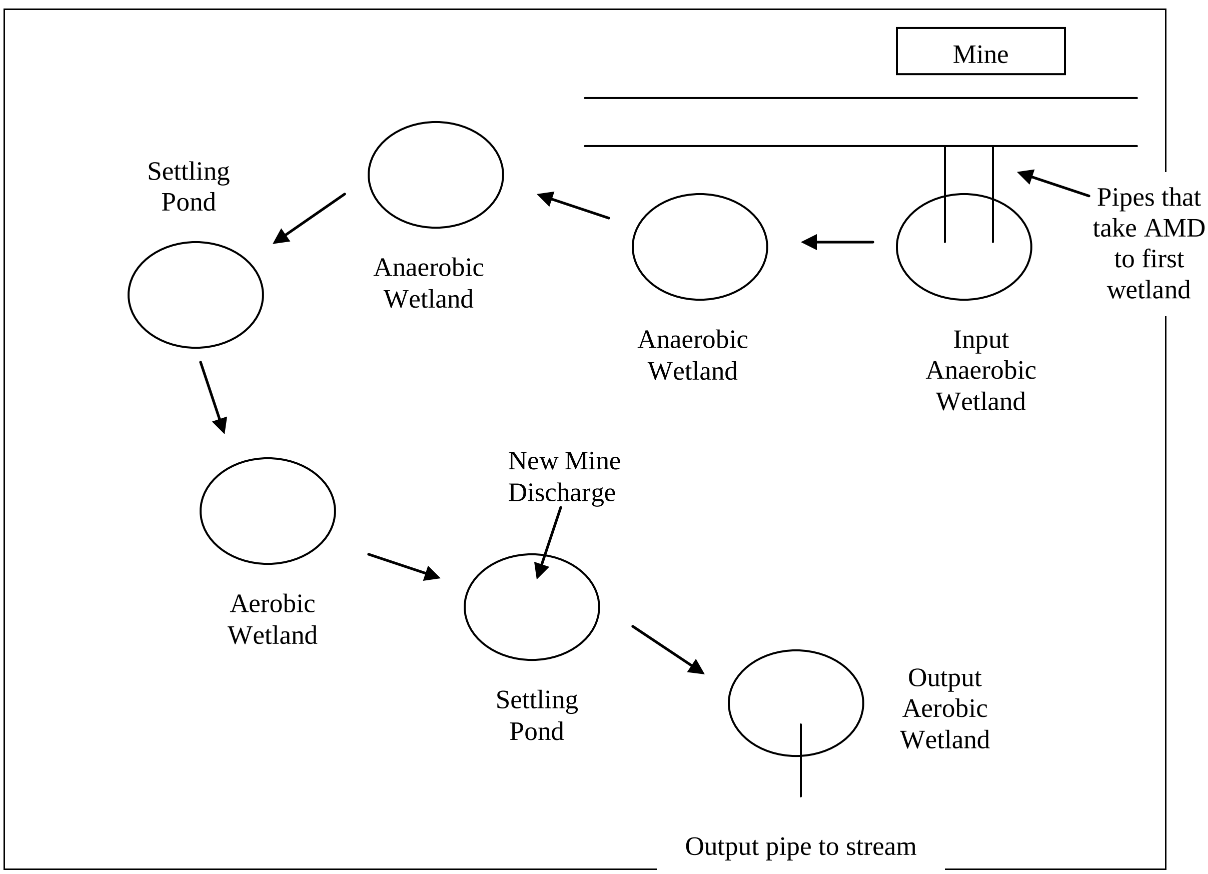

Figure 1. Set-up of the vertical flow acid mine drainage treatment system located in Joller, Pennsylvania in 2002.

METHODS AND MATERIALS

Students from Central High School in Martinsburg, Pennsylvania, collected data on the pH, dissolved oxygen and iron concentration of the system at Joller. Different students collected data 7 times over a 4-year period (1999-2002) using 5 to 15 replicate samples per parameter per visit. The students recorded pH, dissolved oxygen and iron concentration from two locations, the first wetland (input) and the last wetland (output) (Fig. 1). The students used a HACH pH meter, either Winkler titrations or a HACH Dissolved Oxygen meter and a HACH spectrophotometer to measure iron concentration (HACH 1994, 1996).

