

limestone-based systems. On all sampling events when the influent was net acidic, acidity was neutralized and/or alkalinity was generated resulting in net alkalinity generation. For the purposes of this research, net alkalinity is defined as the sum of the decrease in acidity and the increase in alkalinity.

System Performance

Variation in SAPS performance is one of the primary concerns that inspired this research. Figures 3.1, 3.2, and 3.3 show the performance of the PMAC system as it relates to pH adjustment, total iron removal, and alkalinity generation respectively. The PMAC system demonstrated a consistent ability to treat severely contaminated AMD when maintained properly. It has raised the pH approximately two units and discharged net-alkaline water consistently and year-round. Iron was removed to less than 10 mg/l on all but 5 occasions for the two years the system was under observation.

Beginning in August of 1998, a steady increase in effluent iron and decrease in influent acidity were noted. It was postulated that both the SAPS and the ALD that feeds the system were being clogged with a loose floc of aluminum hydroxide since a white precipitate was detected at the effluent pipe. Earlier studies on ALDs and SAPS indicated that if aluminum is present in the AMD, it will precipitate once the pH exceeds 4.5 reducing the effective solubility of the limestone and causing a decline in system performance (Kepler and McCleary, 1997). The influent water was analyzed for aluminum and was found to contain an average of 19.7mg/l. The system was then shut down and a flushing pipe was installed as per the design in Kepler and McCleary, (1997). This pipe was located below the elevation of the effluent pipe and was fitted with a valve. When opened, the head pressure of the water forced a rapid drawdown of the wetland and dislodged the loose floc in the limestone layer. This muddy colored floc was easily identifiable in the effluent stream

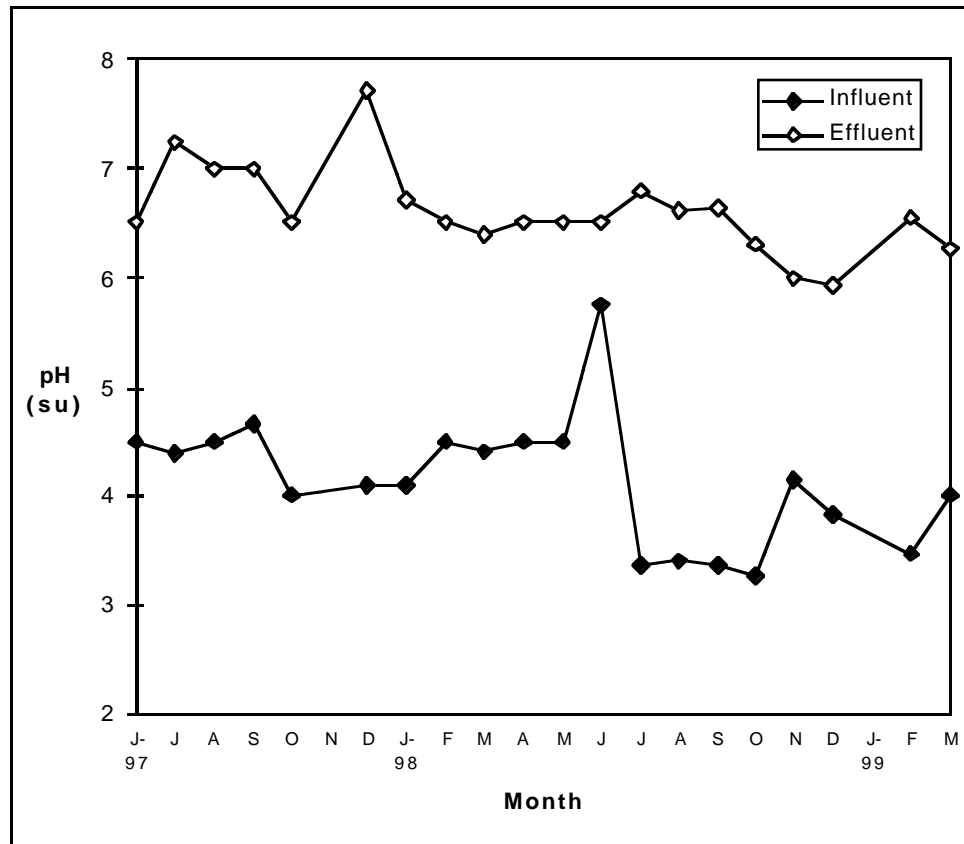


Figure 3.1 Long-term pH adjustment performance for the PMAC system from June 1997 through March 1999.

