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Literature Review: Biocement for Stabilization of Expansive Soils in Las Vegas, Nevada

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LITERATURE REVIEW: BIOCEMENT FOR STABILIZATION OF EXPANSIVE SOILS IN LAS VEGAS, NEVADA

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Background

The aim of this study was to present a possibility for the use of biocement on expansive clay. Expansive soil is a type of clay when exposed to water and moisture changes its volume. Due to the clays swelling and shrinkage behaviour its difficult to use it in engineering and construction projects, therefore costly and unhealthy techniques have been used to stabilise expansive soil in order to address the problem [6]. A possible healthy and environmentally friendly solution is Biocement which uses microbial induced calcite precipitation (MICP) in order to help aggregate soil to form a stable cementitious material. MICP is dependent on the innate process of urea production in Microorganisms that utilizes the production of urea to form carbonate through the process of hydrolysis speed up by the urease enzyme [2]. The use of biocementation is being applied to many fields such as construction and erosion control [5]. However, there are many other processes that can utilize this technology for its benefit.

Method

- For this paper we did a systematic review in order to offer a reliable and replicable way to search for articles for answering our research questions 1 and 2.

1. Would the chosen bacteria be able to aggregate and work on expansive clay to form biocement?
2. What would be the most reliable bacteria in stabilizing expansive soil specifically for the southern Nevada environment?

- In order to conduct a systematic literature review we chose to search for research articles through University of Nevada, Las Vegas Library website which offers peer-reviewed articles from multiple journals in one location . We ended up with 13 research papers through the use of filters and parameters summarized in *Figure 1*.

Systematic Review Flowchart

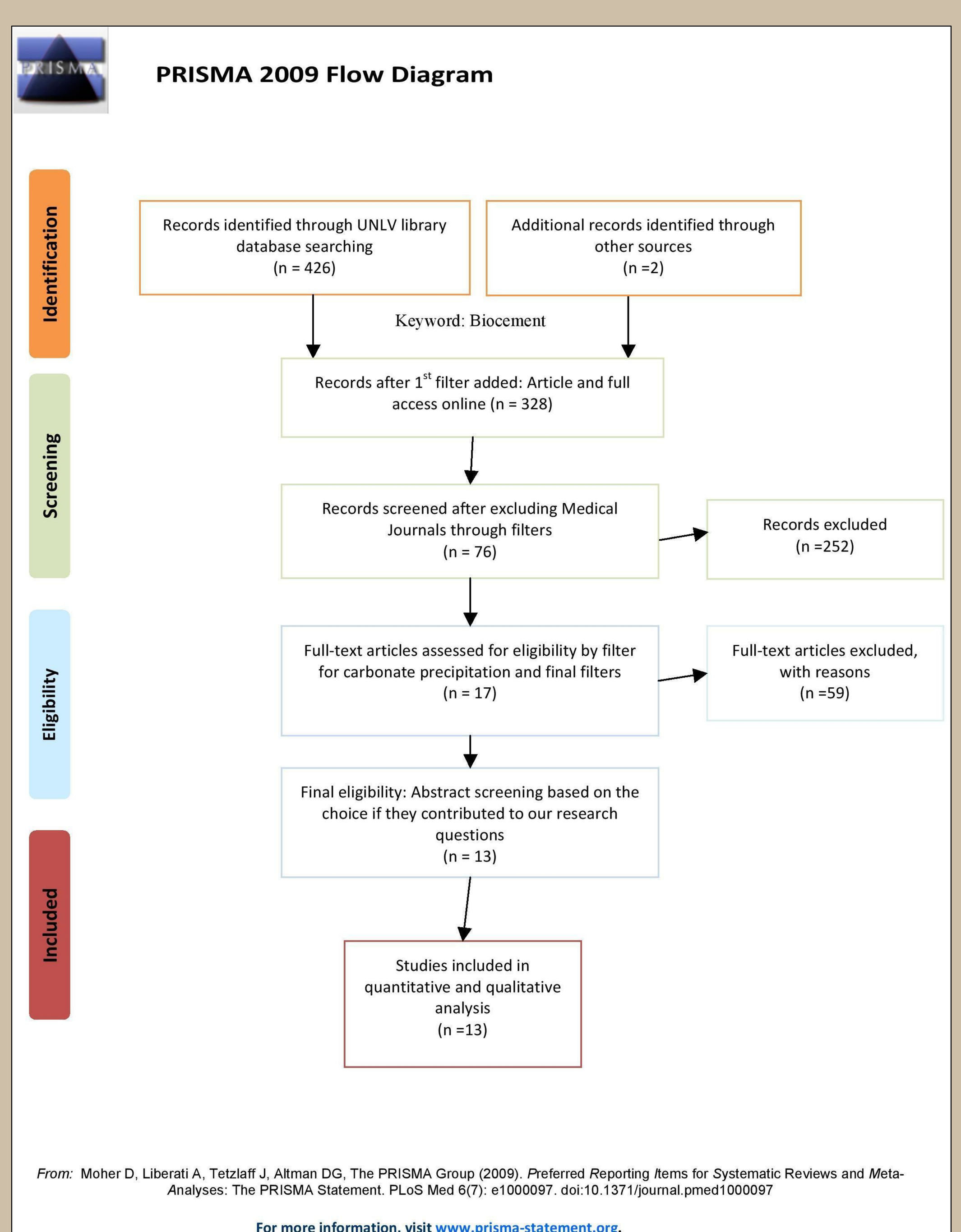

Figure 1: Summary of the systematic review conducted for biocement. Filters and parameters where chosen based on the two research questions we wanted to address. Flow chart template was used from PRISM.

