

Comparative Analysis of Nanoplastic Sedimentation Efficiency Mediated by Cyanobacteria in Freshwater Ecosystems

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Abstract

Nanoplastic pollution in freshwater ecosystems poses significant environmental risks due to the persistence of these particles and their harmful effects on aquatic life and human health. Traditional remediation methods, such as membrane filtration and coagulation, are costly and energy-intensive. Cyanobacteria offer a sustainable alternative by producing extracellular polymeric substances (EPS), which promote particle aggregation and sedimentation. This study examines the sedimentation efficiency of *Synechococcus elongatus* and *Gloeocapsa* sp. in nanoplastic aggregation under freshwater conditions, focusing on morphology and size. Nanoplastics (0.005 g/mL), synthesized via emulsion polymerization, were introduced into a sedimentation experiment with three-week-old cyanobacterial cultures. Sedimentation efficiency was assessed by absorbance at 750 nm over six hours, and microscopic analysis compared particle size distribution before and after sedimentation. Results showed that nanoplastics aggregated with *Synechococcus elongatus* exhibited higher sedimentation efficiency than those with *Gloeocapsa* sp., attributed to differences in cell size affecting cellular mass. These findings highlight cyanobacteria's potential as a cost-effective, eco-friendly solution for mitigating nanoplastic contamination, offering insights into sustainable bioremediation strategies as alternatives to conventional water treatment technologies.

Introduction

Nanoplastic pollution in freshwater ecosystems has emerged as a significant environmental concern due to the particles' minute size, which allows them to infiltrate food chains and disrupt aquatic life at the cellular level. Conventional removal methods, such as chemical coagulation, electrostatic particle capture, and membrane filtration, remain limited by high costs, energy consumption, and potential toxicity. This study explores the potential of cyanobacteria (*Synechococcus elongatus* and *Gloeocapsa* sp.) to mediate nanoplastic sedimentation. The focus lies on the production of extracellular polymeric substances (EPS) by these cyanobacteria, which may facilitate the aggregation and removal of nanoplastics from freshwater environments. If successful, this research could offer an eco-friendly and sustainable approach to managing nanoplastic pollution, addressing a critical gap in current remediation technologies.

Objectives

1. To compare the nanoplastic sedimentation capabilities of the cyanobacteria *Synechococcus elongatus* and *Gloeocapsa* sp. in freshwater conditions.
2. To investigate the factors influencing sedimentation, such as shape and size of both cyanobacterial species.

Material and Method

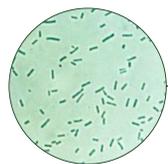
1. Cyanobacteria preparation



Cultivation of both cyanobacteria species in BG-11 broth



Examine the quality of the cyanobacteria before testing

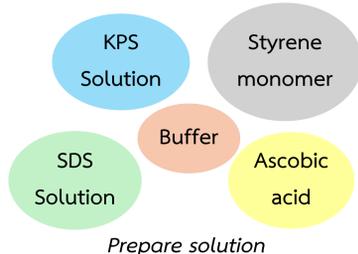


Synechococcus elongatus

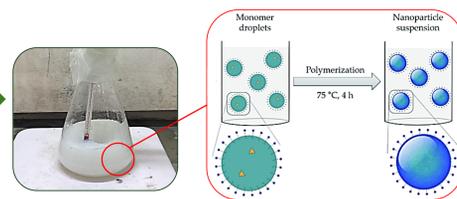


Gloeocapsa sp.

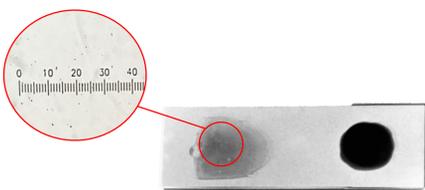
2. Nanoplastics preparation



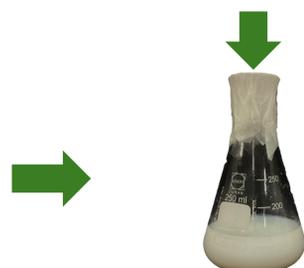
Prepare solution



Emulsion Polymerization



Staining nanoplastics with Sudan Black to observe the characteristics and size of nanoplastics under a microscope.