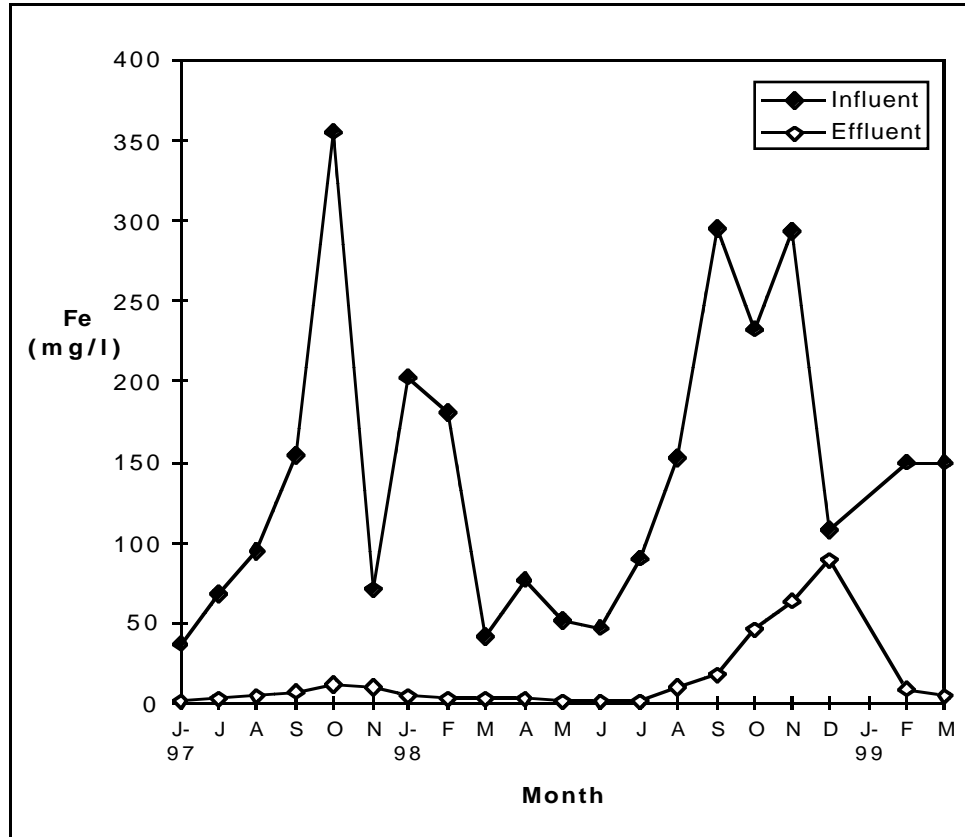


Figure 3.2 Long-term iron removal performance for the PMAC system from June 1997 through March 1999.

