



Impacts of Microplastics on Photosynthetic Efficiency and Pigment Composition in *Chlorella pyrenoidosa*

Gosego Boitumelo Morei 

College of Environmental Science and Engineering, State Key Laboratory of Pollution Control and Resources Reuse
Tongji University, Shanghai 200092, China

Zhang Yalei

College of Environmental Science and Engineering, State Key Laboratory of Pollution Control and Resources Reuse
Tongji University, Shanghai 200092, China

Suggested Citation

Morei, G.B. & Yalei, Z. (2024).
Impacts of Microplastics on
Photosynthetic Efficiency and
Pigment Composition in *Chlorella
pyrenoidosa*. *European Journal of
Theoretical and Applied Sciences*, 2(3),
551-564.
DOI: [10.59324/ejtas.2024.2\(3\).42](https://doi.org/10.59324/ejtas.2024.2(3).42)

Abstract:

The presence of polyethylene (PE) and polystyrene (PS) microplastics affects the ability of the microalga *Chlorella pyrenoidosa* to carry out photosynthesis efficiently and regulate its pigments. *C. pyrenoidosa* is an important primary producer in aquatic ecosystems. This study evaluates the impacts of different concentrations of microplastics on chlorophyll and carotenoid levels over a four-day period by precisely measuring optical density at 680 nm and quantifying the amounts of these compounds. The findings reveal a distinct decline in photosynthetic performance that is directly related to the concentration of the substance. This decline is particularly

evident in the considerable decrease in the Fv/Fm ratios, which serve as a crucial measure of photosystem II efficiency. Significantly, when the microplastic concentrations were greater (250 mg/L and 500 mg/L), the Fv/Fm ratios plummeted to levels that were roughly 50% lower than those seen in the control samples. This indicates a serious degradation of the photosynthetic machinery. In addition, there was a significant decrease in the concentrations of chlorophyll a and b, with reductions of up to 40% and 35% respectively at the highest concentrations of microplastics examined, compared to the control group. Carotenoid levels also experienced a decrease, although it was not as noticeable, declining by around 25% under comparable circumstances. The results of this study have significant ecological consequences, suggesting that the presence of microplastic pollution could significantly reduce the ability of aquatic systems to produce energy from sunlight, thereby causing disruptions in the food chain and overall deterioration of ecosystem health. The study highlights the importance of conducting further research on the long-term effects of microplastics on photosynthetic organisms in water and emphasizes the necessity of implementing effective measures to decrease microplastic pollution in both marine and freshwater ecosystems.

Keywords: *Microplastics, Photosynthetic Efficiency, Chlorella pyrenoidosa, Aquatic Toxicology, Pigment Composition.*

Introduction

The problem of microplastic contamination has become a critical environmental concern, having important consequences for aquatic ecosystems

around the globe (Cheng Yu-Ru and Hsiang-Yu., 2022). Microplastics, which are often less than 5 millimeters in size, are derived from a range of sources, including the fragmentation of bigger



plastic trash, industrial activities, and consumer goods like cosmetics and apparel(Kiki C et al., 2022). Once introduced into the environment, microplastics are ubiquitous pollutants, present in both marine and freshwater ecosystems spanning from the polar regions to the equator. This distribution pattern suggests that they have a significant and far-reaching influence on global water bodies(Ansari F. A et al., 2021).

Microplastics originate from various sources, encompassing both primary microplastics, intentionally produced to be minute, and secondary microplastics, formed through the breakdown of bigger plastic waste(Barboza L. G. A et al., 2018),(Sharma Shivika and Subhankar., 2017). Primary microplastics are commonly discharged directly into water bodies through home and industrial waste, while secondary microplastics enter aquatic habitats as bigger plastic objects break down over time owing to photochemical, biological, and mechanical processes(Liu G et al., 2020).

Polyethylene (PE) and polystyrene (PS) are extensively utilized polymers on a global scale, commonly found in a wide range of consumer goods, packaging materials, and industrial uses. Their functionality extends from common objects such as plastic bags and containers to single-use utensils and insulating materials(Huo Y et al., 2022). Nevertheless, the long-lasting nature and ability to withstand deterioration that give PE and PS their commercial value also make them enduring environmental contaminants when they are introduced into aquatic environments in the form of microplastics(Miloloža M et al., 2021).

PE microplastics commonly arise from the decomposition of items such as plastic bags, bottles, and films through physical, chemical, and photo-degradation mechanisms(Govindan N et al., 2021). Microplastics possess notable attributes of flexibility and durability, enabling them to endure in the environment for prolonged durations(Li Z et al., 2022). Conversely, microplastics from consumer items such as foam packing, cups, and food containers are the usual source of PS microplastics. In contrast to PE, PS exhibits greater rigidity and

brittleness, leading to its fragmentation into smaller particles that can be readily disseminated across marine and freshwater ecosystems(Podbielska Magdalena and Ewa., 2023).

Once microplastics enter the aquatic environment, they are dispersed by ocean currents, surface currents driven by wind, and transportation through rivers. Due to their diminutive size, these particles can be consumed by a diverse array of creatures and can accumulate within food chains, resulting in both physical and chemical effects that can alter the health of species and the dynamics of ecosystems(Amelia T.S.M et al., 2021).

Microplastics directly endanger aquatic species by being ingested, causing entanglement, and serving as carriers for chemical contaminants. Research has demonstrated that a wide variety of aquatic organisms, ranging from tiny plankton to huge marine mammals, can consume microplastics(Cole M et al., 2013). Microplastics present in organisms can cause gastrointestinal obstructions, decreased calorie intake, and internal damage. From a chemical perspective, microplastics have the ability to release harmful compounds such as plasticizers, flame retardants, and other additives into both water and the bodies of creatures(Jiang Y et al., 2022). Furthermore, these particles have the ability to attract and retain pollutants from the nearby water, resulting in their accumulation and potential transfer of these harmful compounds via different stages of the food chain(Zhao Y et al., 2023).

Microalgae, like *Chlorella pyrenoidosa*, are fundamental components of aquatic ecosystems, playing crucial roles in carbon fixation, oxygen generation, and serving as primary producers in food chains(Govindan N et al., 2021). Comprehending the effects of microplastics on these creatures is essential(Wang Q et al., 2020) because disturbances to their physiological processes can have a ripple effect across the ecosystem, influencing biodiversity, water quality, and the stability of aquatic populations(Cao M et al., 2021).

