Bill Newman

We believe that Clearwater BioLogic has a biological treatment system that should be considered as an alternative treatment technology for sulfate impacted waters. The system uses fixed film bioreactors with reclaimed carpet fibers as an attachment media and crop derived electron donors to reduce sulfate to sulfide. Sulfide is removed using two direct reduced iron (DRI) pellet based treatment methods. The bioreactors are capable of reducing sulfate concentrations a high as 2,000 mg/L to less than the 10 mg/L wild rice standard. The combination of the bioreactors and DRI based sulfide treatment systems have low operating costs, require minimal energy inputs, and add no harmful chemicals or byproducts to the final effluent. Two US patents have been issued on the bioreactor technology and the DRI sulfide treatment systems are patent pending.

Floating Bioreactor Development – Clearwater Layline: The floating bioreactors were first developed by Jeff Hanson of Clearwater Layline. Field trials of the floating bioreactors were conducted for over four years treating water from the Area 5 mine pit lake at the former Erie Mine Site (future New Range site). The influent concentrations of 1,100 mg/L to 1,200 mg/L were effectively treated year-round, at times producing sulfate effluent concentrations of less than 10 mg/L. An ethanol electron donor was delivered to the fiber filled floating bioreactors to provide food for attached sulfate reducing bacteria biofilm. The native microbes used the sulfate as an electron acceptor reducing sulfate to sulfide. A gear pump and timer was used to feed ethanol at five minute intervals which may have resulted in variable ethanol concentrations within the fiber beds. We believe that this was the cause of variable effluent quality. The bioreactors often reduced the 1,100 mg/L of sulfate to less than 10 mg/L sulfate but at times higher concentrations were observed. Two chemical treatment methods were tested to remove the sulfide produced by the bioreactors. Iron sulfide precipitation using ferric chloride was effective but resulted in the addition of over 1,000 mg/L of chloride and had high reagent costs. Precipitation of elemental sulfur using pH adjustment and partial oxidation with hydrogen peroxide worked well but operation was difficult and reagent costs were also high. Overall the bioreactor technology was cost effective but it was determined that better sulfide treatment methods needed to be developed. Results from this initial field trial are available at https://conservancy.umn.edu/items/47e0df53-3924-48c4-9f5e-5f02905a3d31produce.

Bioreactor Optimization and DRI Treatment Development – Clearwater BioLogic: In 2018 Clearwater BioLogic, LLC was incorporated by Jeff Hanson and Bill Newman to continue development of the sulfate treatment systems. The bioreactor system was optimized using a more continuous electron donor feed to ensure that the bioreactor effluent is less than the 10 mg/L wild rice standard. A new glycerin and ethanol electron donor blend was tested in large scale bioreactor column tests along with two new DRI sulfide treatment methods. Mining impacted waters with sulfate concentrations ranging from 30 mg/L to 700 mg/L were consistently reduced to less than 3 mg/L of sulfate in the effluent. The sulfide produced by the bioreactor columns was first treated with a DRI electrode system that uses a sacrificial anode to add iron cations without adding unwanted chloride, resulting in the precipitation of iron sulfides. Sulfide that is not removed by the electrodes is treated by adsorption onto the surface of a bed of DRI pellets. Both the iron sulfide precipitated solids and the sulfidized iron pellet have potential commercial applications in environmental remediation for the treatment of chlorinated solvents and toxic metals.

Treatment Cost Estimates: The four treatment systems described by Barr Engineering have a total design flow capacity of 13,000 gpm (up to 6,832,800,00 gallons per year). The combined mechanical and chemical treatment systems have an estimated annual operating cost of $105 million dollars per year. In reviewing the MPCA treatment system description It is not clear what mass of sulfate would be removed by the four systems as no weighted average concentration is presented for the total design flow of 13,000 gpm. Treatment costs using the Clearwater BioLogic technologies are proportional to the mass of sulfate removed so we need the proposed mass removal needs to accurately estimate treatment costs. Treatment of 13,000 gallons per minute of 30 mg/L sulfate would require removal of 776 metric tons of sulfate per year. If we assume a higher concentration of 150 mg/L of sulfate with the same flow rate we would need to remove 3,880 metric tons of sulfate per year. Electron donor costs for bulk ethanol are estimated to be about $1,000 per metric ton of sulfate removed. The cost of DRI and electricity for the sulfide treatment could add an additional $250 per metric ton to operating costs. Labor costs might add an additional $250 per ton of sulfate removed. If we assume $500 per metric ton to service capital costs and provide reasonable gross margin the total treatment cost should be approximately $2000 per metric ton. Note that both the precipitated iron sulfide and sulfidized DRI pellets may have commercial value that would offset some of the treatment costs. If we use the total treatment cost estimate of $2000 per ton of sulfate removed and a range of 776 to 3,880 metric tons per year treatment might cost 1.55 million dollars per year for the low mass assumption and 7.76 to six million dollars per year far less than the estimated costs of reverse osmosis based treatment. Capital costs for the treatment system would be approximately $5000 per bioreactor module with 500 to 1000 modules required. perhaps 2.5 million to 5 million dollars required to build systems in four locations and requiring capital investments in the range of 2.5 to 5 million dollars.

Proving The System at Scale: Clearwater BioLogic now has a pilot test trailer we can use to confirm the effectiveness of treatment with site specific water chemistry, optimize electron donor feed rates/costs, determine maximum flow rates per module and to optimize electrode operation and DRI adsorption sulfide treatment. The trailer has the capacity to treat approximately one seventh of a full scale floating bioreactor module. After confirming treatment effectiveness on site with the treatment trailer pilot test we would recommend operating several full scale bioreactor modules and a larger scale DRI treatment system at a larger scale for 100-200 gpm field trials. We believe that the above pilot test and field trials could be completed in less than a year and full scale treatment systems could be designed and build soon after. We look forward to the opportunity to prove the systems at scale.