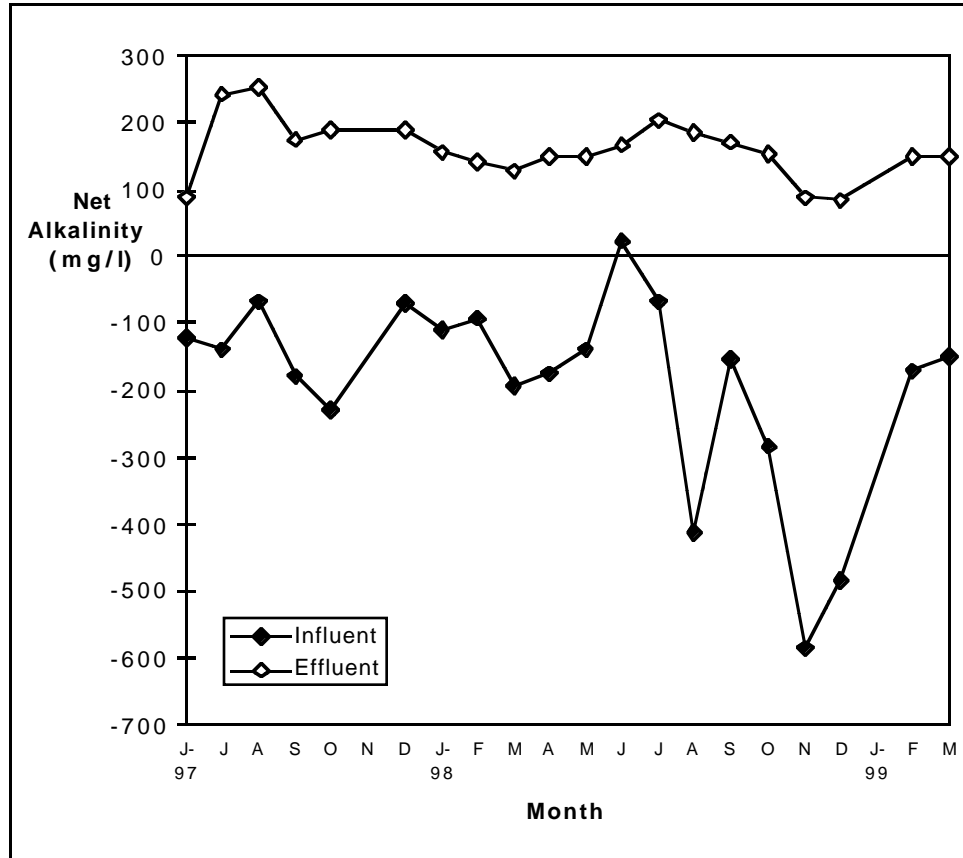


Figure 3.3 Long-term net alkalinity generation performance for the PMAC system from June 1997 through March 1999. Values reflect CaCO₃ equivalent. Negative values represent net acidic water

and when the water turned clear after five to ten minutes, the valve was closed and the SAPS was restored to proper functioning order. This return to normal was noted in the first two months of operation after installation of the flushing valve (February and March of 1999) with the reduction of effluent iron back to previous levels (Figure 3.2).

The USC1 system is an example of a marginally functioning SAPS that is not able to consistently improve the water quality of the influent AMD. The long term performance of selected parameters for the USC1 system are illustrated in figures 3.4, 3.5, and 3.6. Figure 3.4 demonstrates the consistent, but marginal ability of this SAPS to raise the pH of the AMD about 0.5 pH units on a year-round basis. Iron removal and alkalinity generation, however, proved to be quite variable with half of the sampling events showing a net iron discharge and two events showing net acid generation (Figures 3.5 and 3.6). The variation in iron removal could be due to the difficulty in further decreasing low influent iron concentrations. The alkalinity generation also appears to decline as the system ages, which could indicate a problem of metal precipitation in the limestone layer such as that experienced in the PMAC system. Sampling indicated that this system removes approximately of 10 mg/l of aluminum from an average influent concentration of 39.7 mg/l which could contribute to the degradation in system performance.