Research has demonstrated that microplastics can directly impact microalgae through physical interactions, such as shadowing and smothering, leading to a decrease in the amount of light available for photosynthesis (Wang S, 2023), (Mao Y et al., 2018). Leached additives or adsorbed contaminants can cause chemical interactions that result in oxidative stress and metabolic disturbances in microalgae (Song Y et al., 2023). Understanding the precise effects of microplastics on microalgae is crucial for gaining insights into the wider ecological implications of microplastic contamination, considering the important role microalgae play in aquatic ecosystems (Song C et al., 2020).

The ecological ramifications of microplastic contamination are intricate and diverse (Kumar R et al., 2021b). Microplastics have the ability to change the characteristics of aquatic environments, such as the way light passes through and the amount of oxygen present (Prata J. C et al., 2019). These changes can then have a ripple impact on processes driven by photosynthesis and biochemical cycles (Franzellitti S et al., 2019). Microplastics can affect photosynthesis and nutrient intake in primary producers such as *C. pyrenoidosa* by interfering with cellular architecture, limiting growth, and altering energy metabolism (Prata J. C et al., 2019).

The consequences for ecosystems are similarly dire. Decreased photosynthetic efficiency in primary producers can result in reduced overall productivity, impacting species dependent on these producers for sustenance and oxygen (Andrady, 2017). Moreover, the accumulation of microplastics in the bodies of larger predators has the potential to result in the bioaccumulation of toxins (Brennecke D et al., 2016). This can have an impact on the reproductive and survival rates of these predators, ultimately causing changes in the structure of communities and biodiversity (Pinheiro L. M et al., 2020).

The objective of this study is to evaluate the impact of PE and PS microplastics on the photosynthetic efficiency and pigment content of *C. pyrenoidosa*. The study will assess the specific

biochemical effects on chlorophyll fluorescence activity and the levels of important pigments, including chlorophyll *a*, chlorophyll *b*, and carotenoids, by examining these two prevalent forms of microplastics. The pigments play a vital role in absorbing light energy and transforming it into chemical energy through photosynthesis, which is essential for the survival and production of microalgae.

The study will utilize multiple assays to quantify alterations in optical density at 680 nm as an indicator of biomass, in addition to conducting comprehensive assessments of pigment degradation or modification. The research seeks to contribute to broader conversations on the management and mitigation of microplastic pollution in aquatic environments. It specifically focuses on protecting microalgae and, consequently, the overall health of global aquatic ecosystems. The results will not only improve our comprehension of the harmful effects of microplastics, but also provide valuable insights for developing environmental policies and conservation initiatives to protect aquatic ecosystems.

Materials and Methods

Experimental Materials

Microalgae Cultivation

The *C. pyrenoidosa* microalgae was placed in a 500mL serum container and the medium was sterilized at a temperature of 121°C for a duration of 20 minutes. After being cooled, 1mL of algae cells were introduced into a 250 mL Erlenmeyer flask containing BG11 medium. The activation culture was conducted in a light incubator with a culture temperature of 25°C, a light intensity of 3000 lx, and a light-dark cycle ratio of 14 h:10 h. Additionally, 5% CO₂ was introduced, and the ventilation rate was set at 0.1vvm (50 mL/min). The static culture was conducted for a duration of 4 days, namely during the exponential phase. The broth was manually agitated three times a day at consistent intervals to avoid the settling of algal sediment.

The Polyethylene (PE) and Polystyrene (PS) microplastics were procured from Zhonglian Petrochemical Materials (Guangdong, China).

Algal Preparation

Sterilized a 2000L Erlenmeyer flask along with 50mL centrifuge tubes by subjecting them to high-pressure steam overnight. Obtained the pre-cultivated algae and distributed 50mL evenly among all the centrifuge tubes. Centrifuged the tubes at a speed of 8000rpm, at a temperature of 4°C, for a duration of 2 minutes. Disposed of the liquid above the sediment, rinsed the substance once with purified water, and introduced 5mL of purified water into each tube and mixed vigorously. Transferred the algae from the tubes to the 2000L Erlenmeyer flask and added 1200mL of the basal medium to the flask. The flask was labeled with the date and name, and then stored and was shaken three times a day at regular intervals.

The experimental and control groups were subjected to different concentrations of polyethylene and polystyrene microplastics, specifically 0, 5, 20, 50, 100, and 250 mg/L. The concentrations are designed to mimic varying degrees of environmental pollution, ranging from low to moderate to high levels. Control groups are maintained in a microplastic-free environment to create a standard for growth and physiological comparability. The duration of the exposure experiments was four days. Every experiment was conducted in duplicate.

Modified the algae solution's concentration by combining it with the basal medium to attain a concentration of 0.52 at a wavelength of 680 using a UV spectrophotometer. The provided microplastic mass was introduced into 250mL Erlenmeyer flasks as per the instructions. Subsequently, 200mL of the algal solution was added to each flask. The flasks were then kept and shaken three times daily.

Experimental Analysis Methods

Optical Density (OD) 680 Test

In order to ascertain the OD680 value of the algal liquid, 3 mL of both control and treatment samples were placed in 10 mL centrifuge tubes. The OD680 value was subsequently determined

using a Double Beam UV-visible spectrophotometer at a wavelength of 680nm. The OD680 was measured at a 24-hour interval over a span of four days.

Chlorophyll Content Measurement

Two 10 mL centrifuge tubes were filled with 5 mL of algal solution in order to quantify the levels of chlorophyll a, chlorophyll b, and carotenoid. The algal solution underwent centrifugation at a temperature of 3 degrees Celsius, with a rotational speed of 10000 revolutions per minute, for a duration of 2 minutes. The resulting liquid portion was discarded, while the solid residue was subjected to a freezing process for 15 minutes, followed by thawing for 5 minutes. This freezing and thawing cycle was done three times. 5 mL of 100% ethanol was added to each tube. The tubes were then stored in a dark 4°C refrigerator for 24 hours. Afterward, they were centrifuged at 3°C and 10000 rpm for 2 minutes. The supernatant was transferred to a fresh tube, and the absorbance was measured at wavelengths of 663 nm, 645 nm, and 470 nm using a Double Beam UV-visible spectrophotometer. Chlorophyll a, chlorophyll b, and carotenoid levels were assessed at 24-hour intervals over a period of four days. The Chl a, Chl b, and carotenoid content were calculated using the following formulas:

$$Chl\ a\ \left(\frac{mg}{L}\right) = 12.21_{A663} - 2.81_{A645} \quad (1)$$

$$Chl\ b\ \left(\frac{mg}{L}\right) = 20.13_{A645} - 5.03_{A663} \quad (2)$$

$$Chl\ carotenoid\ \left(\frac{mg}{L}\right) = \frac{(1000_{A470} - 3.27_{A663} - 10.4_{A645})}{229} \quad (3)$$

Chlorophyll Fluorescence Activity

A 1 mL aliquot of algal solution was introduced into a 10 mL centrifuge tube, and subsequently diluted by a factor of 20. An additional 1 mL of deionized water was then added to the tube. 4.5 mL of deionized water were added to new tubes, and then 0.5 mL of the diluted algae was added. A 5mL sample of an algal dilution solution was subjected to storage in both dark and light conditions for a duration of 20 minutes. The chlorophyll fluorescence activity was assessed by employing an AquaPen PSI instrument to measure the maximum quantum yield of photosystem II (PSII) photochemistry, denoted as Fv/Fm.

