MICROBIALLY INDUCED PERMEABILITY REDUCTION: EXAMPLE OF PROJECT SEALOR FOR SOUTH FLORIDA FLOOD MANAGEMENT

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KEY POINTS

- The Novel Bio-Based Technology "SEALOR" uses Microbially Induced Carbonate Precipitation to create a subsurface barrier to strengthens porous carbonate sediments and reduce their permeability to mitigate seawater infiltration and flooding.
- The technology can be used for both Infrastructure Protection & Carbon Sequestration.
- The technology not only enhances coastal resilience by protecting infrastructure but also acts as a carbon-negative solution, permanently sequestering up to 44% of its applied weight as solid CO_2 underground.
- The project is at Technology Readiness Level 4, with over 150 lab tests confirming robust calcium carbonate crystal formation, pore-space reduction, and significant consolidation of sediment samples, demonstrating the method's effectiveness.
- Beyond coastal flood management, SEALOR's approach offers potential applications for Carbon Capture, Utilization and Storage, reservoir integrity, wellbore stabilization, and other areas of interest to the energy and subsurface engineering industries.

BACKGROUND & MOTIVATION

Coastal cities built on porous carbonate foundations face unprecedented risk from sea-level rise, saltwater intrusion, and compound flooding (Cantelon et al., 2022). The Intergovernmental Panel on Climate Change (IPCC) emphasizes disproportionate risks to low-lying carbonate coasts from mean and extreme Sea Level Rise (SLR), with South Florida facing up to 2 feet by 2060, degrading wetlands and aquifers (Oppenheimer and DeConto, 2019). In South Florida alone, billions of dollars are spent on seawall repairs, road elevation, pump installations, and emergency mitigation (Staletovich, 2024). Miami Beach invested $400 million since 2014 to raise 80 streets and install 90 pumps. Citywide projections exceed $3.8 billion by 2060 for upgrades, while statewide SLR endangers $619 billion in assets by century's end (Harris, 2021). These interventions remain costly and temporary.

SEALOR, a novel bio-based subsurface barrier technology, offers a scalable, carbon-negative solution to strengthen carbonate sediments, mitigate seawater infiltration, and preserve coastal infrastructure. A microbially induced carbonate precipitation (MICP)-based subsurface barrier (Zhang et al., 2023), where naturally occurring bacterial species make limestone, has the potential to counter the risks of saltwater intrusion, and compound flooding at the source by inducing calcite precipitation in carbonate strata, slashing permeability by up to 78% to block infiltration and to stabilize foundations (Xia and Song, 2024).

By utilizing MICP , SEALOR introduces a mechanism that not only enhances subsurface impermeability but has the potential sequesters up to 44% of its applied weight as solid CO_2, permanently stored underground (Fouladi et al., 2023).

CURRENT DEVELOPMENT STATUS

SEALOR is currently at technology readiness level (TRL) 4, with extensive laboratory testing completed under a National Science Foundation (NSF) SBIR Phase I award. More than 150 controlled tests have been performed across chip, cube, sand, and scaled block experiments, demonstrating robust $CaCO_3$ crystal formation, pore-space reduction, and improved mechanical integrity. Testing included urea activity optimization (>20 combinations), growth resiliency under variable salinity and temperature, and $CaCO_3$ content verification. Microscopy (SEM/EDS, petrography) and plug tests (petrophysics) are planned to confirm crystal morphology, distribution and changes in permeability.

At the University of Miami Rosenstiel School, SEALOR has undergone advanced petrophysical testing, including helium porosity measurements, permeability plug tests on limestone plug samples, simulating natural Miami oolite and related formations. These results establish a technical foundation for scaling SEALOR to controlled field pilots.

The first sets of measured cubes (2x2x1cm) demonstrated 20–25% weight increase following treatment. Visually, the cubes appear to have changed from +30% porosity to solid and consolidated (Figure 1), while porosity measurements are ongoing and scheduled for completion by the end of October.

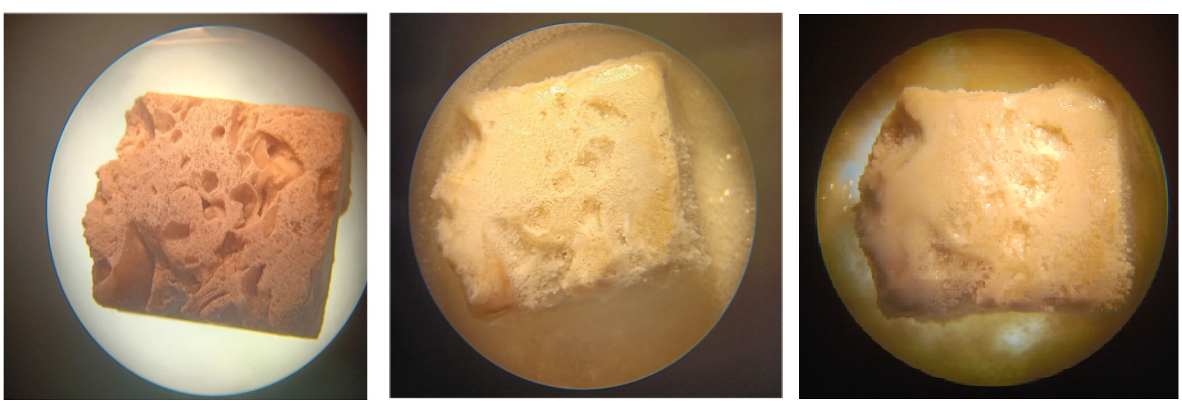

Figure 1: image of cube before MICP treatment (left), image of cube after 9 days of MICP treatment (center), and image of cube after 33 days of MICP treatment (right).

PARTNERSHIP ACADEMIA WITH INDUSTRY

The development of SEALOR has been strongly interdisciplinary:

1) University of Miami (Rosenstiel School of Marine, Atmospheric, and Earth Science): Petrophysical characterization, thin-section petrography, and core analysis before and after treatment.

2) Nova Southeastern University: Microbiology and chemistry validation, including ingredient substitution and environmental compatibility.
3) Nexuma LLC: PI NSF - SBIR Phase I, concept inventor, IP owner, chemistry validation, lab work, system integration, application design, and commercialization.

This collaboration ensures third-party validation, regulatory alignment, and scientific rigor as SEALOR advances toward Phase II NSF SBIR funding and field deployment.

RELEVANCE TO CSL AND INDUSTRY MEMBERS

SEALOR represents a unique intersection of carbonate sedimentology, energy transition, and applied subsurface engineering. The approach provides:

- Flood & Infrastructure Protection: Enabling long-lasting, low-toxicity reinforcement of porous carbonates, directly relevant to coastal urban resilience.
- Carbon Sequestration at Scale: Permanent mineralization of CO_2, aligned with global decarbonization goals.
- New Pathways for Carbonate Engineering: Insights into pore-filling, strength enhancement, and permeability control in carbonate reservoirs, directly translating to subsurface storage, enhanced recovery, and wellbore stabilization.
- Industrial Synergies: Oil and gas companies exploring Carbon Capture, Utilization & Storage (CCUS) and reservoir integrity can adapt SEALOR 's methodology to carbonate formations globally.

OUTLOOK

SEALOR aims to establish itself as a global standard for subsurface flood resilience and carbonate strengthening, beginning with seawall retrofits in South Florida and expanding into building foundations and barrier walls. Beyond civil engineering, SEALOR's carbonate-based precipitation pathway offers potential applications for reservoir sealing, leakage prevention, and carbon-negative well interventions, all of which directly overlap with CSL members' expertise and long-term experience.

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