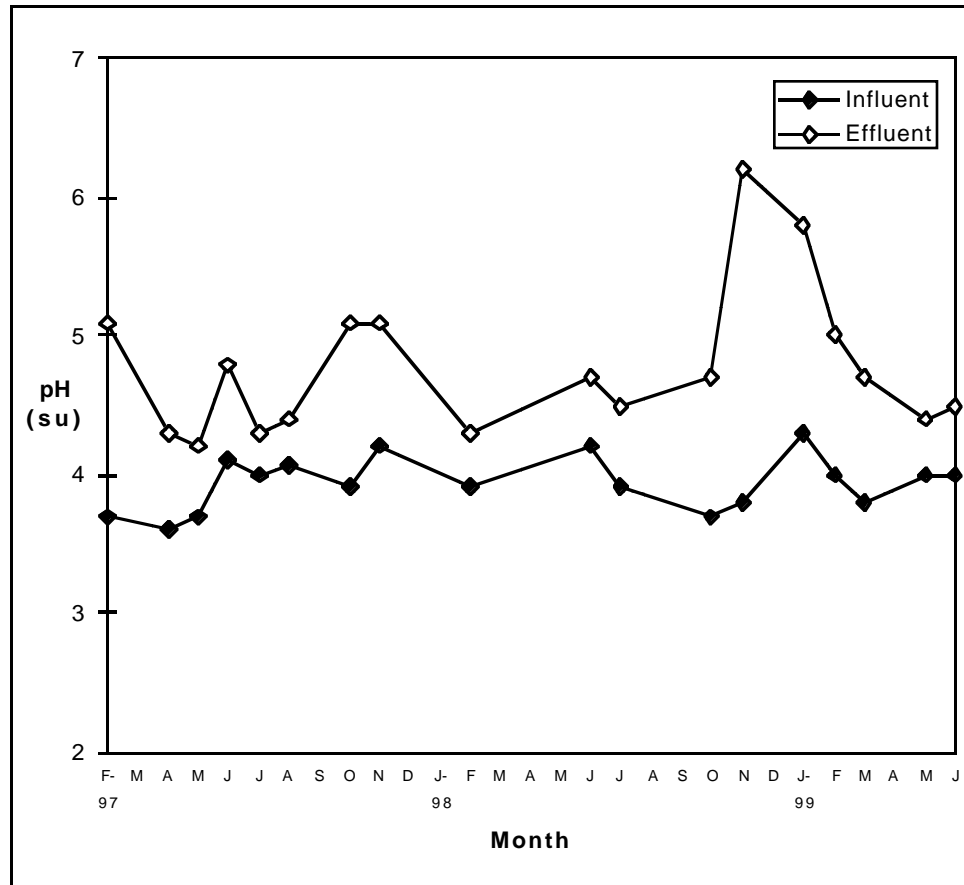


Figure 3.4 Long-term pH adjustment performance for the USC1 system from February 1997 through June 1999.

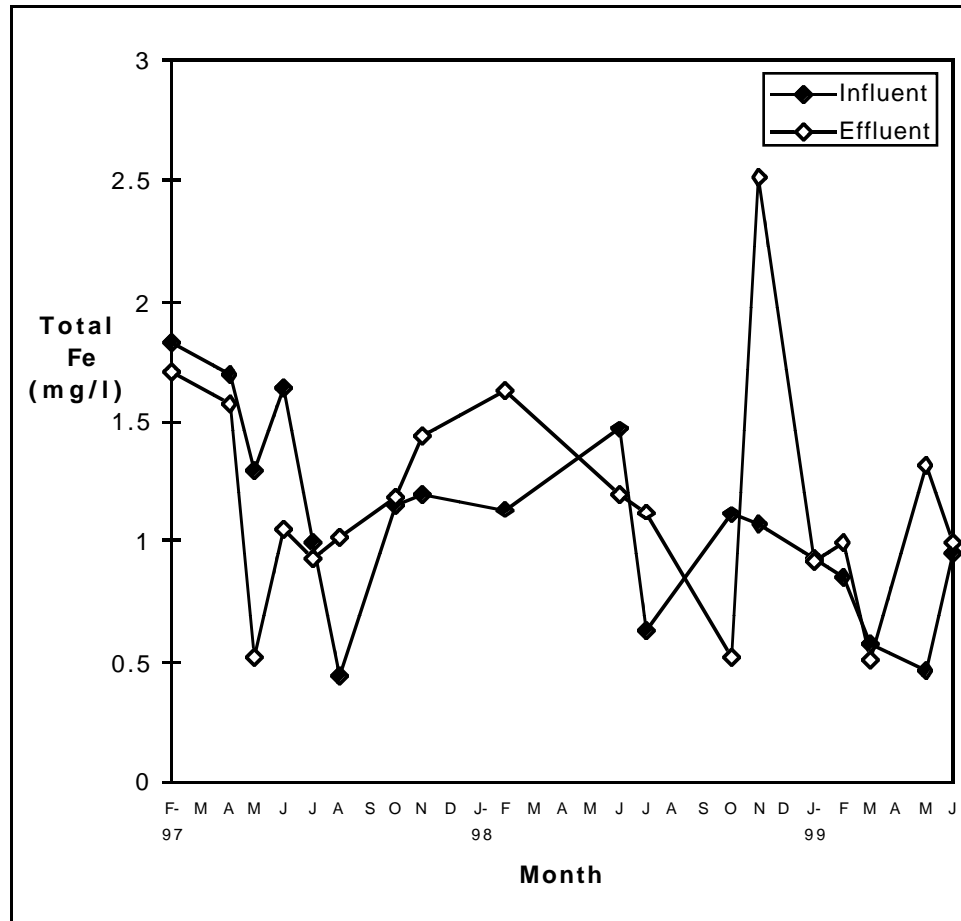


Figure 3.5 Long-term iron removal performance for the USC1 system from February 1997 through June 1999.