I first paired the input data to the output data for each parameter by sample date and then compared the dissolved oxygen and pH of the input to the output using a paired t-test (Hampton 1994). I compared the iron concentration of the input wetland to the output wetland using a Wilcoxin Signed Rank Test (Hampton 1994). I considered differences to be significant if $P \leq 0.05$.

RESULTS

The pH of the input (2.99 ± 0.14) was significantly higher than the output (4.38 ± 1.03) (t = 3.51; df = 6; P = 0.006). In addition, the dissolved oxygen was significantly lower in the input (8.50 ± 1.77 mg/L) than the output (9.70 ± 1.72 mg/L) (t = 2.16; df = 6; P = 0.037) and the iron concentration was significantly higher in the input wetland (36.5 ± 36.9 ppm) than the output wetland (5.79 ± 6.9 ppm) (W = 28.0; df = 6; P = 0.011).

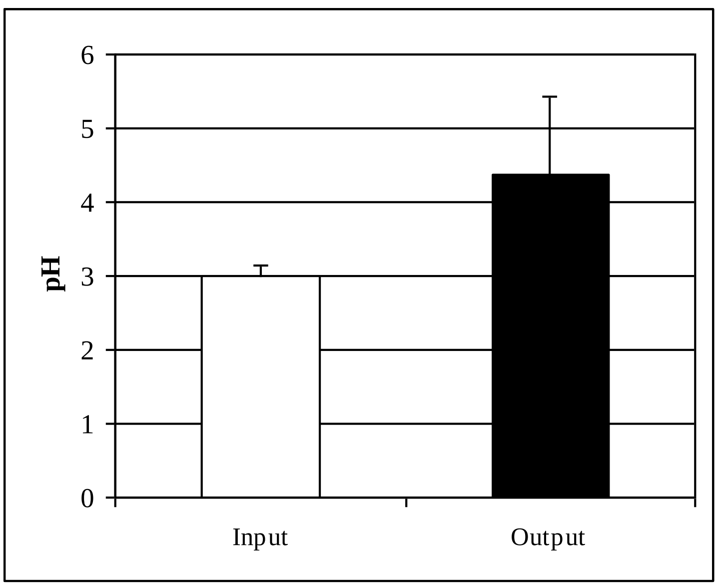

Figure 2. Mean pH for the input and output wetlands at Joller, Pennsylvania, 1999-2002.

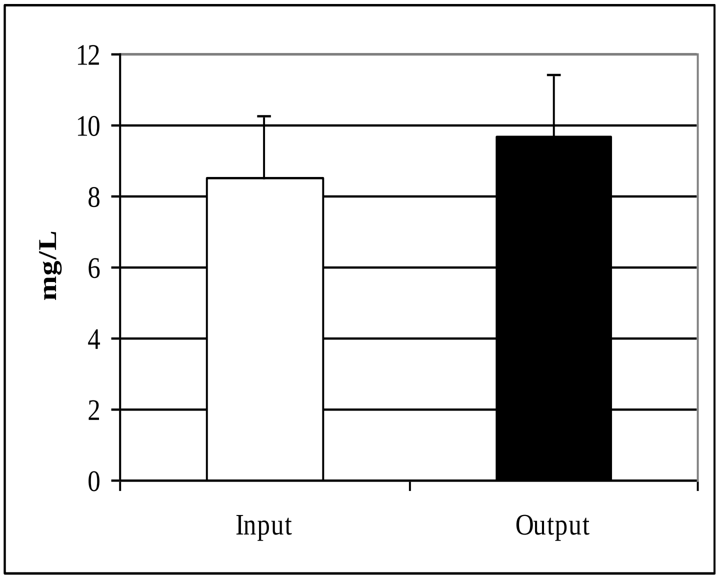

Figure 3. Mean dissolved oxygen for the input and output wetlands at Joller, Pennsylvania, 1999-2002.

