Volume 4, Issue 3, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

EFFECTS OF MICROPLASTIC EXPOSURE ON PHYSIOLOGICAL AND ANTIOXIDANT RESPONSES OF REEF-BUILDING CORAL *POCILLOPORA DAMICORNIS*

Hamza Yousaf[1], Sadia Mubeen[*2], Shehzad Zareen[*3], Mubasher Khan[4], Yasir Mustafa[5], Zafran Faraz[6], Naila Gul[7], Abdul Wahab Khan[8]

[1, *2, *3,7,8]*Department of Zoology, Kohat University of Science and Technology (KUST), Kohat, Khyber Pakhtunkhwa, Pakistan*

[4]*Department of Microbiology, Kohat University of Science and Technology (KUST), Kohat, Khyber Pakhtunkhwa, Pakistan*

[5]*University of Science and Technology Bannu, Khyber Pakhtunkhwa, Pakistan*

[6]*National Institute of Medical Sciences (NIMS), Kohat, Khyber Pakhtunkhwa, Pakistan*

[1]m.hamzayousaf671@gmail.com, [*2]sadiamobeen7@gmail.com, [*3]shehzadzareen1@kust.edu.pk, [4]mubasherk410@gmail.com, [5]dryasirqureshi@gmail.com, [6]zafranfaraz828@gmail.com, [7]nailagul@kust.edu.pk, [8]wahabwazir346@gmail.com

DOI: https://doi.org/10.5281/zenodo.21289373

Keywords

Microplastics, coral reefs, oxidative stress, antioxidant enzymes, chlorophyll, Pocillopora damicornis, marine pollution.

Article History

Received: 24 January 2026
Accepted: 06 March 2026
Published: 21 March 2026

Copyright @Author

Corresponding Author: *
Sadia Mubeen
Shehzad Zareen

Abstract

Microplastic pollution has emerged as a major environmental concern in marine ecosystems due to its persistence, widespread distribution, and potential harmful effects on aquatic organisms. Coral reefs are particularly vulnerable to environmental stressors, yet limited information is available regarding the physiological and antioxidant responses of reef-building corals to microplastic exposure. Therefore, the present study was conducted to evaluate the effects of microplastics on the physiological and antioxidant responses of Pocillopora damicornis under controlled laboratory conditions. Healthy coral fragments of Pocillopora damicornis were obtained from a commercial marine aquarium supplier and acclimatized prior to experimentation. Corals were exposed to different concentrations of polyethylene microplastics, including 0 mg/L (control), 10 mg/L, 50 mg/L, and 100 mg/L for a period of six weeks. Physiological parameters such as growth performance, polyp activity, bleaching response, and chlorophyll content were evaluated. Antioxidant and oxidative stress biomarkers including reactive oxygen species (ROS), superoxide dismutase (SOD), and catalase (CAT) activities were also analyzed. The results demonstrated that increasing concentrations of microplastics negatively affected coral physiology. Coral fragments exposed to higher microplastic concentrations exhibited reduced growth, decreased polyp extension, mild bleaching, and lower chlorophyll content compared with the control group. Furthermore, ROS production significantly increased in treated groups, indicating elevated oxidative stress. Antioxidant enzyme activities, including SOD and CAT, also increased progressively with increasing microplastic concentrations, suggesting activation of cellular defense mechanisms against oxidative damage. Although complete coral mortality was

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

not observed during the experimental period, the findings indicated that continuous exposure to microplastics may gradually impair coral health and physiological stability. The present study concluded that microplastic pollution poses a significant threat to reef-building corals by inducing physiological disturbances and oxidative stress responses. This study provides preliminary baseline information regarding the effects of microplastics on corals and highlights the importance of reducing plastic pollution to protect coral reef ecosystems and marine biodiversity.

INTRODUCTION

Coral reefs are among the most biologically diverse and ecologically significant marine ecosystems on Earth. They provide habitat, feeding grounds, and nursery areas for numerous marine organisms while also contributing substantially to fisheries, tourism, and coastal protection (Hoegh-Guldberg *et al.*, 2007). Despite occupying less than one percent of the ocean floor, coral reefs support nearly 25% of all marine species, highlighting their immense ecological importance (Reaka-Kudla, 1997). Coral reef ecosystems are increasingly threatened by a combination of anthropogenic and environmental stressors, including rising sea surface temperatures, ocean acidification, overfishing, sedimentation, and marine pollution (Hughes *et al.*, 2017). Among emerging marine pollutants, microplastics have received considerable scientific attention due to their persistence, widespread distribution, and harmful ecological impacts. Microplastics are plastic particles smaller than 5 mm that originate either from the fragmentation of larger plastic materials or from primary industrial and domestic sources such as synthetic fibers, cosmetic microbeads, and plastic pellets (Andrady, 2011). Because of their durability and resistance to degradation, microplastics have accumulated extensively in marine environments, including coral reef ecosystems (Law & Thompson, 2014). Their small size allows them to interact directly with marine organisms at different trophic levels, resulting in physical, physiological, and biochemical disturbances.