Data Collection and Analysis Methods

The statistical analysis of the results was performed using OriginPro 9 64-bit software, with additional data manipulation and visualization carried out using Microsoft Office Excel 2021. The significance of the findings obtained from the completely randomized experimental design was evaluated using one-way analysis of variance (ANOVA), with a specified significance level of $p = 0.05$. This approach facilitated the comparison of mean values across duplicated datasets. The variability was assessed by systematically computing the standard deviation (SD) values, which were subsequently shown as error bars in visual displays. The experimental data was subjected to a meticulous analysis using advanced statistical methods in combination with Excel, resulting in increased reliability of the study's conclusions.

Results

Optical Density Findings

The study's data reveals a distinct trend of decreasing optical density in *Chlorella pyrenoidosa* when subjected to polystyrene (PS) and polyethylene (PE) microplastics for four days. This indicates a decrease in the amount of algal biomass. This pattern remains stable regardless of the different levels of both types of microplastics, with a more noticeable effect reported at higher concentrations.

Regarding PS microplastics, there was a clear reduction in optical density seen from Day 1 to Day 4 for all tested doses. Notably, the highest concentration of 500 mg/L exhibited the most substantial drop in algal growth (Fig 1). The impact was substantially milder at intermediate dosages (50, 100, 250 mg/L), whilst the lower concentrations (5, 20 mg/L) and the control group exhibited consistently steady optical density values, suggesting minimal influence. On the fourth day, even lower concentrations started to fall compared to the control. The concentrations of 20 and 50 mg/L showed a more pronounced decline (Fig 1).

Similarly, Fig 1 illustrated that the optical density of PE microplastics decreased over time, and the highest concentration (500 mg/L) had the most significant decrease in growth. Concentrations of 5, 20, and 50 mg/L showed a less pronounced but still observable decrease compared to the control. The impact of polyethylene (PE) microplastics became more evident on Day 4, especially at concentrations of 250 and 500 mg/L. At these higher concentrations, the optical density was dramatically reduced compared to the control, indicating a more pronounced detrimental influence on the growth of algae.

These data indicate that both PS and PE microplastics have an inhibitory effect on the growth of *Chlorella pyrenoidosa*, and this effect is dependent on the concentration of the microplastics. Higher concentrations of microplastics result in greater reductions in the biomass of the algae over time.

Chlorophyll Fluorescence Results

Analysis of chlorophyll fluorescence in *Chlorella pyrenoidosa*, when exposed to polystyrene (PS) and polyethylene (PE) microplastics, demonstrates a significant decrease in photosynthetic efficiency as the concentration of microplastics increases as shown in Fig 2. Both in light and dark settings, there is a noticeable decrease in the Fv/Fm ratios for PS microplastics, indicating a clear decreasing trend. At lower concentrations (0 to 50 mg/L), the impact is quite minor. The decrease in Fv/Fm is gradual, suggesting a subtle stress response. As

the concentrations increase from 100 to 500 mg/L, there is a significant and sudden decrease in these ratios. Specifically, when the

concentration is 500 mg/L, the Fv/Fm ratio decreases to around 0.50 (Fig 2).

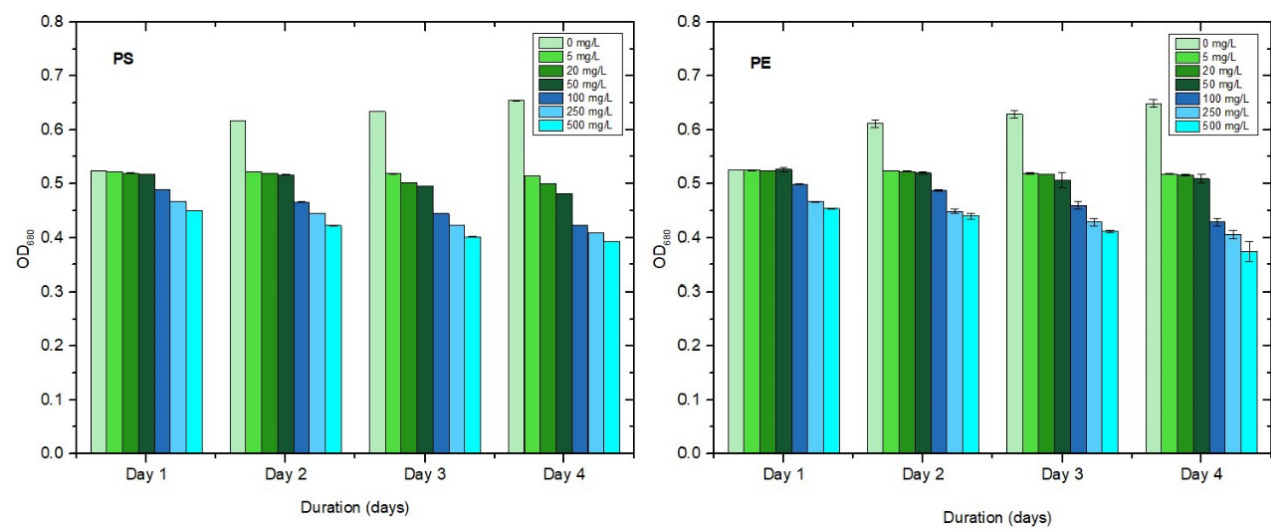


Figure 1. PS and PE Microplastics Effect on Microalgal Growth

Fig 2 further indicated that the Fv/Fm ratios of PE microplastics consistently decrease as concentrations increase, with the effect being more noticeable under light circumstances. Beginning at initial levels close to the norm, the ratio experiences a significant decline as

concentrations rise to the range of 100 to 500 mg/L. The most notable decrease is noticed at a concentration of 500 mg/L, where the Fv/Fm ratio approaches 0.48 in the presence of light, which is slightly lower than in the absence of light.

