Wind erosion suppression using biological methods revisited:
The use of microbial/enzymatic-induced calcite precipitation and biopolymers

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Introduction

Wind erosion poses a significant challenge worldwide, affecting quality of life in regions such as the southwestern USA, western China, Saharan Africa, and much of the Middle East. Its impacts extend beyond environmental threats to dust-origin settlements, as it also disrupts infrastructure, industry, and resources. Financial losses in the aviation industry, damage to crop growth and yields, and the spread of dust-borne microorganisms causing health issues are all exacerbated by wind erosion.

In response to this pervasive issue, numerous soil stabilization techniques have been proposed. However, traditional methods and chemical mulches have been deemed unsustainable and environmentally unfriendly due to their high CO2 footprint. As a result, innovative alternatives have emerged, such as **microbially-induced calcite precipitation (MICP), enzyme-induced carbonate precipitation (EICP), and the use of biopolymers**. This poster provides a brief review and analysis of these promising, eco-friendly solutions.

Biologically-induced calcite precipitation

Inspired by naturally cemented cliffs of western Australia, the so-called Stromatolites, **Figure 1**, scientists have resorted to micro-organisms capable of precipitating minerals, among which most commonly the biologically-induced calcium carbonate has been targeted.

In doing so, various metabolic paths can be employed. MICP involving the nitrogen cycle, **ureolytic MICP**, and MICP involving the carbon cycle (i.e., oxidation of organic salts) (**non-ureolytic MICP**) are some of these pathways [1-3] .

Figure 1. Stromatolites, Hamelin Pool, Shark Bay in Western Australia, Courtesy of Paul Harrison (Reading, UK)

Biologically-induced calcite precipitation versus biopolymers

Ureolytic versus nonureolytic

In microbially induced calcite precipitation based on the ureolytic pathway, **the ammonium ions** produced during carbonate precipitation are considered an undesirable by-product when produced in large volumes. Therefore, the use of **nonureolytic MICP** in soil and wind erosion stabilization has been examined recently, and different calcium sources and microorganisms have been examined for stabilizing sand dunes against wind erosion [1], which have been proved to be promising: **Figures 2-3.**

BICP=MICP and EICP

Having known that microbially induced calcite precipitation is mediated through the enzymes produced by bacteria, some studies have directly employed enzymes such as urease for calcium carbonate precipitation. EICP suffers a lack of nuclei. Other issues of concern are the stability of enzymes together with their workability **(Figure 2:** bacteria cells serve as a nucleus for calcium carbonate precipitation in MICP, contrary to EICP).

