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Study on the effect of microbial induced calcium carbonate precipitation on improving the damage of desert soil wind erosion

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Abstract *: Abstract: In desert areas, high-speed winds will drive sand particles, which can seriously lead to sandstorms, seriously affecting people's health and daily life. In this study, microbially induced calcium carbonate precipitation (MICP) was used to fix the desert surface soil to prevent it from being eroded by wind. MICP technology is a fast, efficient and environmentally friendly method, which conforms to the concept of green and sustainable development, and has great economic and social value. The soil samples used in this study came from the Taklimakan Desert in Xinjiang Province, which is the most severely affected region in China by wind-blown sand. MICP technology is used to strengthen the soil, and the calcium carbonate content of all samples is tested under the condition of different solution ratio, spray liquid content and curing age, so as to provide reference for practical engineering application.*

Key words: *wind erosion; desert ；micp ；bacillus megaterium*

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I. Introduction

China is one of the countries most seriously affected by desertification and desertification in the world. The total area of desertification land in China is 2,611,600 square kilometers, accounting for 27.2% of the total land area, and the total area of desertification land is 1,71,200 square kilometers, accounting for 17.93% of the total land area.

MICP is a ubiquitous process that plays an important role in the cementation of natural systems such as caves, soils, sediments, aquifers and open waters [1-3]. Due to its natural ability to precipitate metal ions, consolidate cement sand, soil, minerals and sequester carbon dioxide, MICP is considered to have great potential in metal repair, soil reinforcement and building restoration [4-6]. In recent years, microbially induced calcium carbonate deposition (MICP), as a new technology for soil improvement and structural repair, has been gradually applied to engineering construction [7,8]. This technology mainly relies on specific microbial metabolism to produce carbonate ions, which combine with exogenous calcium ions to quickly generate cementing calcite crystals and glue loose particles together. Making it a structure with a certain strength can effectively alleviate wind erosion.

The urease-producing microbe used in this paper is Bacillus megaterium (strain ATCC 14581). Bacillus megaterium is a kind of Gram-positive bacteria that exists widely in nature, mainly in soil [9]. Bacillus megaterium has been shown to have the ability to induce calcite precipitation in natural soils [10,11]. In this study, the optimal conditions for consolidation were explored by changing different spraying amount, urea-$CaCl_2$ concentration ratio and curing time, which provided theoretical basis and process optimization parameters for curing Taklimakan desert soil.

II. Materials and methods

2.1 Biologics

In this study, the bacteria used were Bacillus pasteurelli (strain No. ATCC 11859) and Bacillus megaterium (strain No. ATCC 14581), which were purchased from the Shanghai Conservation Biotechnology Center. Since microbial strains are purchased, activation and culture are required to obtain more strains for testing. The process of bacterial activation culture is shown in Figure 1.

