Batch operating limestone treatment systems (BOLTS): A novel approach to treating mine drainage at lower cost

Travis Tasker[1], Ben Roman[2], James Eckenrode[3], Nicole Himes[4], Henry Warner[5], Buck Neely[6], Cliff Denholm[7], William Strosnider[8], Julie LaBar[9], Tim Danehy[10]

[1]Saint Francis University, Loretto, PA, USA, ttasker@francis.edu , ORCID 0000-0001-5040-7579

[2]Saint Francis University, Loretto, PA, USA, broman@osmre.gov , ORCID 000-0003-3974-6961

[3]Saint Francis University, Loretto, PA, USA, jeckenrode@francis.edu

[4]Saint Francis University, Loretto, PA, USA, nxh125@francis.edu

5Saint Francis University, Loretto, PA, USA, hjw402@francis.edu

[6]BioMost, Inc. Mars, PA, USA, buck@biomost.com

[7]Stream Restoration Inc, Slippery Rock, PA, USA, cliff@streamrestorationinc.org

[8]University of South Carolina, Baruch Marine Field Laboratory, Georgetown, SC, USA, bill@baruch.sc.edu , ORCID 0000-0002-0839-4468

[9]Oklahoma State University, Stillwater, OK, USA, jlabar@okstate.edu

[10]BioMost, Inc. Mars, PA, USA, timdanehy@biomost.com

Extended Abstract

In the work herein, a novel batch operating limestone treatment system (BOLTS) was used to treat mine drainage (MD) near Puritan, PA, United States of America. Passive treatment technologies for remediating MD typically operate in flowthrough mode where MD continuously flows into and out of the system. Challenges with systems operating in flowthrough mode can include clogging and short circuiting (Cravotta 2008; Cravotta et al. 2004; Rakotonimaro et al. 2018; Rötting et al. 2008; Rötting et al. 2007).

A BOLTS can overcome some of these challenges by quickly flushing MD into a limestone treatment pond, holding it for some set time, and then quickly flushing the treated water from the system and into a settling pond. This study tested the hypothesis that a BOLTS treating MD for a set HRT (i.e. hold time) could achieve higher acidity removal rates than an auto flushing vertical flow pond (AFVFP) operating in flowthrough. This hypothesis was tested at a passive MD treatment system near Puritan, PA that includes both a BOLTS and an AFVFP. The system was configured to treat the MD in the BOLTS or AFVFP at a 4.5 or 9-h theoretical HRT. Influent and effluent net acidity and alkalinity were measured for each treatment configuration.

In comparison to the AFVFP, the BOLTS achieved more alkaline and consistent effluent water quality. During one of the field tests, the AFVFP took 9 hours to fill the limestone at the influent flowrate. Once the limestone bed was full at 9 h and MD was flowing through, the effluent pH increased from 3.8 at 9.1 h to 4.9 at 23 h, producing 0 mg/L of alkalinity. At 24 hours, the AFVFP was flushed to empty, and the chemistry of the flush water improved (max pH: 5.41 and max alkalinity: 40.17 mg/L). However, all flowthrough and flush water chemistry from the AFVFP was more acidic than the effluent from the BOLTs. MD treated for 9 h in the BOLTS had a pH of 5.72 ±0.21 and alkalinity of 50.2 mg/L ±17.3 mg/L.

The BOLTs also achieved higher acidity removal rates than the AFVFP. When treated at a 9-h HRT, the net acidity of the MD decreased from 341 mg/L to –26.2 mg/L in the BOLTS and from 267 to 71.5 mg/L in the AFVFP. Based on all the field experiments, the BOLTS achieved a higher surface area normalized acidity removal rate (i.e. ksa of -8.3×10^{-4} m^3/m^2h or -1.2×10^{-4} yd^3/ft^2h) than the AFVFP (i.e., ksa of $2.1 \times 10^{-4} m^3/m^2h$ or -3.1×10^{-5} yd^3/ft^2h). These differences were attributed to preferential flow paths and short circuiting that likely lowered the true HRT in the AFVFP.

Using the calculated surface area normalized rate constants, an AFVFP would require more limestone than a BOLTS to achieve the same level of treatment. For example, to treat 1,135 L/min (i.e., 300 gpm) of the MD for 20 years, a BOLTS would require approximately 6553 t (i.e., 5,945 short tons) of limestone whereas an AFVFP would require 12,873 t (i.e., 11,679 short tons).

In summary, the BOLTS system herein has been shown to increase MD treatment efficiency for a given quantity of limestone. This increase in MD neutralization could also result in an initial reduction in design size (i.e. land area) and an increase in system longevity.

Keywords: Mine drainage, treatment

References

Cravotta III, C. A. (2008). Laboratory and field evaluation of a flushable oxic limestone drain for treatment of net-acidic drainage from a flooded anthracite mine, Pennsylvania, USA. Applied Geochemistry, 23(12), 3404–3422.

Cravotta III, C. A., Ward, S. J., Koury, D. J., & Koch, R. D. (2004). Optimization of limestone drains for long-term treatment of mine drainage, Swatara Creek Basin, Schuylkill County, PA. Proceedings America Society of Mining and Reclamation, 366–411.

Rakotonimaro, T. V., Neculita, C. M., Bussière, B., Genty, T., & Zagury, G. J. (2018). Performance assessment of laboratory and field-scale multi-step passive treatment of iron-rich acid mine drainage for design improvement. Environmental Science and Pollution Research, 25, 17575-17589.

Rötting, T. S., Caraballo, M. A., Serrano, J. A., Ayora, C., & Carrera, J. (2008). Field application of calcite Dispersed Alkaline Substrate (calcite-DAS) for passive treatment of acid mine drainage with high Al and metal concentrations. Applied Geochemistry, 23(6), 1660–1674.

Rötting, T. S., Ayora, C., & Carrera, J. (2007). Chemical and hydraulic performance of "Dispersed Alkaline Substrate" (DAS) for passive treatment of acid mine drainage with high metal concentrations. Proceedings of the International Mine Water Association Symposium, Water in Mining Environments, Cagliari, Italy (pp. 27–31).