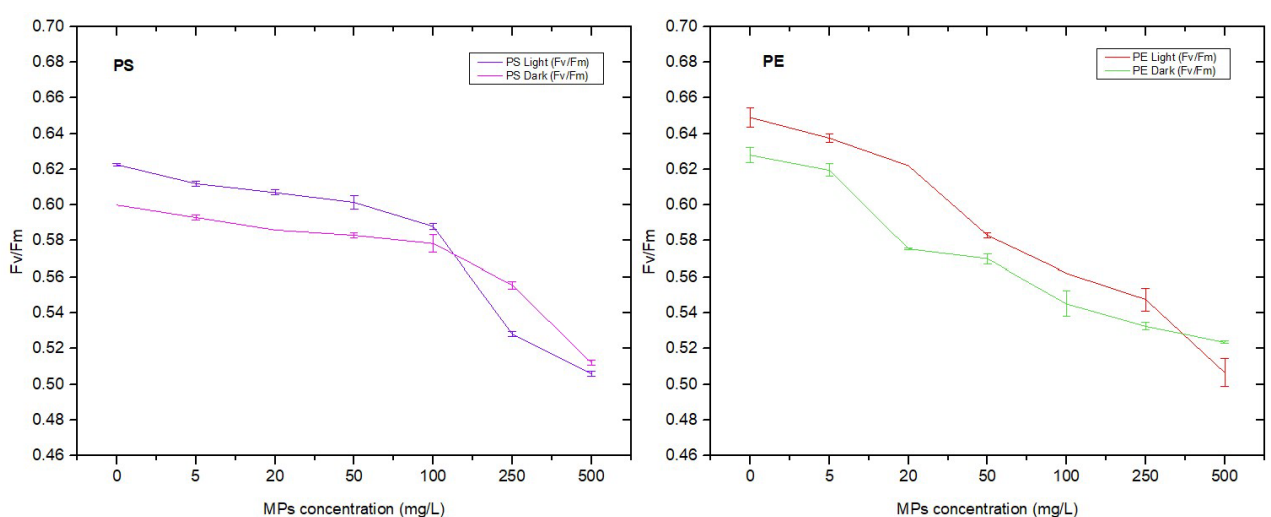


Figure 2. PS and PE Microplastic Effect on Microalgal Photosynthetic Efficiency

Pigment Composition Changes

Chlorophyll *a*, the main pigment accountable for photosynthesis, exhibits a constant decline in concentration from Day 1 to Day 4 for all evaluated concentrations of PS microplastics. The decrease is particularly notable at the maximum dose of 500 mg/L. The values of 5 mg/L and 20 mg/L exhibit negligible departure from the control (Fig 3).

Chlorophyll *b* exhibits a consistent decline over the course of the four-day period. The most pronounced impacts are detected at the highest dosages (500 mg/L and 250 mg/L), where the decrease in chlorophyll *b* is significantly visible (Fig 3). Decreased concentrations lead to a less severe decrease, consistent with the reported patterns for chlorophyll *a*.

Carotenoids exhibit a subtly distinct pattern as illustrated in Fig 3. Although there is a general decline in concentration, it does not follow a strictly linear pattern like that observed with chlorophyll *a* and *b*. Initially, the levels of carotenoids remain reasonably constant even when exposed to greater concentrations. However, by Day 4, noticeable decreases in carotenoid levels are observed at doses of 500 mg/L and 250 mg/L.

The collective observations suggest that PS microplastics have an inhibitory influence on the pigment concentrations in *Chlorella pyrenoidosa*, which is dependent on the dose. Higher concentrations of PS microplastics lead to more significant disruptions.

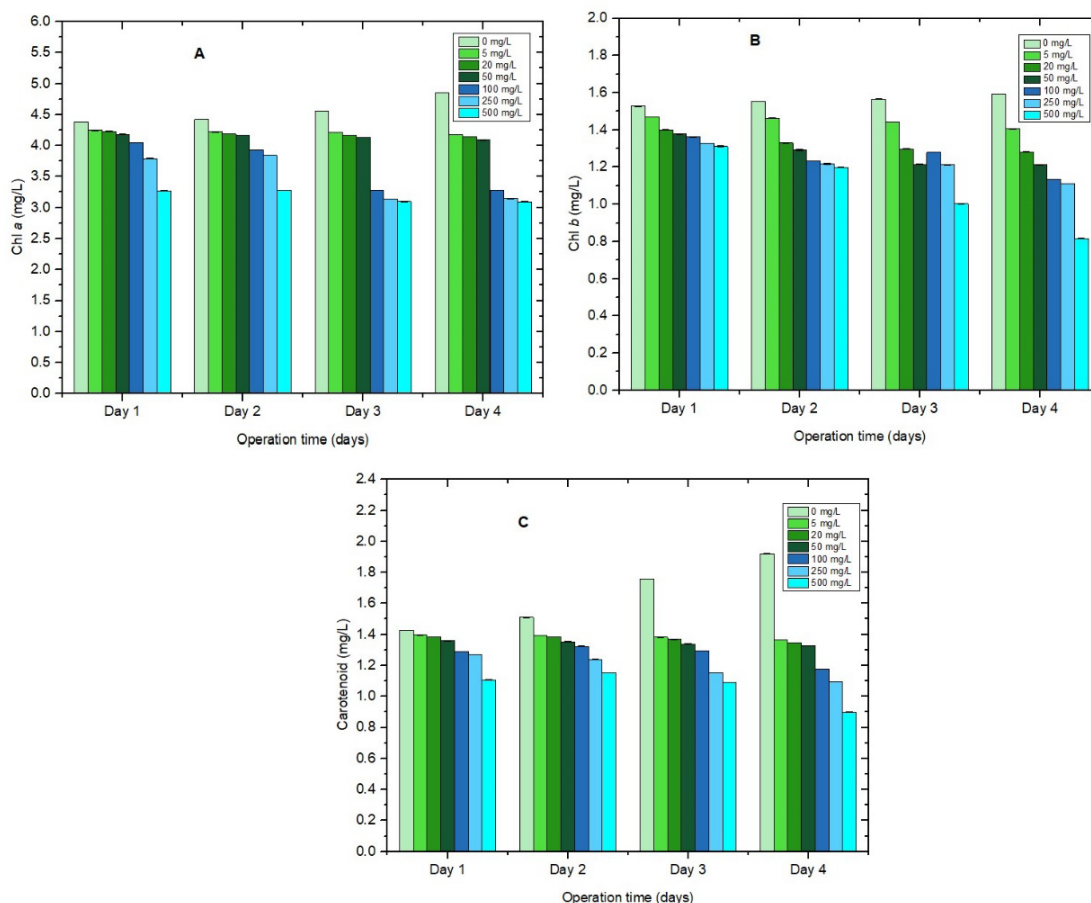


Figure 3. PS Impact on Microalgal Photosynthetic Activity

Fig 4 shows that on Day 1, the levels of chlorophyll *a* remain stable across all concentrations of microplastics, showing no significant difference compared to the control. Nevertheless, as the experiment advances, there is a noticeable pattern of decrease by Day 4, especially at higher dosages (100, 250, 500 mg/L), with a substantial decrease noted at 250 mg/L and 500 mg/L.

