Validation of an Innovative Portable Decontamination System for Rapid and Widespread Restoration of Polluted Water Bodies

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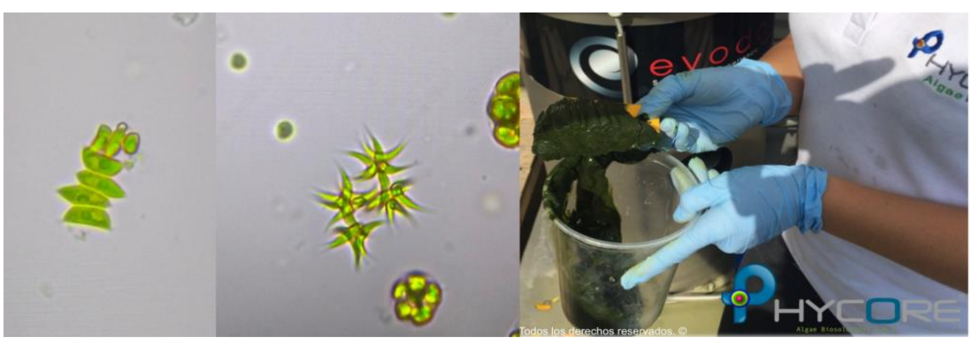
Executive Summary

Water pollution is a pressing global issue with profound environmental, economic, and health consequences. Over 80% of wastewater worldwide is released untreated into rivers, lakes, and coastal waters, leading to ecosystem degradation marked by nutrient overload, harmful algal blooms, and oxygen depletion. This degradation poses significant health risks, contributing to more than 485,000 deaths annually from diarrheal diseases alone. Additionally, 3.5 million Americans fall ill each year due to contact with contaminated water sources. The economic toll is equally staggering, with global costs exceeding $260 billion annually due to poor water quality. Addressing water pollution is critical to safeguarding public health and restoring the health of affected water bodies worldwide.

https://www.americanrivers.org/threats-solutions/clean-water/sewage-pollution/

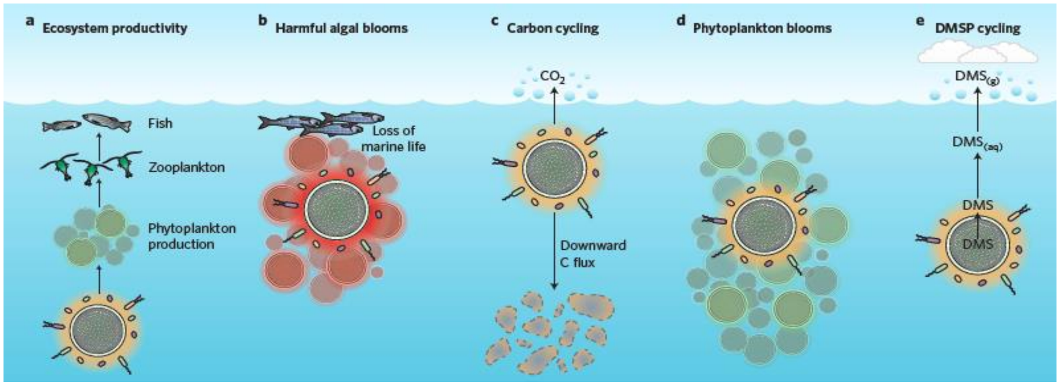
Effective and scalable decontamination technologies are urgently needed to tackle global water pollution issues. Advanced filtration and bioremediation techniques, supported by academic research, have proven effective in removing contaminants and restoring water quality (Gupta et al., 2015; Singh & Singh, 2017).
Utilizing microalgae for water decontamination offers significant advantages over current physical-chemical methods, as it is more cost-effective and environmentally friendly (El-Sheekh et al., 2022; Sforza et al., 2018). Microalgae demonstrate remarkable bioremediation capabilities against heavy metals, phenols, antibiotics, nitrogen, phosphorus, viruses, pesticides, and oils in both industrial and natural water sources, leveraging species-specific bioremediation capacities (Usher et al., 2014). However, widespread adoption of native algae species for local water bodies remains relatively nascent globally (Bajunaid Hariz & Sobri Takriff, 2017; Beltrán Rocha, 2014; Gutiérrez et al., 2021, 2022; Mora et al., 2005; Ortiz-Villota et al., 2018).



Gutiérrez JE, Gutiérrez-Hoyos N, Gutiérrez JS, Vives MJ, Sivasubramanian V. Bioremediation of a Sewage-Contaminated Tropical Swamp Through Bioaugmentation with a Microalgae-Predominant Microbial Consortium. Indian J Microbiol. 2022 Jun;62(2):307-311.