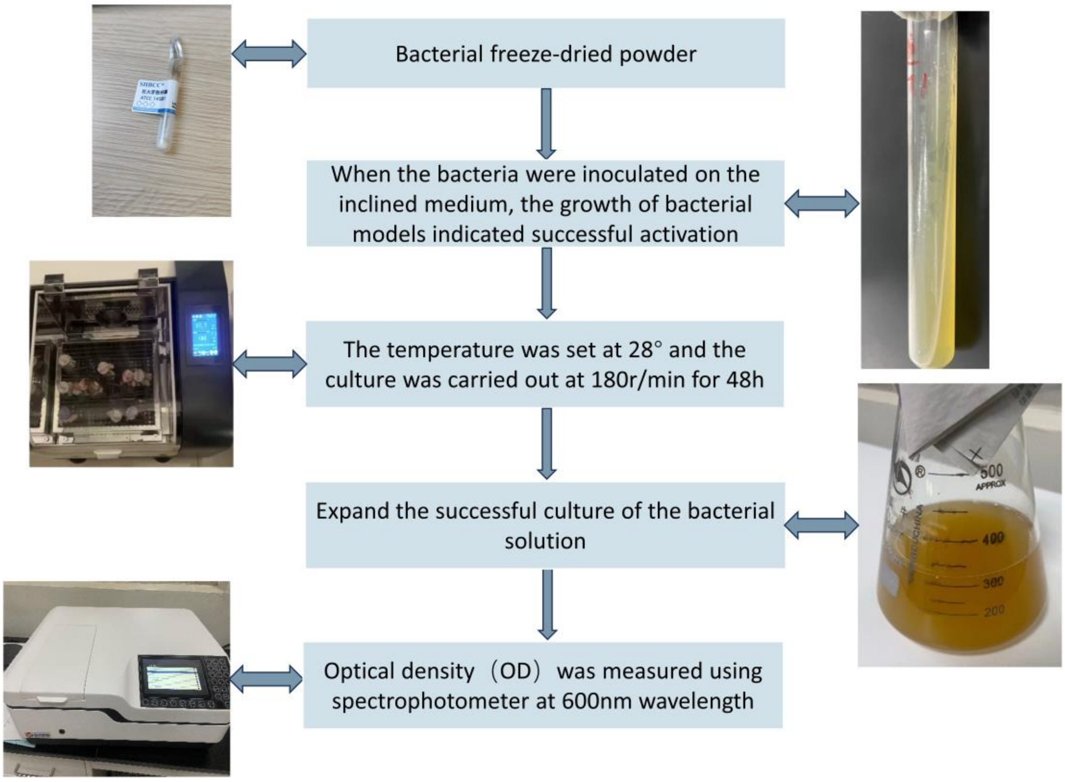

FIG. 1 Schematic diagram of microbial culture system

2.2 Soil

The experimental soil was taken from Taklimakan desert at the junction of Maigeti County and Yuepu Lake County. According to ASTM D2487 soil classification standard, the sand is fine sand, with fine grains accounting for 99.77%, and is poorly graded soil.

2.3 Samples and their conditions

In this study, an oval plastic mold with a depth of 25mm, a length of 250 mm and a width of 195mm was selected. The initial weight of each sample is 500g, part of which is shown in Figure 2.

FIG.2 Samples

To prepare the solution for spraying the sample, a cementing solution consisting of distilled water, urea and calcium chloride was prepared. According to the chemical reaction equation of urea hydrolysis in the process of calcium carbonate precipitation induced by microorganisms, the optimal molar ratio of urea to calcium chloride is 1:1.

Three treatment variables were considered in this study :(1) the amount of bacterial solution and urea-CACL2 spray (bacterial solution: urea-CACL2 =1:1); (2) concentration of cementing agent; (3) Maintenance age. The values for these variables are listed in Table 2. All experiments were conducted in parallel three times. Spraying of the samples was done evenly from a distance of 30 cm above the samples. It should be noted that after spraying, the samples were placed in the laboratory environment at 30° C temperature for 1, 3, 6, 10, and 15 days as curing duration.

Table 1 Sample groups

Treatment type	ID	Bacterial solution type	Spray liquid volume (ml)	concentration of cementing agent (mol/L)
Different Bacterial solution type	A1	Deionized water	20	/
	A2	Bacillus megaterium	20	0.5
	A3	Bacillus pasteurii	20	0.5
	A4	/	/	/
Different concentration of cementing agent	B1	Bacillus megaterium	20	0.1
	B2			0.3
	B3			0.5
	B4			0.7
	B5			1
Different spray liquid volume	C1	Bacillus megaterium	10	0.5
	C2		15	0.5
	C3		20	0.5
	C4		25	0.5

Table 2 Precipitation quality of calcium carbonate in each group

Group	ID	Curing time (d) 1	3	6	10	15
A	A1	1.47	1.47	1.47	1.47	1.47
	A2	1.47	1.47	1.47	1.47	1.47
	A3	1.51	1.72	1.84	1.95	1.97
	A4	1.97	2.62	2.78	2.79	2.83
B	B1	1.47	1.47	1.60	1.61	1.62
	B2	1.50	1.50	1.67	1.68	1.68
	B3	1.97	2.62	2.78	2.79	2.83
	B4	1.60	1.76	1.79	1.80	1.81
	B5	1.53	1.75	1.77	1.77	1.78
C	C1	1.47	1.56	1.63	1.63	1.63
	C2	1.52	1.76	1.79	1.79	1.81
	C3	1.97	2.62	2.78	2.79	2.83
	C4	1.65	2.55	2.54	2.55	2.56

