Chapter IV

SAPS Column Study

Introduction

Most published SAPS investigations have examined the changes from influent to effluent, but few have looked at the water chemistry within the SAPS itself (i.e. Hendricks, 1991; Kepler and McCleary, 1994; Nairn et al., 1999). As noted in Chapter 3, the alteration of mine water chemistry as it flows through the SAPS is critical to ensure proper operation. One of the most important elements affecting SAPS’s function is the removal of dissolved oxygen from the water column and the promotion of reducing conditions. This prevents the armoring of limestone by iron oxyhydroxides and the consequent decline of system performance. These conditions also allow for the microbial reduction of sulfate. This process aids in the neutralization of acidity through the generation of bicarbonate alkalinity. The sulfide produced from this process can also play a role in sequestering metal cations through the formation of insoluble metal-sulfide complexes (Skousen et al., 1998).
Some investigators have examined certain aspects of internal chemistry of SAPS in both the field and the laboratory. Duddleston (1993) found in a study of SAPS mesocosms that changes in influent water chemistry affected the biological activity in the organic layer. Dietz and Stidinger (1996) examined the vertical changes in water quality for two SAPS in western Pennsylvania. They found from two sampling events that the oxidized portion of the organic layer extends much deeper in SAPS than in surface flow systems. Watzlaf (1997) examined the performance of a SAPS laboratory column for a period of 97 weeks and noted that the organic layer performance declined over time with respect to metals removal, pH adjustment, and sulfate reduction.

This study employed a series of laboratory scale SAPS columns that were operated and monitored for the purpose of examining the long-term effect of residence time and temperature on system performance and internal chemistry.

**Objectives**

Using columns of identical construction receiving the same quality of AMD, this study aimed to:

- Examine the effect of residence time on SAPS performance
- Monitor the vertical changes in water chemistry
- Determine the effect of temperature on system performance

**Methods**

**Column Design**

Nine columns were constructed using 15 cm (6 in) diameter polyvinyl chloride (PVC) pipe (Fig. 4.1). Each column consisted of a 77 cm (30 in) layer of 2 cm (3/4 in) diameter, high calcium limestone (94% CaCO₃) overlain by a 30 cm (12 in) of composted hardwood bark mulch. A 15 cm (6 in) head of water was
Figure 4.1 Schematic diagram of the SAPS columns. Drawing not to scale.
maintained over the compost by positioning the effluent pipe at the appropriate height. Sampling ports were located in the column wall and positioned in the middle of the mulch layer (port 1) and at the mulch/limestone interface (port 2). The columns were divided randomly into three groups of three columns each. Each group received influent AMD at one of three different rates to achieve the limestone residence time treatments of 15, 30, or 60 hours respectively.

The AMD was fed into the columns from a 1609 l (425 gal) polyethylene reservoir via a multi-channel peristaltic pump. Each column’s influent flow was regulated by calibrating the peristaltic pump. The effluent from each column was discharged into one of three 189 l (50 gal) polyethylene barrels which served as oxidation/settling tanks. Each barrel received the effluent of three columns grouped according to residence time treatment.

The AMD used in this experiment was synthesized due to the difficulty in hauling preexisting AMD to the site and the desire to standardize the influent chemistry. Salts of manganous sulfate monohydrate and ferrous sulfate were added to tap water and acidified with sulfuric acid to produce a solution averaging 20 mg/l Fe, 8 mg/l Mn, and a pH of 2 – 3.

The columns began receiving AMD in September of 1998. They were operated for approximately 3 months under high-flow conditions to rapidly “age” the materials. This process was designed to flush out the fine organic and limestone particulate matter and saturate the exchange complexes in the organic matter with the metal cations in solution. Flow rates were adjusted in December to achieve the three desired residence times. The columns were then operated continuously for a period of twelve months. The first samples were taken in January 1999. Actual
average residence times for the three sets of columns over the period of operation were 17.01, 30.54, and 60.25 hours respectively.

**Sample Analysis**

Samples from each column were collected on a monthly basis and kept refrigerated until analysis. Dissolved oxygen, temperature, and pH were measured at the time of sampling using calibrated field probes. Flow was measured by capturing a 10-minute discharge of the supply tube with a graduated cylinder. Total alkalinity was measured by titrating 50ml of raw sample with 0.1N H₂SO₄ to pH 4.6. Total acidity was determined by boiling 50ml of raw sample with 1ml of 30% H₂O₂ and titrating to pH 8.3 with 0.02N NaOH (APHA, 1985). Both alkalinity and acidity were analyzed within 24 hours of sampling. Concentrations of Fe, Mn, and Ca were measured for acidified filtered samples using inductively coupled argon plasma spectroscopy (ICP). Sulfate was measured as total S and determined using the ICP. The theoretical retention time \( t_r \) in hours for the columns was estimated using the equation:

\[
    t_r = 4.403 \cdot V_b \cdot V_v \cdot Q^{-1}
\]

where,

\( V_b = \) Volume of limestone (m³)

\( V_v = \) Bulk void volume expressed as a decimal

\( Q = \) Volume of flow into the system (GPM)

**Results and Discussion**

Table 4.1 shows the average water quality parameters for each of the sampling points. Influent AMD chemistry was maintained relatively consistently with the exception of September when the acidity was nearly three times average (706.67 mg/l as CaCO₃). Acid soluble metals and pH responded to the fluctuation in acidity.