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Influence of microplastic exposure on nutrient uptake and growth performance of *Chlorella vulgaris*

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Abstract

Background: Microplastics (MPs) are persistent emerging contaminants frequently detected in wastewater (WW), where conventional treatment systems often fail to remove them, posing environmental and Human health risks [1]. Microalgae-based systems have emerged as sustainable alternatives for WW remediation due to their capacity for contaminants and nutrient removal [2]. However, the effects of MPs on microalgal performance and treatment efficiency under different WW operational conditions remain poorly understood. **Objective:** This study evaluated the physiological responses and bioremediation performance of *Chlorella vulgaris* exposed to different types of MPs under varying WW conditions. **Methods:** *C. vulgaris* was exposed to 100 mg/L [3] of five commonly detected MPs: polypropylene (PP), polystyrene (PS), polyamide (PA), low-density polyethylene (LDPE), and high-density polyethylene (HDPE). Experiments were conducted under different WW conditions: variations in nitrogen (N) availability, organic carbon concentration, and photoperiod regimes (12:12 h light/dark cycle versus continuous light). Microalgal growth, metabolic activity, and bioremediation efficiency were assessed. **Results:** MPs induced heterogeneous metabolic responses depending on the MPs' type and environmental conditions. HDPE and LDPE consistently reduced esterase activity, whereas PS increased esterase activity under N-limited conditions. LDPE also induced intracellular oxidative stress specifically under N limitation. Despite these effects, *C. vulgaris* maintained growth and biomass production in most scenarios. Growth inhibition (13-27%) occurred only under combined nutrient starvation and a 12:12 h photoperiod. Heterotrophic metabolism partially compensated for reduced photosynthetic activity during dark phases. Under N-limited conditions, *C. vulgaris* achieved high bioremediation efficiency, removing up to 94 % of N and >97.5 % of glucose even in the presence of MPs. In contrast, limited organic carbon impaired nutrient removal due to energy constraints. **Conclusions:** Overall, WW conditions strongly modulated the physiological stress induced by MPs. Nutrient limitation and light/dark cycles intensified metabolic disturbances, whereas N-limited environments promoted adaptive responses that supported microalgal resilience. *C. vulgaris* maintained high bioremediation capacity in most conditions, highlighting its potential as a robust and eco-friendly tool for polishing MP-contaminated wastewater.

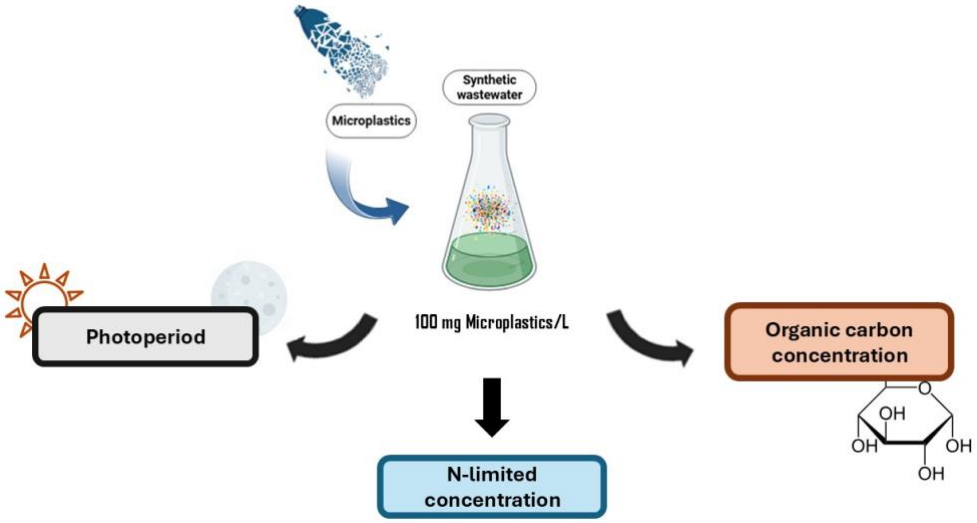

Figure 1. Wastewater bioremediation performance by exposing *Chlorella vulgaris* to different types of MPs, at 100 mg/L, under varying wastewater operational conditions.

Keywords: microalgae based-systems; microplastics; wastewater bioremediation

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