III. Results and discussion

3.1 Controlled trial

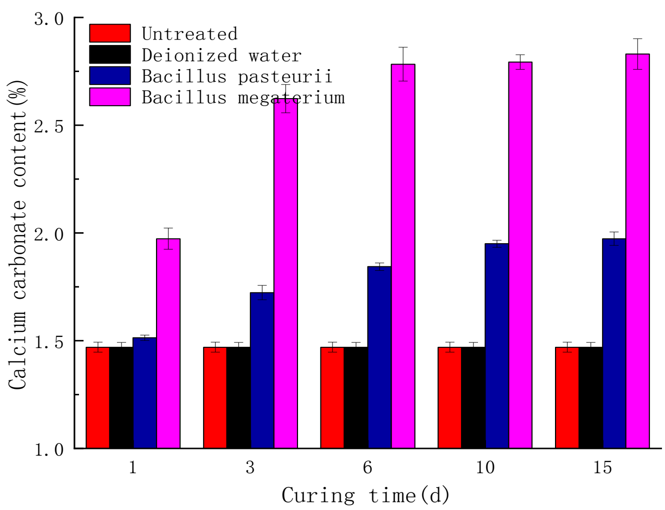

Fig. 3 Calcium carbonate production of different bacterial solution samples

As can be seen from FIG. 3, the calcium carbonate generation amount of water treated samples and soil samples is the same. With the increase of time, the calcium carbonate content of Bacillus pasteurii samples is significantly higher than that of soil samples and water removed samples, because Bacillus pasteurii in the bacterial solution participates in the MICP reaction, but the calcium carbonate content of Bacillus pasteurii samples is significantly lower than that of Bacillus megaterium. The calcium carbonate content of Bacillus megaterium samples increased significantly in the first three days and only slightly after the sixth day. This is because over time, the nutrients in the B. megaterium solution are consumed and B. megaterium begins to die off in large numbers.

3.2 Different cementing fluid concentrations

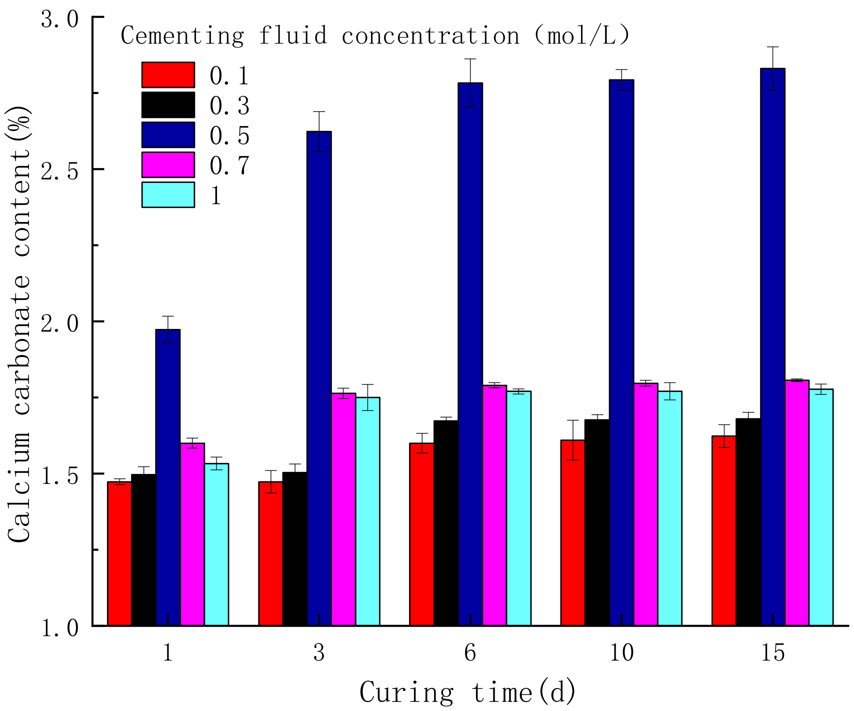

FIG. 4 Calcium carbonate production at different cementing fluid concentrations

FIG. 4 shows the column diagram of calcium carbonate generation of the sample with the increase of curing age when the spray liquid content is 20ml and the concentration of cementing fluid changes. It can be intuitively seen from the figure that the calcium carbonate content of the sample increases with the increase of the cementing fluid concentration from 0.1mol/L to 0.5mol/L, especially when the cementing fluid concentration is from 0.3mol/L to 0.5mol/L, the calcium carbonate content increases significantly. The calcium carbonate content of the sample decreased with the increase of the cementing fluid concentration from 0.5mol/L to 1mol/L, and the calcium carbonate content of the sample showed a significant decline when the cementing fluid concentration was from 0.5mol/L to 0.7mol/L. It can be concluded that the best cementing fluid concentration of the sample is 0.5mol/L.

