

Chapter III

Evaluation of Field SAPS

Introduction

The evolution of passive treatment systems for renovating acidic mine drainage (AMD) has resulted in the development of several specialized systems that are each designed to treat a specific type of drainage (Chapter 2). The Successive Alkalinity-Producing System (SAPS) is one of the latest results of this process. The SAPS is capable of treating highly acidic AMD containing elevated concentrations of iron, aluminum, and dissolved oxygen (Skousen et al., 1997; Kepler and McCleary 1994). SAPSs are constructed using a bed of high calcium limestone (>90% CaCO₃) located beneath a layer of composted organic matter. A network of perforated drainage pipes is placed in the lower portion of the limestone layer to draw the water down through organic matter and limestone and discharge it into an adjacent settling pond. When operational, a head of standing water is maintained above the organic matter to drive the hydraulics of the system.

The fundamental principle behind the function of a SAPS is to generate sufficient alkalinity to neutralize the influent acidity. This causes an increase in the pH of the water and allows for the removal of the acid soluble metals via the formation of insoluble oxyhydroxide complexes. This process begins by drawing the AMD that enters the SAPS down through the organic matter. In this layer, two essential functions are performed. Dissolved oxygen is removed from the water through the action of fermentative bacteria in the upper portion of the organic matter which creates reducing conditions below. These reducing conditions allow for the colonization of sulfate reducing bacteria (*Desulfibrio sp.*) which, as a result of their biological activity, generate bicarbonate alkalinity and hydrogen sulfide. The alkalinity serves to neutralize the acidity in the water and can be a significant contributor during the summer and early fall when their biological activity is at its peak. The hydrogen sulfide can react with the metals in solution to form insoluble metal-sulfide complexes and remove them from solution (Hedin et al, 1994a).

After passing through the organic layer, the AMD comes in contact with the limestone and begins to dissolve it, generating additional bicarbonate alkalinity. The anoxic conditions ensure unfettered limestone dissolution by reducing the ferric iron in solution to ferrous iron, therefore limiting the potential for limestone armoring. In addition, the closed-system nature of this layer increases the solubility of the limestone by increasing the partial pressure of CO_2 that results from the decomposition of organic matter and the neutralization of proton acidity. This allows for higher bicarbonate concentrations than aerobic environments, and thus greater acid-neutralization potential (Hedin et al., 1994b).

The water in the limestone layer is then drawn into the perforated drainpipes and discharged in the adjacent settling pond. The settling pond allows for re-oxygenation of the water, neutralization of acidity, increase in pH, and the

subsequent precipitation of the metals in solution. If the settling pond residence time is sufficient, the water reaches chemical equilibrium and the suspended particles fall from the water column before the water is discharged to the receiving stream. In the event that water quality standard compliance is not achieved, the water can be directed into an additional SAPS for further treatment.

The first known systems of this type were constructed in 1988 in Virginia (Hendricks, 1991). Later, and through independent invention, Kepler and McCleary (1994) documented similar systems in Pennsylvania and coined the term SAPS as these systems have now come to be known. These systems ranged in size from 150 - 3100 m² with limestone layers of 0.30 - 0.60 m deep and compost layers ranging from 0.30 - 0.45 m in depth. Studies of SAPS performance indicated an ability for these systems to remove acidity ranged from an average of 51 g/d/m² (Narin et al. 1999), to 61.8 g/d/m² of acidity (Dietz and Stidinger, 1996). Kepler and McCleary (1994) reported acidity removal capacities of 150-300 mg/l. What is unclear from these studies, however, is how acid neutralization is affected by influent AMD chemistry and system design.

Current design guidelines call for a limestone layer of 0.60 – 0.90 m (2 – 3 ft.) in depth, a organic layer (preferably spent mushroom compost) of 0.15 – 0.45 m (0.5 – 1.5 ft.) deep, and 0.9 - 1.5 m (3 – 5 ft.) deep body of water above the organic layer (Skovran and Clouser, 1998; Skousen et al., 1997). In addition, a residence time in the limestone layer of between 12 – 15 hours is regarded as adequate for achieving maximum alkalinity generation, based on studies of the performance of ALDs (Skovran and Clouser, 1998; Kepler and McCleary, 1994). These guidelines, however, originate from the early observations of a handful of systems and appear to be rather restrictive. If, for example, residence time in the limestone were an essential factor to system performance, a volumetric basis for the design of the limestone layer

would be more logical. This would allow for the manipulation of system depth in areas where space is limited to achieve the recommended residence time and, thus, desired treatment goals. Moreover, since the kinetics of limestone dissolution are affected by such factors as acidity, pH, and dissolved metal concentrations (Rose, 1999; Hedin and Watzlaf, 1994), influent AMD chemistry should play a role in determining the optimal residence time for a specific situation. This Thesis begins to address these questions by studying eight SAPS in the field and relating their overall performance to design and influent AMD chemistry.

Objectives

The specific objectives of this research are:

- To determine the effect of influent water quality and system design on the ability of Successive Alkalinity-Producing Systems to generate net alkalinity.
- To develop a numerical model that relates net alkalinity generation to system design and influent water quality characteristics.

Site Selection

Eight SAPS were identified in Virginia and West Virginia for inclusion in this study. As a requirement, each system had to be of the basic system design outlined above with a lower limestone layer, overlying bed of organic matter, and a subsurface drainage network. In addition, each SAPS had to receive a net acidic influent as these systems are not intended for treating net alkaline discharges.

Methods

Construction and materials data for all systems were obtained from field measurements, as-built drawings, and personal communication with design engineers. Water samples were collected on a monthly basis from the influent and effluent points of each SAPS cell. Sample collection and analyses were performed by private testing laboratories contracted by the operators of the individual systems. All sites were visited on a regular basis to ensure the proper collection and analysis of the samples. Flow and pH were measured in the field. Flow was measured using a calibrated bucket and stopwatch. The pH was measured using a calibrated field probe. Total alkalinity was measured by titrating the raw sample with 0.1N H₂SO₄ to pH 4.6. Total acidity was determined by boiling the raw sample with 1ml of 30% H₂O₂ and titrating to pH 8.3 with 0.02N NaOH (APHA, 1985). Concentrations of Fe, Mn, and Al were measured for acidified samples using inductively coupled argon plasma spectroscopy (ICP). Sulfate was determined using either ion chromatography or ICP. The theoretical retention time in hours (t_r) for each of the systems was estimated using the equation:

$$t_r = 4.403 V_{ls} V_v Q^{-1}$$

where,

V_{ls} = Volume of limestone (m³)

V_v = Bulk void volume expressed as a decimal

Q = Volume of flow into the system (GPM)

Results and Discussion

System Construction and Design

The generalized construction data for each of the systems included in this study are shown in table 3.1. The BEL SAPSs are the first two cells of a series of