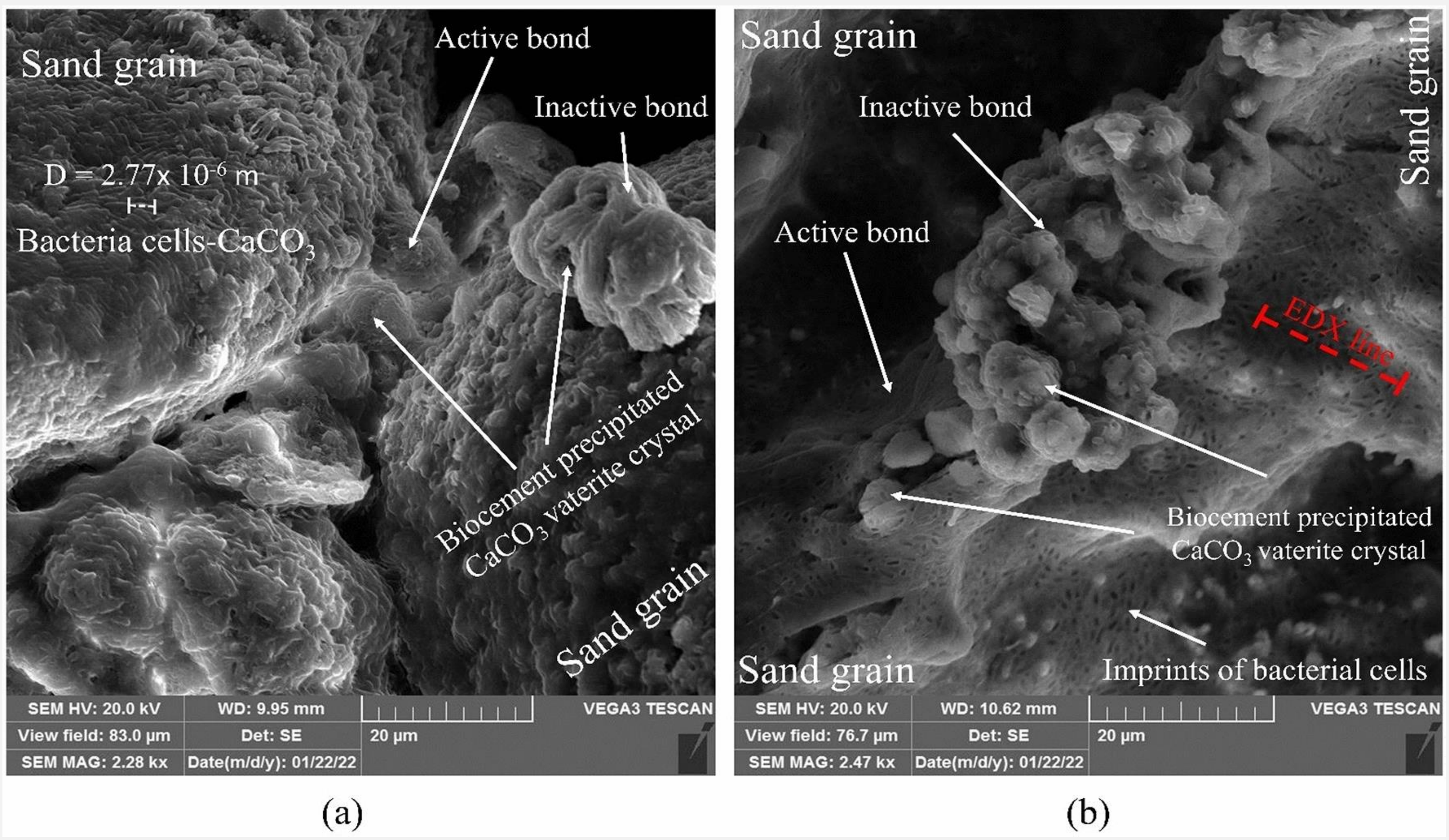

Figure 2. $CaCO_3$ induced active and inactive bonds, and imprints of bacteria cells on precipitation in (a) Calcium Acetate-Bacillus subtilis composition, nonureolytic MICP and (b) Calcium Formate-Bacillus subtilis composition, nonureolytic MICP, [1].

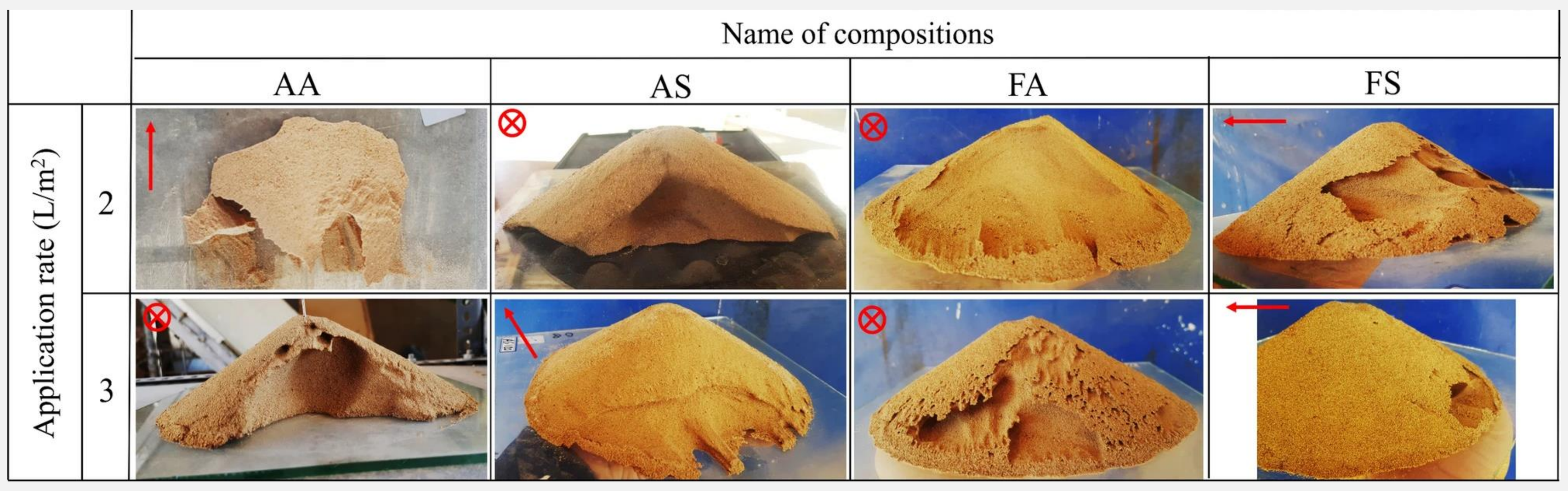

Figure 3. Treated sand dunes after sand bombardment for different compositions of nonureolytic MICP at 2 and 3 L/m^2 application rate (the arrows indicate wind direction, and the cross denotes wind direction perpendicular to the figure plane). [1]

Biopolymers

While the research on biological soil stabilization is still active, the need for exo-cultivation of bacteria, the cost of enzymatic treatment, and practical hurdles have led scientists to explore the use of biopolymers, organic compounds which can be obtained from several waste sources such as paper and agricultural wastes, and carboxymethyl cellulose (**CMC**) [4] for wind erosion mitigation.

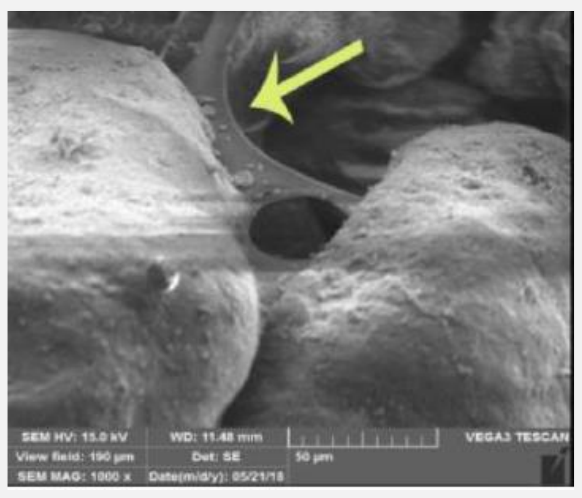

Figure 4. SEM micrograph of treated sand with **CMC [4]**

Takeaway messages/new directions

Given the global warming and CO_2 footprint of traditional materials, the use of bio-inspired methods for soil stabilization seems more appealing than ever. The use of waste resources for preparing the culture media of microorganisms, the biological stimulation of most proper indigenous bacteria and enzymes which can tolerate harsh conditions are new directions.

References

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