Pilot-scale feasibility study for remediation of coal tailings via microbial-induced calcite precipitation

S. Rodin[1,2], P. Champagne[1,2]

[1]Department of Civil Engineering, Queen's University, Kingston Ontario, K7L 3N6, Canada
Beaty Water Research Centre, Queen's University, Kingston, Ontario, K7L 3N6, Canada

Keywords: Microbial induced calcite-precipitation, coal tailings, acid mine drainage

Presenting author email: pascale.champagne@queensu.ca

One of the most prevalent issues faced by the global mining industry is the safe and environmentally responsible disposal of mine tailings deposits. Tailings are the waste material produced in the refining of minerals from ore (Dimitrova and Yanful 2012). Elevated concentrations of metals generally found in tailings make them unsafe to discharge, and mines must often transport them to a separate storage facility known as a tailings pond. Pyrite-containing tailings, in particular, can generate acid mine drainage (AMD) whereby pyrite oxidizes in the presence of air and water to form sulphates, resulting in a lowered pH and increased concentrations of dissolved metals (Garcı 2005). The seepage of acidic water from a tailings pond has the potential to contaminate surrounding ecosystems, waterways, and communities.

Microbial-induced calcite precipitation (MICP) uses ureolytic bacteria to produce calcium carbonate deposits, which can aid in improving the structural properties of soil (Harkes et al. 2010). When applied to tailings storage facilities, this process has the potential to increase pH, immobilize metals, and improve the structural integrity of its tailings. Bench-scale studies have proven effective for the cementation of mine tailings (Gui et al. 2018). However, scaling up of this treatment process is required for industrial application. The purpose of this study is to determine the feasibility of using the MICP process for the remediation of mine tailings on a larger scale. If feasible, this process could serve as a viable approach for mines to physically and chemically stabilize tailings and reduce the overall hazard to the environment.

Sporosarcina pasteurii is a gram negative bacteria widely used in the study of MICP due to the high activity of its urease enzyme, which is used to hydrolyze urea into carbonate (Williams et al. 2016). For this study, *S. pasteurii* was cultivated in a batch reactor using a yeast extract medium, the bacterial cells were then resuspended in a urea-based medium. The bacterial suspension, along with a supplemental solution containing calcium chloride ($CaCl_2$), was applied to a 0.5 m^3 pilot-scale versions of a coal tailings storage facility. Three application techniques were investigated to simulate agricultural equipment that could be deployed for field-scale treatment. This included 1) spraying on the treatment solution to each cell with irrigation sprinklers and mixing the tailings, 2) applying the treatment solution with a rototiller, or 3) distributing treatment solution via shallow trenches using an excavator ripper. After the bacterial suspension and $CaCl_2$ solution were applied to each test cell, the tailings were left undisturbed for a period of 28 days at 18˚C to allow for cementation to occur. A control test with no addition of treatment solution was used for comparison of results.

Water quality and soil geochemistry analyses were completed to evaluate the effectiveness of different application methods for minimizing AMD. The pH of pore water extracted from each test was found to have increased over the testing period, suggesting MICP can assist in stabilizing the pH of tailings prone to AMD.

Table 1: Measured strength of tailings at surface level from each application technique 28 days after treatment.

Application Method	Average Surface Strength (kPa)	% Increase (%)
Control	47.36	-
Spray-on	74.04	56.35
Rototiller	52.60	11.08
Shallow Trench	52.10	10.01

Strength and permeability testing were used to evaluate the effectiveness of cementation. Table 1 summarizes the average strength of the tailings measured at surface level with a penetrometer. Results indicate that each application method improved the strength of the tailings in comparison to the control test cell. The spray-on method showed the greatest improvement, with in an increase in surface strength of over 50%. Distributing treatment solution using trenches was found to be less effective and resulted in greater variability in the material properties of treated tailings. The use of rototilling equipment provided a more homogenous distribution of the treatment solution, however the disruption to the tailings material was found to be less effective for facilitating MICP.

A spray-on application technique allowed for homogenous distribution of treatment solution with minimal disruption to the coal tailings. Additionally, this method increased the physical and chemical stability of the tailings, making it a promising strategy for future remediation efforts. Further research must be conducted to determine the response of the treatment to more adverse climate conditions, including cold weather and seasonal rainfall. The economics for further scale-up of this treatment procedures must also be better understood before large-scale application can take place.

Acknowledgements

The author would like to acknowledge the contributions made by the Beaty Water Research Centre, BGC Engineering, and Innovative Solutions Canada for project funding and resources.

References

Dimitrova, Rozalina S, and Ernest K Yanful. 2012. "Factors Affecting the Shear Strength of Mine Tailings / Clay Mixtures with Varying Clay Content and Clay Mineralogy." *Engineering Geology* 125: 11–25. http://dx.doi.org/10.1016/j.enggeo.2011.10.013.

Garcı, C. 2005. "Pyrite Behaviour in a Tailings Pond." 76: 25–36.

Gui, Rong et al. 2018. "Experimental Study on the Fine-Grained Uranium Tailings Reinforced by MICP." 2018.

Harkes, Marien P et al. 2010. "Fixation and Distribution of Bacterial Activity in Sand to Induce Carbonate Precipitation for Ground Reinforcement." 36: 112–17.

Williams, Sarah L, Mary Jo, Kirisits Raissa, and Douglas Ferron. 2016. "Optimization of Growth Medium for Sporosarcina Pasteurii in Bio - Based Cement Pastes to Mitigate Delay in Hydration Kinetics." *Journal of Industrial Microbiology & Biotechnology* 43(4): 567–75.