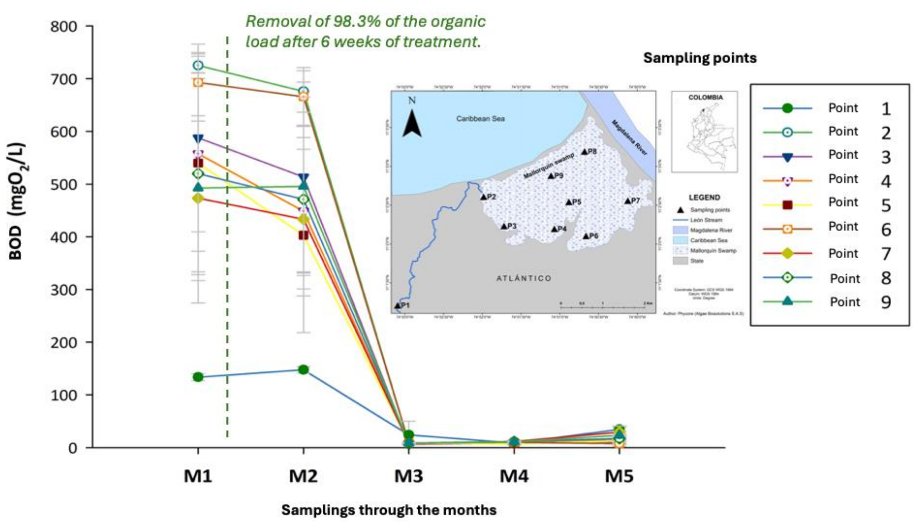
Our team has pioneered an innovative approach over the past decade, focusing on harnessing native microalgae consortia and their phycosphere—a diverse microbial community (MPMC: Microalgae-

Predominant Microbial Consortium)—as effective decontaminants for natural water bodies impacted by human activities, offering a pioneering solution integrating various microbiological consortia (Indian J Microbiol. 2022 Jun;62(2):307-311). The microalgal phycosphere has turned out to be the physiological basis of virtually all ecosystems, and despite being microscopic, the effects of the processes that occur within it are of ecosystemic magnitude.



Seymour, J. R., Amin, S. A., Raina, J. B., & Stocker, R. (2017). Zooming in on the phycosphere: The ecological interface for phytoplankton-bacteria relationships. *Nature Microbiology*, *2*(May). https://doi.org/10.1038/nmicrobiol.2017.65

Our research allowed us to take advantage of this capacity of the MPMC to successfully decontaminate two streams, two swamps and a reservoir in Colombia, demonstrating that this methodology is effective and safe to remediate natural water bodies of more than 700 hectares. These successes have been awarded international awards for their relevance and impact (Sivasubramanian, 2016, Gutiérrez et al., 2021, Gutiérrez et al., 2022).



Example of the capacity of PMMC to remove organic contamination (sewage) from a 750-hectare swamp, lowering it from more than 800 to less than 20 mgO_2/L in 6 weeks. Indian J Microbiol. 2022 Jun;62(2):307-311. doi: 10.1007/s12088-021-00990-y. Epub 2021 Nov 11. PMID: 35462717; PMCID: PMC8980186.

However, the logistical requirements and costs of these processes were considerable. Each one required the installation of provisional phycoculture plants, intensive in civil works, transportation, logistics and personnel. As a result, the estimated cost of decontaminating a hectare of swamp or lake ranges between USD 2,400 to 2,900 per hectare, for a one-time process that takes between 12 and 24 months to develop. This is costly for the environmental entities that usually finance these interventions, and affects the acquisition cost of each client, which is also non-recurring. All the above has made it only viable to offer projects for cases of decontamination of large bodies of water, when 90% of cases of environmental pollution occur in medium or small waterbodies.

Example of a hectare phycoculture plant needed to decontaminate the Santiago Apostol swamp, compared to 0.011898 hectares that would be occupied by four compact reactors capable of doing the same work.

Through our innovation process, we have successfully developed compact, autonomous mobile devices that minimize operational and maintenance requirements. This technological advancement allows us to achieve comparable effectiveness with significantly reduced spatial, logistical, security and human resource needs. Previously, a one-hectare temporary plant with 10 operators is now replaced by four containers and only two operators. Additionally, equipment can often be installed directly at discharge sites, eliminating the need for daily MPMC transportation.
This innovation will allow us to lower costs to USD 750 to 900 per hectare annually, making it affordable for Colombian environmental organizations, and even more for entities in other countries with more resources. This, added to the speed of deployment and the lack of need for major civil works, will allow virtually all bodies of water to be decontaminated and kept decontaminated.