Results Summary Table

					Optimal environment			
Reference	Bacteria	Soil used	Permeability	Porosity	Strength	Temperature	PH	Cell Concentratio
Stabnikov, Naeimi, Ivanov, and Chu (2011)	*Bacillus subtilis*	Sand	Lowered, from 10^{-4} m/s to $1.6\cdot10^{-7}$ m/s	40%	Increased from 7.5MPa to 35.9 MPa	30°C	Adjusted to 7	X
Choi, Chu, Brown, Wang, and Wen (2017)	*Sporosarcina pasteurii*	Sand	reduced from 10^{-4} m/s to 8.17-1.52 x 10^{-6} m/s	X	1100 MPa –At 9% of $CaCO_3$, the column has a strength ratio of 6.87 (unconfined compressive stress (UCS) and tensile stress (TS))	X	Adjusted to 7.0-7.5	OD_{600} = 0.8−1.2
Abo-El-Enein, Ali, Talkhan, and Abdel-Gawwad (2013)	*Sporosarcina pasteurii*	Portland cement and Egyptian sand (1:3 ratio)	X	- Decreased	3% improvement	23°C (room temperature)	Optimal at 9.25 but adjusted to 6.5. - Increased during reaction.	X
Dhami, Mukherjee, and Reddy (2016)	*Bacillus megaterium*	Calcareous soils of India	X	X	X	35°C	Increased to 8	5 x10^{8}
Khodadadi Tirkolaei and Bilsel (2015)	*Sporosarcina pasteurii*	Lateritic soil (w/Kaolinite Mineral (clay))	X	X	X	30°C	Grown at 9 and adjusted to 6.5.	10^{7}
Gomez, Anderson, Graddy, Dejong, Nelson, and Ginn (2017)	*Sporosarcina pasteurii*	Concrete Sand	X	X	X	28°C	Increased to 9	3.5 x 10^7 cells/ml
Stabnikov (2016)	*Bacillus subtilis*	X	X	X	X	25°C	8	X
Osinubi, Eberemu, Gadzama, and Ijimdiya (2019)	*Sporosarcina pasteurii*	Lateritic soil (w/Kaolinite Mineral)	X	X	X	X	Adjusted to 9	1.80 × 10^{9} cells/ml at 75% bacteria–25% cementation
Deng & Wang (2018)	*Sporosarcina pasteurii*	Coral sand (Type 1: very fine, Type 2: fine, and Type 3: coarse)	Reduced best in very fine sand.	X	2.61MPa Finer sand was stronger than coarse sand	30°C-35°C	Increased to 9-11	X
Li, Zhu, Mukherjee, Huang, and Achal (2017)	*Bacillus cereus*	Metakaolin	X	28% reduction at 28-days	Increased to 27.4% at 28 days	X	Adjusted to 7.5	5 × 10^{8} cfu per ml.
Naidu, Rao, and Redd	*Sporosarcina pasteurii*	Type 1: river sand (fine), Type 2: crushed stone (coarse), and cement	X	35% decrease	32.74 MPa with a 16.18 % increase	37°C	X	10^{5}
Omoregie, Khoshdelnezamiha, Senian, Ong, and Nissom (2017)	*Sporosarcina pasteurii*	Type 1: fine sand(0.075 mm) and Type 2: fine gravel (4.75 mm)	X	X	700 Psi	25°C -30°C	Increased to 6.5-8	0.8–1.2 x 10^{7}cells/mL
Keykha, Huat, and Asadi (2014)	*Sporosarcina pasteurii*	Soft clay (w/Kaolinite Mineral)	X	X	60 kPa increased 10 times	X	9	X

Table 1: Summary of the data from the 13 reviewed publications pinpointing the organisms and the type of soil they used and the data they found. The data measurements included permeability, porosity, strength, optimal temperature, optimal pH, and cell concentration.

Results

- As shown in one of the experiments by Deng & Wang (2018), finer sand showed better results in strength and permeability compared to the coarse sand tested. In experiment by Naidu, Rao, and Redd there was a 35% decrease in porosity and a 16.18% increase in strength. In all 3 experiments testing different grades of soil, they all showed soil that was fine was able to be used in biocement [3,11,12].
- It was found that biocement was able to work on and aggregate on clay like minerals and that the biocement was able to improve the strength of the clay 10x [7].
- *S. pasteurii* shows good growth in hotter temperatures that would correspond to southern Nevada's temperatures that are predominantly hot temperatures. Among the data collected the bacteria was shown to grow in temperatures varying from 23°C-37°C 1-5, 7-9, 11-15]. The data also shows that the bacteria is able to grow in very alkaline environment as well as growing in extreme variation in pH.
- As summarized in table 1, the bacteria was shown to grow in a large pH range starting at a pH of 6.5 and reaching all the way to a pH of 11 [1-5, 7-9, 11-15].

Conclusion and Future Direction

- Optimal organism for expansive soil stabilization by means of biocementation is *S. pasteurii*. This conclusion was reached by looking at the literatures data on the parameters tested on *S. pasteurii*. Parameters such as the ability to grow in high pH as well as high temperatures mimic Las Vegas's hard water and the hot temperature environment..
- It was found that smaller particle sizes were able to better aggregate the bacteria to form biocement compared to coarse material. This is beneficial information since clay is known to have smaller particle size compared to conventional soil and sand. It was also found that soil that contained clay minerals were able to have biocement produced on it successfully.
- Unfortunately, there is doubt on the accuracy of the conclusions due to the limited data that was collected on types of bacteria and that the materials tested where not specifically on expansive clay themselves.
- Through this review we have seen this processes being narrowed to a specific purpose when this technology could be stretched and benefit so many other processes in construction. As southern Nevada continues to grow in population large construction projects continue to spring up and biocement could have a large impact in the state. Overall, there is a lot of room for improvement and research on other materials to be used for biocement experiments and due to growing populations.

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