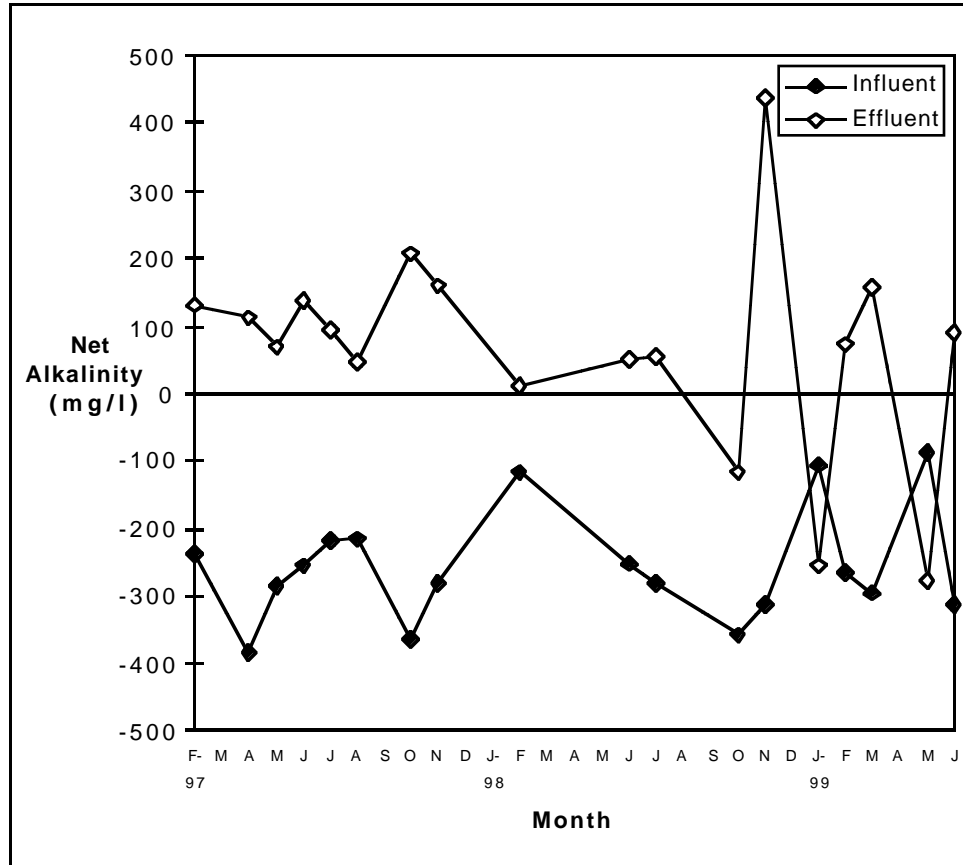


Figure 3.6 Long-term net alkalinity generation performance for the USC1 system from February 1997 through June 1999. Values represent CaCO₃ equivalent. Negative values represent net acidic water.

Model Development

All data collected from the eight systems were pooled to determine the primary factors that govern the alkalinity generation potential of SAPS. A total of 156 sampling events were available for analysis. Certain sampling events were then eliminated based on their failure to comply with several criteria developed to ensure that they were realistic and representative of properly functioning SAPS. Three samples were eliminated due to low flows that resulted in theoretical residence times of greater than 120 days which were viewed as implausible. Five samples were eliminated because they failed to generate at least 5 mg/l as CaCO₃ of net alkalinity. Thirteen samples were eliminated because the influent water chemistry was net-alkaline. This reduced the number of eligible samples to 135.

Initial analysis of the controls on net alkalinity generation was through the development of a Pearson's correlation coefficient (r) matrix using the SAS statistical software package (Table 3.4). All available influent parameters (residence time, pH, total Fe, Mn, SO₄²⁻, and total acidity) were included for analysis. One additional parameter was also developed. An acidity value was calculated to determine the portion of the total acidity that is derived from constituents other than manganese oxidation (non-Mn Acidity). This adjusted acidity value reflects the acidity that is a result of pH and the hydrolysis of iron and aluminum; these components are typically neutralized by SAPS system operation. This was calculated by rearranging the formula derived for calculating the acidity of typical coal mine drainages (Eq. 3.1) to achieve the non-Mn acidity calculation (Eq. 3.2) (adapted from Rose et al., 1998). All input parameters are in milligrams per liter.

Acidity_{calc} =

$$50(2\text{Fe}^{2+}/55.85 + 3\text{Fe}^{3+}/55.85 + 3\text{Al}/26.98 + 2\text{Mn}/54.94 + 10(10^{-(3\text{pH})})) \quad (3.1)$$

$$\text{Non-Mn Acidity} = \text{Acidity}_{\text{calc}} - 1.82\text{Mn} \quad (3.2)$$