Chlorophyll *b* has a comparable trend to chlorophyll *a*, where its initial levels are relatively less impacted at lower doses. On the fourth day,

there is a clear decrease in all values, with the most significant declines seen at 250 mg/L and 500 mg/L.

Carotenoids exhibit a more robust pattern in comparison to chlorophylls, characterized by a broad but less noticeable decrease. The stability of carotenoid levels remains intact until Day 2, even at greater doses. However, on Days 3 and 4, there is a noticeable decline in carotenoid levels, especially at concentrations of 250 mg/L and 500 mg/L (Fig 4).

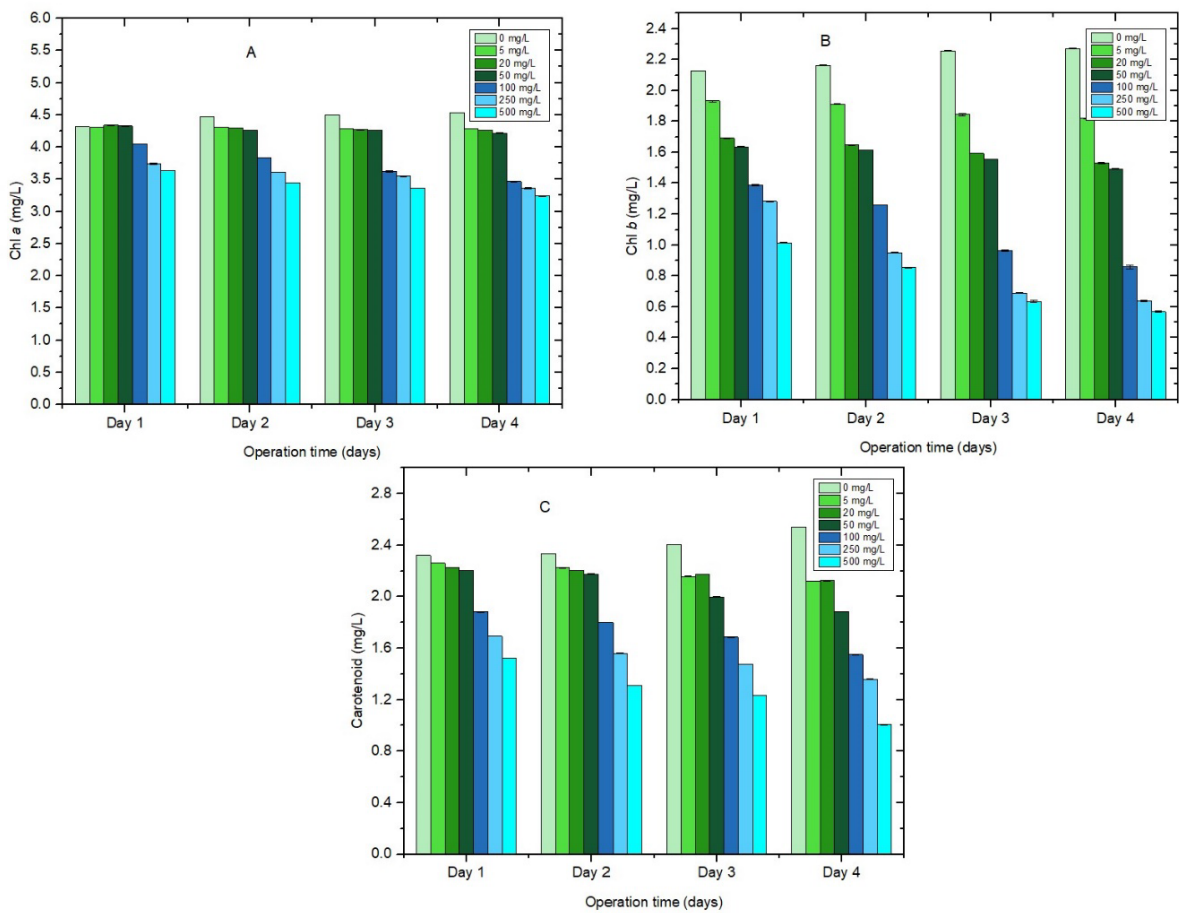


Figure 4. PE Impact on Microalgal Photosynthetic Activity

Dose-Response Relationships

The study's analysis of the dose-response relationships clearly indicates the toxicological

effects of higher concentrations of microplastics on important photosynthetic indices in *C. pyrenoidosa*. The findings exhibit consistent trends across various measurements, including

chlorophyll fluorescence (Fv/Fm ratios), as well as quantities of chlorophyll *a*, chlorophyll *b*, and carotenoids.

Chlorophyll fluorescence is measured by calculating the Fv/Fm ratios. The study observed a significant decline in Fv/Fm ratios as the concentration of microplastics increased, particularly at higher levels (250 mg/L and 500 mg/L). These findings suggest that elevated concentrations of microplastics interfere with photosystem II, a crucial process for the absorption and conversion of energy in algae. This disturbance is likely caused by oxidative stress or physical harm caused by the microplastics.

Chlorophyll *a* and *b* Concentrations: Both forms of chlorophyll had a declining pattern from Day 1 to Day 4, with the most notable decreases observed at the highest levels of microplastic concentration. The observed trend indicates that higher concentrations of microplastics have a harmful impact on the pigment content of the algae. This is likely owing to the disruption of chlorophyll synthesis or the rapid breakdown of chlorophyll caused by stress induced by microplastics.

Carotenoid concentrations decrease as the concentration of microplastics increases, suggesting that the protective mechanisms of carotenoids against oxidative stress are unable to cope with higher doses.