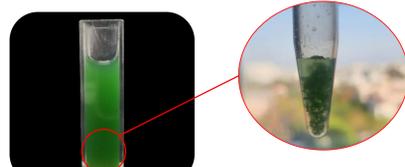


Whatman No. 1 filter paper and 0.45 micrometer syringe filter

3. Sample Characterization



Settling



Observe sedimentation patterns and particle aggregation

Results

1. Preliminary analysis of nanoplastic size

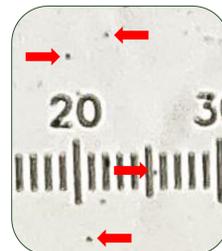


Figure 1

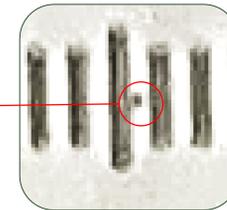


Figure 2

Figure 1 the size of nanoplastics detected under the microscope ranges from 0.5–1 μm .

Figure 2 shows the size of nanoplastics, which are half the width of an ocular micrometer division. This allows their size to be calculated under the microscope as 0.5 μm .

2. Comparison of nanoplastic sedimentation by two cyanobacterial species

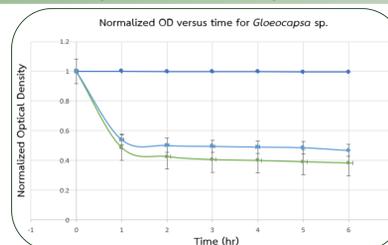


Figure 3 The results shows that nanoplastics that do not precipitate with cyanobacteria cannot settle on their own when left undisturbed, compared to *Gloeocapsa* sp. Nanoplastics that precipitate with *Gloeocapsa* settle rapidly from the first hour, resulting in nsp.o aggregation process with the nanoplastics.

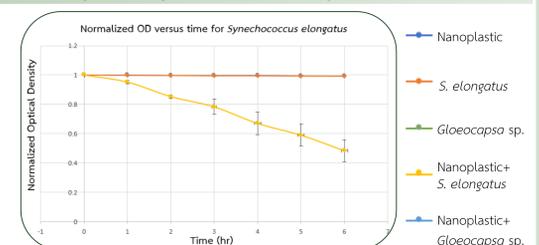


Figure 4 The results shows that nanoplastics precipitating with *Synechococcus elongatus* exhibit a clearly decreasing rate of sedimentation, compared to *Synechococcus elongatus* left undisturbed, where no significant change in absorbance occurs due to the very low sedimentation rate

3. Monitoring sedimentation patterns between nanoplastics and cyanobacteria

Time (hour)	The characteristics of sediment aggregation				
	Nanoplastic	<i>S. elongatus</i>	<i>Gloeocapsa</i> sp.	Nanoplastic + <i>S. elongatus</i>	Nanoplastic + <i>Gloeocapsa</i> sp.
0 hour					
6 hour					

Table 1 shows that aggregation and sedimentation occur in nanoplastics precipitating with *Synechococcus elongatus*. However, when observing the sediment of nanoplastics precipitating with *Gloeocapsa* sp., it is clear that the sediment separates into layers, but this is not due to aggregation with nanoplastics. Instead, it results from the rapid sedimentation of the cells themselves.

4. Observation of sediment aggregation under a microscope

Time (hour)	The characteristics of sediment aggregation			
	<i>S. elongatus</i>	<i>Gloeocapsa</i> sp.	Nanoplastic + <i>S. elongatus</i>	Nanoplastic + <i>Gloeocapsa</i> sp.
0 hour				
6 hour				

Table 2 shows the appearance of the sediment under the microscope, where it is clearly seen that nanoplastics precipitating with *Synechococcus elongatus* form large, irregularly shaped aggregates. In contrast, nanoplastics precipitating with *Gloeocapsa* sp. show only the aggregation of *Gloeocapsa* sp. cells, with no aggregation of the nanoplastic particles.

Discussion and Conclusion

The experimental results show that *Synechococcus elongatus* has the ability to bind with nanoplastic particles, leading to sedimentation. In contrast, *Gloeocapsa* sp. does not bind with nanoplastic particles. This is because *Synechococcus elongatus* is small in size, similar to nanoplastic particles, and has the ability to produce EPS that facilitates binding with the nanoplastic particles. On the other hand, *Gloeocapsa* sp. also produces EPS, but due to its larger size compared to *Synechococcus elongatus*, the cells sediment quickly, making it difficult for the nanoplastic particles to bind to the cells. The findings from this experiment can serve as a guideline for designing sustainable and environmentally friendly microbial-based systems for treating water contaminated with nanoplastics.