3.3 Different spray liquid content

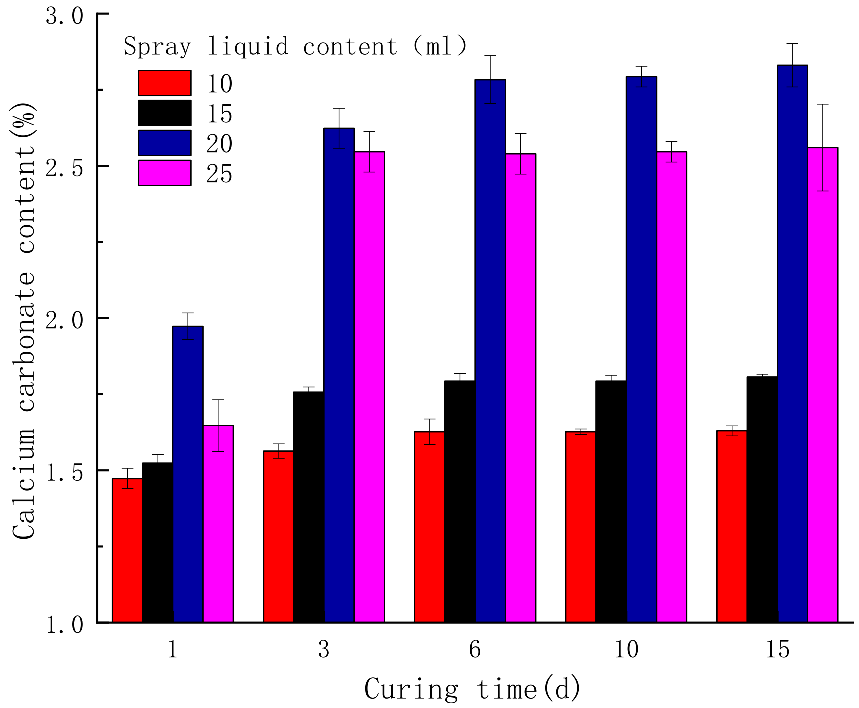

Fig.5 Calcium carbonate production with different spray liquid contents

FIG.5 shows the column diagram of calcium carbonate generation in the sample with different spray liquid contents when the concentration of cementing fluid is 0.5mol/L. The yield of calcium carbonate in the 10ml and 15ml spray samples was not ideal, because in the lower (10,15ml) spray sample, there was not enough bacterial and cementing fluid to react, resulting in too low calcium carbonate production. The samples with the spray liquid content of 20ml and 25ml produced more calcium carbonate, but the spray liquid content with the highest calcium carbonate generation was 20ml. When the spray liquid content was 25ml, the calcium carbonate generation volume of the sample decreased, because with the increase of the spray liquid (25ml), a large amount of calcium carbonate was easy to block at the grout. As a result, bacterial fluid and cementing fluid failed to react with soil particles completely.

IV. Conclusion

In this paper, soil samples, deionized water treated samples, Bacillus pasteurii treated samples and Bacillus megaterium treated samples were prepared. For Bacillus megaterium treated samples, spray liquid content was set as 10, 15, 20 and 25ml, and cement liquid concentration was set as 0.1, 0.3, 0.5, 0.7 and 1mol/L, respectively. After curing for 1, 3, 6, 10 and 15 days, the curing effect of Bacillus megaterium on the soil of Taklimakan Desert was compared, and the influence of different spray liquid content and cementing fluid concentration on the wind erosion resistance of soil was studied. The conclusions were as follows:

(1) Deionized water treatment samples could not increase the content of calcium carbonate in soil, and both Bacillus megaterium and Bacillus pasteurii could effectively increase the content of calcium carbonate in soil. At the curing age of 15 days, the calcium carbonate content of the samples treated by Bacillus pasteurii increased by 34.01% compared with that of the plain soil, and the calcium carbonate content of the samples treated by Bacillus megaterium increased by 92.51% compared with that of the plain soil.

(2) The concentration of cementing fluid has a significant influence on the calcium carbonate yield of the Taklimakan Desert soil. Within the range of curing ages, the calcium carbonate content of the sample first increases and then decreases with the increase of the concentration of cementing fluid, and the calcium carbonate content reaches the highest when the concentration of cementing fluid is 0.5mol/L.

(3) The content of spray liquid has a significant influence on the calcium carbonate generation of Taklimakan Desert soil. In the range of curing ages, the content of calcium carbonate in the sample first increased and then decreased with the increase of spray liquid content, and reached the highest when the spray

liquid content was 20ml.

This study is a preliminary step towards a site-specific practice of bio-mediated erosion control. However, several aspects of MICP-based treatment need to be further addressed, such as the effects of seasonal heat variations, dry and wet cycles, and applicability under real field conditions. This study recommends a small-scale field trial to further investigate the ecological sustainability of MICP-based erosion control treatments under actual environmental conditions in the Taklimakan Desert.

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