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Editorial

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Editorial

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Biological processes, associated with microbes and root structures alike, are prevalent throughout the geoenvironment and have the potential to transform soil fabric and behavior. Harnessing these bio-geo processes in soil can lead to more sustainable approaches to meet societies ever-evolving needs. The papers presented within this themed issue, the bio-geo interface, aim at deepening our understanding of how biological processes effect the engineering properties of soil and the performance of geotechnical systems.

One area of intensive research and interest of recent years is bio-mediated soil improvement. Geochemical reactions within the soil environment are often mediated by microorganism metabolic activity. Bio-mediated reactions can result in products such as bio-mineralization, biofilms, and bio-generated gas, all of which in turn can influence the mechanical performance of the soil (DeJong *et al*., 2013). Continued development of these novel soil improvement approaches will strengthen within the bio-geo research community in years to come. The work represented by the papers within this special issue is evidence of the potential impact bio-mediated soil improvement can have to address societal needs. In addition, funding agencies have shown continued support for innovative work, as demonstrated by the recently establish NSF Center for Bio-inspired and Bio-mediated Geotechnics.

Bio-mineralization mechanisms, specifically microbial induced carbonate precipitation (MICP), have received significant research attention because of the potential to address geotechnical and environmental challenges. Much of the recent work related to MICP utilizes ureolytic soil bacteria to increase the alkalinity of the subsurface and induce calcium carbonate precipitation (Mortensen *et al*., 2011). The precipitated calcium carbonate in turn improves the strength, stiffness, and dilative tendencies of the soil (Feng *et al*., 2017; Montoya and DeJong, 2015). The transformation of these soil properties leads to improved behavior under a variety of conditions, including dynamic loading (Montoya *et al*., 2013).

Urea hydrolysis for MICP applications can be induced through either augmenting the soil with ureolytic bacteria or stimulating the indigenous ureolytic bacteria in the subsurface. When implementing MICP in situ, the environment will be populated by multiple microbial species. Tsesarsky *et al*. (2018) demonstrates that in a multi-microbe environment, augmented exogenous bacteria may be vulnerable to predation or starvation-related urease release. Furthermore, the authors discuss treatment strategies with regard to the nutrient concentrations for inducing MICP in situ using the indigenous bacteria communities.

MICP may be implemented through metabolic processes other than urea hydrolysis, including denitrification. Compared to urea hydrolysis, which produces ammonium, denitrification may lead to nitrogen gas, which in itself may be used as a soil improvement mechanism. However, the rate of reaction is low compared to urea hydrolysis. Pham *et al*. (2018) demonstrate that denitrification coupled with calcium carbonate precipitation is more efficient than denitrification alone because the calcium carbonate precipitation buffers the pH and prevents the accumulation of toxic intermediates in the denitrification process. The authors also consider how the pressures generated from the microbial produced nitrogen gas can have negative effects for the stabilization aspects of MICP at low confinements because the gas pressures can induce cracks within the stabilized sand.

Impoundments associated with the storage of mine tailings have several geotechnical and environmental related challenges, such as impoundment stability, dust emissions, and heavy metal migration. As the tailings material tend to consist of fine grained particles, the geotechnical properties of mine tailings also present new challenges with regards to MICP (Zamani and Montoya, 2018). Two of the papers included in the special issue address aspects of these challenges. Buikema *et al*. (2018) implement MICP within fine-grained mine tailings susceptible to dust emissions, and demonstrate how a biocalcified crust can increase the surface strength of the tailings. The authors also demonstrate that calcium carbonate can be precipitated within fine-grained iron tailings with both exogenous and indigenous ureolytic microorganism. Immobilization of heavy metals within mine tailings using MICP was investigated by Chen *et al*. (2018). The tailings contained significant concentrations of arsenic and molybdenum. When ureolytic-driven MICP was applied within the tailings the molybdenum concentration was significantly reduced and an improvement in mechanical behavior, assessed though compression-wave velocity and unconfined compression tests, was observed. The combination of these papers demonstrate that considering the subsurface environment as a holistic living system, even within mining-related tailings, has the potential to address serious geotechnical and environmental related challenges facing society.

In situ application of microbial polysaccharides to create biofilm connections between soil particles also has potential to increase soil strength and decrease the permeability. Ta *et al*. (2018) investigated how geophysical properties of the soil is affected by bacterial dextran. The authors demonstrate that when significant dextran accumulates within the soil, the permeability reduced and the seismic wave attenuation and electrical resistivity increased. Additionally, the dextran within the soil matrix had minimal influence on the compression and shear wave velocities, indicating that the stiffness of the soil was not affected by the accumulation of dextran.

The final paper in the bio-geo interface special issue investigates the role of transpiration from vegetation on the formation of cracks within the soil. Gadi *et al*. (2018) compared the crack intensity of vegetated and bare soil during wetting and drying cycles and found that vegetated soil experienced more cracking and the observed cracks were dependent in part on plant age. The results from their study have implications when designing systems such as vegetated clay liners.

The bio-geo interface is a dynamic and interdisciplinary field, as represented by the papers presented in this special issue. I hope you find these papers enlightening and thought-provoking. Here's to continued innovation and success exploring the bio-geo interface.

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