Mission and Objectives

- Compact, modular and portable decontamination system will be constructed to decontaminate two natural water bodies in hot and cold thermal floors.
- Rigorous field tests in hot and cold thermal floors will validate the deployment efficiency and decontamination effectiveness achieved by these compact systems.
- The scalability potential of the developed system will be evaluated for large-scale implementation in developed and developing regions.
- Comprehensive guidelines and training modules will be formulated for stakeholders involved in the implementation and operation of the system, ensuring effective regional implementation and its sustainability.

General Objective
Validate a compact, modular and portable decontamination system capable of efficiently restoring contaminated natural water bodies.

Specific objective 1: Execute two phycoremediation processes in hot and cold thermal floor environments to validate the efficiency and effectiveness of the implementation of the compact systems developed to remove contaminants from natural water bodies.

Specific objective 2: Evaluate the deployment efficiency and decontamination effectiveness of the developed compact systems in removing contaminants from the two natural water bodies.

Specific objective 3: Evaluate the scalability potential of the developed compact decontamination system for large-scale implementation in diverse regions and formulate comprehensive guidelines and training modules to ensure effective regional implementation and long-term sustainability.

Implementation Plan

This project, a collaboration between the Microbiological Research Center (CIMIC) at Universidad de Los Andes and the biotechnology startup Phycore®, leverages CIMIC's expertise in environmental microbiology and Phycore®'s track record in advancing phycoremediation processes using microbial consortia predominantly of microalgae (MPMC) in large natural bodies of water.

Spanning 24 months, the initiative aims to evaluate the effectiveness of a compact, modular, and portable decontamination system in removing pollutants under varying climatic conditions across two regions. The project activities are depicted in the following timeline graph:

Schedule																										
General Objective	Specific objective	Actividades	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Validate a compact, modular and portable decontamination system capable of efficiently restoring contaminated natural water bodies.	SO1. Execute two phycoremediation processes in hot and cold thermal floor environments to validate the efficiency and effectiveness of the implementation of the compact systems developed to remove contaminants from natural water bodies.	A1. Carry out bioaugmentation by phycoremediation of the waters of the Bogotá River or one of its tributaries, and the internal water bodies of the city of Cartagena.			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
	SO2. Evaluate the deployment efficiency and decontamination effectiveness of the developed compact systems in removing contaminants from the two natural water bodies.	A2. Determine the water quality parameters in the body of water before and during the intervention.	■					■						■						■					■	
		A3. Carry out hydrobiological studies in the body of water and formulate the microbial consortium of microalgal predominance (CMPM) necessary to strengthen microbiological diversity and improve water quality.	■											■											■	
	SO3. Evaluate the scalability potential of the developed compact decontamination system for large-scale implementation in diverse regions and formulate comprehensive guidelines and training modules to ensure effective regional implementation and long-term sustainability.	A4. Conduct stakeholder consultations and needs assessments across diverse regions to tailor the compact decontamination system, ensuring alignment with local environmental challenges and regulatory frameworks.			■			■			■			■			■			■			■		■	
		A5.Gather continuous feedback from stakeholders and refine operational protocols for optimal scalability and performance.			■			■			■			■			■			■			■			■
		A6. Develop comprehensive guidelines and training modules in collaboration with stakeholders, integrating local insights and best practices to equip regional communities with the necessary skills for effective implementation and long-term sustainability of the decontamination system.					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Funding Requirements

To achieve these objectives, we seek to raise USD$ 4,030,900.07 in donations that will be received and administered from the University. Funds will be allocated over the course of 2 years, as follows:

1. Operational Costs USD$1,087,912.62: 24 months of salaries for the scientific staff made up of seven scientists, five professionals and ten technicians. Administrative support staff consisting of three more professionals, and administrative overhead costs.

2. Technological equipment USD$ 1,701,456.31: 10 compact, modular and portable decontamination system of 20,000 liters each for phycoremediation field tests in hot and cold thermal floors.

3. Laboratory testing USD$240,873.86: Physicochemical analysis of water quality in the water bodies before and after treatment with compact, modular and portable decontamination system.

4. Participatory action research (PAR) activities USD$272,228.13: Community workshops to to tailor the compact decontamination system, ensuring alignment with local environmental challenges and regulatory frameworks.

5. Sub-contractors Costs USD$ 254,053.40: Property security, logistics, and transportation of work equipment and the 10 compact, modular and portable decontamination systems.

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