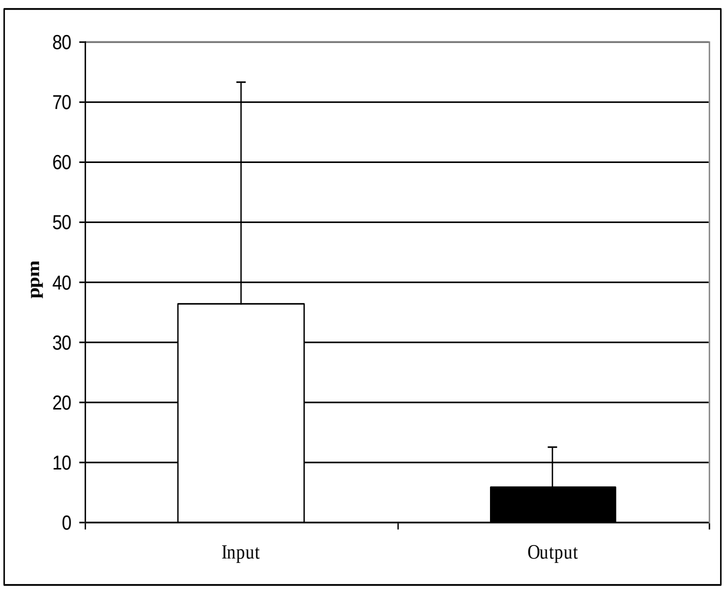

Figure 4. Mean iron concentration for the input and output wetlands at Joller, Pennsylvania, 1999-2002

DISCUSSION

The higher output pH indicates that the wetland treatment system is increasing the alkalinity in the water. This highly significant difference is likely caused by the mushroom compost is reducing sulphate and increasing alkalinity. In the Pennsylvania Code for water quality (1992), the effluent pH for a cold-water high quality fishery varies between 6 and 9. The output pH of 4.38 is lower than Pennsylvania water quality standards. This could be because of the AMD discharge in the second to last wetland, which suggests that additional treatment is needed (pers comm.) According to the Pennsylvania Department of Environmental Protection, the system effluent must be more alkaline than the influent for an AMD treatment system to working effectively (Undated). This was true for the passive treatment system at Joller.

The higher dissolved oxygen in the output wetland indicates that the treatment system is oxygenating the water as it moves through the aerobic wetlands. I expected the dissolved oxygen to be low in the input anaerobic wetland because the mushroom mulch should remove oxygen from the water and prevent more acid mine drainage from forming. I expected the oxygen would increase through the system after it left the anaerobic pools because there are areas along the wetland system that aerate the water. There was a lot of variability in the first half of the dissolved oxygen data (1999-2000). According to Gregg Burns, the first few years that the system was in operation mushroom mulch was overflowing into the lower wetlands (pers comm.). The decomposition of mushroom mulch in the output wetland would decrease the dissolved oxygen. However, this did not appear to significantly affect my results. According to the Pennsylvania Code for water quality, the minimum dissolved oxygen level for a high quality cold-water fishery should be 7.0mg/L (1992). My output value of 9.6mg/L indicates that the vertical flow passive treatment system is effectively aerating the water.

My finding of a lowered iron concentration in the output indicates that the limestone is precipitating the iron and possibly other metal ions in the drainage. However, the Pennsylvania Code lists the daily average for iron concentration as 1.5ppm (1992). This value is less then the mean iron concentration (5.79 ± 6.9ppm) for the output wetland at Joller. In addition, the iron concentration must decrease by 90 percent (Pennsylvania Department of Environmental Protection Undated). However, there was only an 85 percent decrease in the iron concentration. This may be a result of the treatment system not functioning properly in the earlier years or a result of the AMD discharge in the second to last wetland (pers comm., Milavec 2002).

Other studies indicate that anoxic limestone drains work effectively to treat acid mine drainage and treat it in accordance with Pennsylvania Department of Environmental Protection standards (Hedin 1994). One factor that contributes to the effectiveness of the treatment system at Joller is that it employs multiple types of passive treatments. P.F. Ziemkiewicz suggests that coupling these systems allows one system to partly treat the water and then it allows additional treatment from another system (1997). The results of my study indicate that the treatment system is improving the water quality. However, the wetland system may not be improving water quality enough for Pennsylvania standards. It is important to continue monitoring the wetland system and to study the impacts that the introduction of addition AMD in the second to last wetland is having on the effectiveness of the treatment system.

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