The collective results emphasize a correlation between the concentration of microplastics and the negative effects on the efficiency of photosynthesis and stability of pigments in *C. pyrenoidosa*, which is dependent on the dosage. These findings emphasize crucial limits at which microplastic pollution can cause substantial ecological harm.

Discussion

The research results offer valuable insights into the harmful effects of microplastics, particularly polyethylene and polystyrene, on the photosynthetic process and pigment production in *C. pyrenoidosa*. The dose-response analysis

demonstrates a noticeable pattern in which higher concentrations of microplastics result in significant disruptions in photosynthetic efficiency (Tunali M et al., 2020), as indicated by the decreasing Fv/Fm ratios. This ratio is a crucial measure of the highest possible quantum efficiency of photosystem II (PSII), which is necessary for the light-dependent processes of photosynthesis (Li Z et al., 2022). A decrease in Fv/Fm indicates that microplastics may be causing physical harm to the photosynthetic equipment or triggering oxidative stress that hampers the functioning of PSII (Wu D, 2021).

Furthermore, the study's results regarding changes in pigment concentrations, including chlorophyll *a*, chlorophyll *b*, and carotenoids, provide additional evidence supporting the hypothesized effects of stress. Chlorophylls play a crucial role in absorbing light energy and enabling the conversion of solar energy into chemical energy (Hazeem L. J et al., 2020). This process is essential for the survival of photosynthetic organisms (Song Y et al., 2023). The drop in chlorophyll concentrations as microplastic concentrations increase suggests that the microplastics are causing a disruption in the pathways responsible for pigment synthesis or an increase in the breakdown of pigments due to the stress caused by the microplastics (Wang Q et al., 2020). Carotenoids, which have a preventive function against oxidative stress by neutralizing reactive oxygen species, exhibited a decrease, especially at higher levels of microplastics. This implies that the defensive mechanisms are overpowered, resulting in possible harm to cellular components that are crucial for sustaining photosynthetic effectiveness (Song C et al., 2020).

When evaluating the toxicity of PE and PS microplastics, the findings indicate that PS microplastics may have a stronger detrimental effect on the photosynthetic ability of *C. pyrenoidosa* compared to PE microplastics. This observation may be attributed to the inherent physical and chemical properties of the polymers (Amelia T.S.M et al., 2021). Polystyrene (PS), due to its rigidity and sometimes abrasive nature, can cause more significant physical damage to cellular structures compared to the

more flexible and softer polyethylene (PE)(Miloloža M et al., 2021). Furthermore, PS microplastics have the potential to generate highly reactive chemical leachates or efficiently absorb and accumulate environmental pollutants(Wu D, 2021). This can amplify their harmful effects when consumed or when in contact with algal cells(Song Y et al., 2023).

The discoveries have wide-ranging consequences that are environmentally significant. *C. pyrenoidosa* has a crucial role as a fundamental species in aquatic ecosystems, making a significant contribution to primary production and serving as the foundation of food webs(Becker, 2007). Exposure to microplastics can cause a decrease in photosynthesis and pigment concentration in *C. pyrenoidosa*. This might result in lower primary productivity, which may have a ripple impact on aquatic food webs and nutrient cycling(Li Z et al., 2020).

A decline in primary production can result in diminished carbon dioxide fixation, which has an impact on the cycling of carbon within these ecosystems(Llamas Azúa Á et al., 2023),(Prasad R et al., 2021). Moreover, since *C. pyrenoidosa* is consumed by various aquatic organisms, any decrease in its growth and potential buildup of microplastics could have an impact on higher trophic levels(He D et al., 2022). This could result in changes to predator-prey dynamics and potentially cause shifts in species composition and abundance(Parsai T et al., 2022).

Furthermore, the results emphasize the widespread presence of microplastic pollution and its capacity to infiltrate and affect even the minuscule components of ecological systems. The presence of microplastics in even the most isolated and untouched habitats highlights the widespread impact of this issue on non-target organisms such as microalgae(Kumar R et al., 2021a). The worldwide pollution has the potential to weaken attempts to preserve biodiversity and ecological well-being in both freshwater and marine habitats(Sharma Shivika and Subhankar., 2017).

Conclusion

This work has clarified the notable effects of PE and PS microplastics on the ability of *C. pyrenoidosa* to efficiently carry out photosynthesis and maintain its pigment composition. The results of our study show that when the concentrations of these microplastics increase, there is a significant decrease in the Fv/Fm ratios. This suggests a loss in photosynthetic efficiency and probable harm to photosystem II. Furthermore, there was a steady decrease in the levels of crucial pigments, such as chlorophyll *a*, chlorophyll *b*, and carotenoids. The reduction in pigment levels indicates a disturbance in the pathways responsible for synthesizing photosynthetic pigments or an increase in the breakdown of pigments, which may hinder the alga's capacity to carry out photosynthesis efficiently. The ecological consequences of these findings are important, indicating that microplastic pollution may greatly impede primary productivity in aquatic habitats, therefore impacting wider ecological processes and the structures of food webs.

Although the study offers valuable insights, it is also subject to many limitations. The laboratory setup used for the tests may not accurately replicate the intricate interactions and environmental factors seen in real aquatic systems, including interactions with other contaminants, fluctuating light conditions, and temperature variations(Cao Q et al., 2022). In addition, the study specifically examined only two categories of microplastics, which may not accurately reflect the wide range of microplastics prevalent in aquatic ecosystems. The study's temporal scope was limited, which hindered our comprehension of the long-term consequences and potential recuperation of *C. pyrenoidosa* from sustained or intermittent exposure to microplastics.

In order to overcome these constraints and enhance our comprehension of the effects of microplastics on aquatic photosynthetic species, various avenues for future investigation are suggested. Initially, it is imperative for research to investigate a broader array of microplastic varieties, especially those commonly found in

specific aquatic environments, in order to ascertain whether distinct materials or forms have an effect on the magnitude of impact on photosynthesis. Long-term exposure studies are essential for evaluating the long-lasting impacts of microplastics and the possibility of gradual harm or adjustment by photosynthetic organisms. Furthermore, conducting field studies that incorporate natural environmental circumstances would yield more thorough understanding of the interactions between microplastics and other environmental stressors, as well as their impact on aquatic ecosystems at the ecosystem level. Conducting research on the effects of microplastics on many types of aquatic photosynthetic organisms, such as different microalgae species and macrophytes, will provide valuable insights into the broader ecological implications of microplastic pollution.

