AERATING OFF THE GRID: ADVANCING PASSIVE TREATMENT WITH SOLAR AND WIND POWER

Robert W. Nairn[1]

[1]Center for Restoration of Ecosystems and Watersheds, University of Oklahoma

Project Description and Objectives

The purpose of this project was to examine sustainable, low-maintenance and cost-effective passive treatment methods for abandoned coal mine drainage discharges. Methods to enhance aerobic passive treatment are necessary to decrease passive treatment system size and thus reduce construction and maintenance costs. For this project, it was hypothesized that relatively simple, renewable energy-driven re-aeration devices requiring limited operation and maintenance would effectively enhance aerobic passive treatment processes. Three related objectives were pursued in completion of the project goal. Objective 1 was to comprehensively evaluate water quality changes and hydraulic performance of two passive treatment systems, through collection of water quality and water quantity information and performance of tracer studies. Objective 2 was to enhance the iron retention performance of oxidation ponds through design, installation and monitoring of sustainable aeration devices. Objective 3 was to enhance the oxygenation performance of re-aeration ponds through design, installation and monitoring of sustainable aeration devices and to evaluate hydrogen sulfide (H_2S) and biochemical oxygen demand (BOD) removal.

Applicability to Mining and Reclamation

At abandoned mining sites, water quality degradation may last for decades or longer without treatment. Passive treatment technologies, i.e., those that rely on natural biogeochemical and microbiological processes to ameliorate mine drainage problems, provide a viable treatment alternative to costly and laborious active treatment technologies. Aerobic ponds are utilized in two ways in comprehensive passive treatment systems; 1) to promote oxidative iron removal mechanisms and 2) to re-aerate waters discharging from anaerobic process units (e.g., vertical flow bioreactors).

Methodology

Through a combination of water quality and quantity analyses (both temporal inflow/outflow and in situ spatial studies) and tracer studies (to determine retention times and other characteristics), the effects of re-aeration enhancements on treatment performance were evaluated. The project was conducted at three field sites, two of which were included in the original proposal (Mine #6 and Rock Island #7) and a third (Mayer Ranch) added due to flow problems at the Mine #6 site. The efficacies of two different re-aeration devices (wind- and solar-powered) were evaluated as to meeting the objectives of this study. Input/output water quality/quantity monitoring at each of the sites was initially conducted on at least a monthly basis. Spatial water quality at selected locations within the ponds was also assessed. For each sampling event (location-date pair), samples were collected for analysis of total and dissolved metals (e.g., Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn), anions (Br^-, Cl^-, F^-, NO^{2-}, NO^{3-}, PO_4^{-3} and SO_4^{-2}), biochemical oxygen demand (BOD), mineral acidity and total sulfide (S^{-2}). Flow measuring devices were installed to gather accurate volumetric discharge rates at all sites. To complete

conservative tracer studies, pulsed injections of the organic dye Rhodamine were completed at all three sites, with aeration systems both on and off.

Highlights

Commercially-available solar- and wind-driven re-aeration devices commonly used in aquaculture and lake or pond management demonstrated a considerable positive influence on retention of traditional mine drainage constituents of concern, e.g., metals. At all study sites, effluent metal concentrations were significantly lower than influent concentrations and apparent rates of metal retention were similar to expected values. Solar- and wind-driven re-aeration devices also had a demonstrable effect on dissolved oxygen concentrations, oxygen percent saturation and oxidation-reduction potential values. Concentrations of oxygen demanding substances (BOD and total sulfide) in vertical flow bioreactor effluents were effectively decreased by subsequent solar- and wind- driven re-aeration in downstream ponds. Although concentrations varied widely over time, overall decreases were documented. Re-aeration had a considerable influence on the hydraulic characteristics of passive treatment system process units. Re-aeration resulted in considerable differences in hydraulic retention time, number of reactors in series, dispersion number and index of short-circuiting.

Results/Findings

The overall effectiveness of off the grid aeration technologies may be summarized as follows:

> Solar- and wind-driven re-aeration devices demonstrated a considerable positive influence on retention of traditional mine drainage constituents of concern, e.g. metals. At all study sites, effluent metal concentrations were significantly lower than influent concentrations and apparent rates of metal retention were similar to expected values.
>
> These re-aeration devices also had a demonstrable effect on dissolved oxygen concentrations, oxygen percent saturation and oxidation-reduction potential values. The limited local influence of individual air stones appears to be a function of system water quality, process unit depth and placement of the aerator. Multiple air stones may be necessarily to see consistent and dramatic effects on whole system oxygen concentrations.
>
> Concentrations of oxygen demanding substances (BOD and total sulfide) in vertical flow bioreactor effluents were effectively decreased by subsequent solar- and wind- driven reaeration in downstream ponds. Although concentrations varied widely over time, overall decreases were documented. Although measurable, BOD concentrations were not found to be of significant concern at any site. Total sulfide, on the other hand, was found to be at seasonably toxic concentrations. Re-aeration devices helped decrease sulfide concentrations and may represent an effective sulfide removal technology.
>
> Re-aeration may have considerable influence on the hydraulic characteristics of passive treatment system process units. Wind-driven re-aeration resulted in considerable differences in several hydraulic parameters at the Rock Island #7 passive treatment system (e.g., retention time, number of reactors in series, dispersion number and index of short-circuiting). At Mayer Ranch, however, aeration did not substantially change these

values, perhaps due to the deeper, more pond-like design of these units than the shallower wetland-type process units at Rock Island #7.

Capital costs for solar- and wind-driven aeration devices were found to be modest. The large three-diaphragm solar unit at Mine #6 cost just more than $11,000 in 2010. The smaller solar unit at Mayer Ranch cost $5,200 in 2008. Capital costs for the windmills at Mayer Ranch and Rock Island #7 were approximately $2,000-$2,500 each. The much smaller solar unit at Rock Island #7 was purchased for $2,300. Similarly, maintenance commitments were likewise modest. Air stones must be periodically checked for clogging, lines examined for air leaks, and moving parts lubricated on an annual basis.

Off the grid aeration shows promise as a passive treatment tool. Enhanced removal of nuisance constituents like sulfide produced by vertical flow bioreactors shows potential for further application. The influence of these devices on iron oxidation removal rates warrants additional study at a suite of sites with appropriate flow and system conditions. Further inquiry into hydraulic performance is also warranted, as the relationship between specific hydraulic characteristics and water quality improvement performance need to be evaluated.

Website Information:
The final project report and links to supporting documents can be found at:
http://www.osmre.gov/programs/tdt/appliedscience/projects.shtm

Principal Investigator:
Robert W. Nairn, University of Oklahoma (405) 325-3354 nairn@ou.edu

OSMRE Project Technical Representative:
Paul T. Behum, Mid-Continent Region (618) 463-6463 pbehum@osmre.gov

Figure 1 - Solar and wind re-aeration devices installed at the Rock Island No. 7 passive treatment system.