To summarize, this study emphasizes the importance of promptly dealing with microplastic pollution and its possibly harmful impacts on essential biological processes in aquatic ecosystems. By persisting in the examination and resolution of this urgent environmental concern, we may formulate more efficient preservation tactics and regulations to alleviate the influence of microplastics on marine organisms and safeguard the stability of these crucial ecosystems.

References

Amelia, T., Khalik, W.M., Ong, M.C., Shao, Y.T., Pan, H., & Bhubalan, K. (2021). Marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans. *Progress in Earth and Planetary Science*, 8, 1-26. <https://doi.org/10.1186/s40645-020-00405-4>

Andrady A. L. (2017). The plastic in microplastics: A review. *Marine pollution bulletin*, 119(1), 12–22. <https://doi.org/10.1016/j.marpolbul.2017.01.082>

Ansari, F.A., Ratha, S.K., Renuka, N., Ramanna, L., Gupta, S.K., Rawat, I., & Bux, F. (2021). Effect of microplastics on growth and

biochemical composition of microalga *Acutodesmus obliquus*. *Algal Research-Biomass Biofuels and Bioproducts*, 56, 102296. <https://doi.org/10.1016/J.ALGAL.2021.102296>

Barboza, L. G. A., Vieira, L. R., Branco, V., Figueiredo, N., Carvalho, F., Carvalho, C., & Guilhermino, L. (2018). Microplastics cause neurotoxicity, oxidative damage and energy-related changes and interact with the bioaccumulation of mercury in the European seabass, *Dicentrarchus labrax* (Linnaeus, 1758). *Aquatic toxicology (Amsterdam, Netherlands)*, 195, 49–57.

<https://doi.org/10.1016/j.aquatox.2017.12.008>

Becker E. W. (2007). Micro-algae as a source of protein. *Biotechnology advances*, 25(2), 207–210. <https://doi.org/10.1016/j.biotechadv.2006.11.002>

Bhuyar, P., Sundararaju, S., Feng, H., Rahim, M.H., Muniyasamy, S., Maniam, G.P., & Govindan, N. (2021). Evaluation of Microalgae's Plastic Biodeterioration Property by a Consortium of *Chlorella* sp. and *Cyanobacteria* sp. *Environmental Research, Engineering and Management*. 77(3), 86-98. <https://doi.org/10.5755/j01.erem.77.3.25317>

Brennecke, D., Duarte, B., Paiva, F., Caçador, I., & Canning-Clode, J. (2016). Microplastics as vector for heavy metal contamination from the marine environment. *Estuarine Coastal and Shelf Science*, 178, 189-195. <https://doi.org/10.1016/J.ECSS.2015.12.003>

Cao, M., Huang, X., Wang, F., Zhang, Y., Zhou, B., Chen, H., Yuan, R., Ma, S., Geng, H., Xu, D., Yan, C., & Xing, B. (2021). Transcriptomics and Metabolomics Revealed the Biological Response of *Chlorella pyrenoidosa* to Single and Repeated Exposures of AgNPs at Different Concentrations. *Environmental science & technology*, 55(23), 15776–15787. <https://doi.org/10.1021/acs.est.1c04059>

Cao, Q., Sun, W., Yang, T., Zhu, Z., Jiang, Y., Hu, W., Wei, W., Zhang, Y., & Yang, H. (2022). The toxic effects of polystyrene microplastics on freshwater algae *Chlorella pyrenoidosa* depends on the different size of polystyrene

microplastics. *Chemosphere*, 308(Pt 1), 136135. <https://doi.org/10.1016/j.chemosphere.2022.136135>

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., & Galloway, T. S. (2013). Microplastic ingestion by zooplankton. *Environmental science & technology*, 47(12), 6646–6655. <https://doi.org/10.1021/es400663f>

Franzellitti, S., Canesi, L., Auguste, M., Wathsala, R. H. G. R., & Fabbri, E. (2019). Microplastic exposure and effects in aquatic organisms: A physiological perspective. *Environmental toxicology and pharmacology*, 68, 37–51. <https://doi.org/10.1016/j.etap.2019.03.009>

Hazeem, L. J., Yesilay, G., Bououdina, M., Perna, S., Cetin, D., Suludere, Z., Barras, A., & Boukherroub, R. (2020). Investigation of the toxic effects of different polystyrene micro-and nanoplastics on microalgae *Chlorella vulgaris* by analysis of cell viability, pigment content, oxidative stress and ultrastructural changes. *Marine pollution bulletin*, 156, 111278. <https://doi.org/10.1016/j.marpolbul.2020.111278>

He, D., Zeng, Y., & Zhou, G. (2022). The influence of microplastics on the toxic effects and biodegradation of bisphenol A in the microalgae *Chlorella pyrenoidosa*. *Aquatic Ecology*, 56, 1287 – 1296. <https://doi.org/10.1007/s10452-022-09966-6>

Huo, Y., Dijkstra, F. A., Possell, M., & Singh, B. (2022). Ecotoxicological effects of plastics on plants, soil fauna and microorganisms: A meta-analysis. *Environmental pollution (Barking, Essex : 1987)*, 310, 119892. <https://doi.org/10.1016/j.envpol.2022.119892>

Jiang, Y., Yang, F., Hassan Kazmi, S. S. U., Zhao, Y., Chen, M., & Wang, J. (2022). A review of microplastic pollution in seawater, sediments and organisms of the Chinese coastal and marginal seas. *Chemosphere*, 286(Pt 1), 131677. <https://doi.org/10.1016/j.chemosphere.2021.131677>

Kiki, C., Qiu, Y., Wang, Q., Ifon, B. E., Qin, D., Chabi, K., Yu, C. P., Zhu, Y. G., & Sun, Q. (2022). Induced aging, structural change, and

adsorption behavior modifications of microplastics by microalgae. *Environment international*, 166, 107382. <https://doi.org/10.1016/j.envint.2022.107382>

Kumar, R., Sharma, P., Manna, C., & Jain, M. (2021). Abundance, interaction, ingestion, ecological concerns, and mitigation policies of microplastic pollution in riverine ecosystem: A review. *Science of The Total Environment*, 782, 146695. <https://doi.org/10.1016/j.scitotenv.2021.146695>

Kumar, R., Verma, A., Shome, A., Sinha, R., Sinha, S., Jha, P.K., Kumar, P., Kumar, R., Shubham, Das, S., Sharma, P. & Prasad, P. V. V. (2021). Impacts of Plastic Pollution on Ecosystem Services, Sustainable Development Goals, and Need to Focus on Circular Economy and Policy Interventions. *Sustainability*, 13, 9963. <https://doi.org/10.3390/su13179963>

Li, Z., Dong, S., Huang, F., Lin, L., Hu, Z., & Zheng, Y. (2022). Toxicological Effects of Microplastics and Sulfadiazine on the Microalgae *Chlamydomonas reinhardtii*. *Frontiers in microbiology*, 13, 865768. <https://doi.org/10.3389/fmicb.2022.865768>

Li, Z., Yi, X., Zhou, H., Chi, T., Li, W., & Yang, K. (2020). Combined effect of polystyrene microplastics and dibutyl phthalate on the microalgae *Chlorella pyrenoidosa*. *Environmental pollution (Barking, Essex: 1987)*, 257, 113604. <https://doi.org/10.1016/j.envpol.2019.113604>

Liu, G., Jiang, R., You, J., Muir, D. C. G., & Zeng, E. Y. (2020). Microplastic Impacts on Microalgae Growth: Effects of Size and Humic Acid. *Environmental science & technology*, 54(3), 1782–1789. <https://doi.org/10.1021/acs.est.9b06187>

Llamas, A., Leon-Miranda, E., & Tejada-Jimenez, M. (2023). Microalgal and Nitrogen-Fixing Bacterial Consortia: From Interaction to Biotechnological Potential. *Plants (Basel, Switzerland)*, 12(13), 2476. <https://doi.org/10.3390/plants12132476>

Mao, Y., Ai, H., Chen, Y., Zhang, Z., Zeng, P., Kang, L., Li, W., Gu, W., He, Q., & Li, H. (2018). Phytoplankton response to polystyrene

microplastics: Perspective from an entire growth period. *Chemosphere*, 208, 59–68. <https://doi.org/10.1016/j.chemosphere.2018.05.170>

Miloloža, M., Kučić Grgić, D., Bolanča, T., Ukić, Š., Cvetnic, M., Bulatovic, V., Dionysiou, D. & Kusic, H. (2020). Ecotoxicological Assessment of Microplastics in Freshwater Sources—A Review. *Water*, 13, 56. <https://doi.org/10.3390/w13010056>

Parsai, T., Figueiredo, N., Dalvi, V., Martins, M., Malik, A., & Kumar, A. (2022). Implication of microplastic toxicity on functioning of microalgae in aquatic system. *Environmental pollution (Barking, Essex : 1987)*, 308, 119626. <https://doi.org/10.1016/j.envpol.2022.119626>

Pinheiro, L. M., do Sul, J. A. I., & F., C.M. (2020). Uptake and ingestion are the main pathways for microplastics to enter marine benthos: A review. *Food webs*, 24, e00150. <https://doi.org/10.1016/j.fooweb.2020.e00150>

Podbielska, M., & Szpyrka, E. (2023). Microplastics - An emerging contaminants for algae. Critical review and perspectives. *The Science of the total environment*, 885, 163842. <https://doi.org/10.1016/j.scitotenv.2023.163842>

Prasad, R., Gupta, S. K., Shabnam, N., Oliveira, C. Y. B., Nema, A. K., Ansari F. A. & F., B. (2021). Role of microalgae in global CO2 sequestration: Physiological mechanism, recent development, challenges, and future prospective. *Sustainability* 13(23), 13061. <https://doi.org/10.3390/su132313061>

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2019). Effects of microplastics on microalgae populations: A critical review. *The Science of the total environment*, 665, 400–405. <https://doi.org/10.1016/j.scitotenv.2019.02.132>

Sharma, S., & Chatterjee, S. (2017). Microplastic pollution, a threat to marine ecosystem and human health: a short review. *Environmental science and pollution research international*, 24(27), 21530–21547. <https://doi.org/10.1007/s11356-017-9910-8>

Song, C., Liu, Z., Wang, C., Li, S., & Kitamura, Y. (2020). Different interaction performance between microplastics and microalgae: The bio-elimination potential of *Chlorella* sp. L38 and *Phaeodactylum tricornutum* MASCC-0025. *The Science of the total environment*, 723, 138146. <https://doi.org/10.1016/j.scitotenv.2020.138146>

Song, Y., Zhang, B., Si, M., Chen, Z., Geng, J., Liang, F., Xi, M., Liu, X., & Wang, R. (2023). Roles of extracellular polymeric substances on *Microcystis aeruginosa* exposed to different sizes of polystyrene microplastics. *Chemosphere*, 312(Pt 1), 137225. <https://doi.org/10.1016/j.chemosphere.2022.137225>

Tunali, M., Uzoefuna, E. N., Tunali, M. M., & Yenigun, O. (2020). Effect of microplastics and microplastic-metal combinations on growth and chlorophyll a concentration of *Chlorella vulgaris*. *The Science of the total environment*, 743, 140479. <https://doi.org/10.1016/j.scitotenv.2020.140479>

Wang, H.-Y. & Cheng, Y.-R. (2021). Highly Effective Removal of Microplastics by Microalgae *Scenedesmus Abundans*. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3976141>

Wang, Q., Wangjin, X., Zhang, Y., Wang, N., Wang, Y., Meng, G., & Chen, Y. (2020). The toxicity of virgin and UV-aged PVC microplastics on the growth of freshwater algae *Chlamydomonas reinhardtii*. *The Science of the total environment*, 749, 141603. <https://doi.org/10.1016/j.scitotenv.2020.141603>

Wang, S. C., Liu, G. Z., & Liu, F. F. (2023). Physiological and metabolic toxicity of polystyrene microplastics to *Dunaliella salina*. *Environmental pollution (Barking, Essex : 1987)*, 316(Pt 1), 120544. <https://doi.org/10.1016/j.envpol.2022.120544>

Wu, D., Wang, T., Wang, J., Jiang, L., Yin, Y., & Guo, H. (2021). Size-dependent toxic effects of polystyrene microplastic exposure on *Microcystis aeruginosa* growth and microcystin

production. *The Science of the total environment*, 761, 143265.

<https://doi.org/10.1016/j.scitotenv.2020.143265>

Zhao, Y., Tao, S., Liu, S., Hu, T., Zheng, K., Shen, M. & G., M. (2023). Research advances on

impacts micro/nanoplastics and their carried pollutants on algae in aquatic ecosystems: A review. *Aquatic Toxicology*, 264, 106725.

<https://doi.org/10.1016/j.aquatox.2023.106725>