Recent studies have demonstrated that reef-building corals can ingest microplastic particles, often mistaking them for planktonic prey items (Hall *et al.*, 2015). Once ingested, microplastics may obstruct feeding structures, reduce nutrient uptake, impair energy allocation, and induce tissue damage (Rotjan *et al.*, 2019). In addition to physical impacts, microplastics may adsorb toxic chemicals and pathogenic microorganisms from surrounding seawater, thereby increasing the susceptibility of corals to stress and disease (Lamb *et al.*, 2018). The accumulation of microplastics on coral surfaces may also interfere with light penetration and gas exchange, negatively affecting coral metabolism and photosynthetic efficiency. The reef-building coral *Pocillopora damicornis* is widely distributed throughout tropical and subtropical reef ecosystems and is commonly used as a model organism in coral stress physiology studies due to its sensitivity to environmental changes and rapid physiological responses (Rinkevich & Loya, 1979). This species maintains a mutualistic symbiosis with intracellular dinoflagellates known as zooxanthellae, which provide a major portion of the coral's metabolic energy through photosynthesis (Muscatine & Porter, 1977). Environmental disturbances can disrupt this symbiotic relationship, resulting in oxidative stress, reduced photosynthetic performance, bleaching, and ultimately coral mortality. Oxidative stress is considered one of the primary cellular responses of corals exposed to environmental pollutants and adverse conditions. Under stress, excessive production of reactive oxygen species (ROS) can overwhelm antioxidant defense systems and cause oxidative damage to lipids, proteins, and nucleic acids (Downs *et al.*, 2002). To counteract ROS toxicity, corals possess antioxidant defense mechanisms involving enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD). Variations in antioxidant enzyme activities are therefore widely used as biomarkers for assessing physiological stress in corals (Lesser, 2006).

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Exposure to microplastics has been associated with elevated oxidative stress responses, impaired photosynthesis, and alterations in coral metabolic functions (Okubo *et al.*, 2018).

In the context of Pakistan, marine plastic pollution has become a growing environmental concern along the Arabian Sea coastline. Coastal urban centers, particularly Karachi, contribute significantly to plastic waste discharge through industrial effluents, domestic sewage, and ineffective waste management practices. Studies have reported the occurrence of microplastics in seawater, sediments, and marine organisms from the northern Arabian Sea, indicating widespread contamination of coastal ecosystems. Although Pakistan possesses ecologically important coral communities around areas such as Churna Island and the Balochistan coast, research investigating the impacts of microplastics on coral physiology remains extremely limited. So, understanding how microplastics influence physiological and antioxidant responses in reef-building corals is important for evaluating potential ecological risks and developing future conservation strategies. Despite increasing global concern regarding microplastic pollution, limited experimental studies have specifically examined the physiological and antioxidant responses of *Pocillopora damicornis* under controlled microplastic exposure conditions. There remains insufficient information regarding how varying concentrations of microplastics influence oxidative stress biomarkers, coral health, and metabolic functioning. So, the present study aims to investigate the effects of microplastic exposure on the physiological and antioxidant responses of *Pocillopora damicornis*. The findings of this study will contribute to a better understanding of coral stress mechanisms under plastic pollution and provide baseline information for coral reef conservation and marine pollution management.

MATERIALS AND METHODS

Experimental Design

The present study was conducted under controlled laboratory conditions to evaluate the effects of microplastic exposure on the physiological and antioxidant responses of *Pocillopora damicornis*. A completely randomized design (CRD) was adopted with four treatment groups, including one control group and three microplastic exposure groups.The experimental groups were arranged as follows:

- Control group (0 mg/L microplastics)
- Low concentration group (10 mg/L microplastics)
- Medium concentration group (50 mg/L microplastics)
- High concentration group (100 mg/L microplastics)

The exposure experiment was conducted for a period of six weeks.

Procurement and Acclimatization of Coral Fragments

Healthy coral fragments of *Pocillopora damicornis* were procured from a commercial marine aquarium supplier in Islamabad. Coral fragments of approximately 3–5 cm in length were selected to maintain uniformity among experimental samples. The coral fragments were carefully transported to the laboratory in aerated seawater containers to minimize transportation stress. Upon arrival, the corals were acclimatized for seven days in glass aquaria containing artificial seawater prior to the start of the experiment. During acclimatization, water quality parameters were maintained at optimal levels, including temperature (25–27°C), salinity (32–35 ppt), pH (8.0–8.2), and dissolved oxygen (>5 mg/L). Continuous aeration and a 12 hr light/12 hr dark photoperiod were maintained throughout the acclimatization and experimental period. Acclimatization procedures were carried out following standard coral maintenance protocols described by (Hall *et al.*, 2015).

Preparation of Artificial Seawater

Artificial seawater was prepared using commercially available marine salt mixed with dechlorinated water. Salinity was adjusted using a refractometer to maintain a concentration of 32–35 ppt. Water quality parameters including pH, temperature, and dissolved oxygen were monitored daily using standard water testing equipment. Approximately 20% of aquarium water was replaced every three days to maintain

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

suitable water quality and minimize waste accumulation.

Preparation of Microplastics

Polyethylene (PE) plastic particles were used as the source of microplastics due to their widespread occurrence in marine environments (Andrady, 2011). Clean polyethylene plastic materials were manually cut into small pieces and ground into fine particles using a laboratory grinder. The particles were sieved to obtain a uniform particle size ranging between 1–5 mm. Prepared microplastic particles were washed several times with distilled water to remove impurities and then air dried at room temperature before experimental use. Stock solutions of microplastics were prepared separately for each concentration level and added to the experimental aquaria according to the treatment design.

Experimental Exposure

Following acclimatization, coral fragments were randomly distributed into experimental aquaria. Microplastics were added to the treatment tanks at concentrations of 10 mg/L, 50 mg/L, and 100 mg/L, while the control group received no microplastics. Throughout the experimental period, corals were observed daily for changes in behavior, mucus secretion, tissue condition, and polyp activity. Water quality parameters were maintained consistently across all treatment groups to ensure that observed effects were primarily associated with microplastic exposure.

Assessment of Physiological Responses

Growth Measurement

Coral growth was assessed by measuring the initial and final wet weight of each coral fragment using a digital analytical balance. Measurements were recorded at the beginning and end of the experimental period. Linear extension of coral fragments was also measured using a digital Vernier caliper. Growth rate was calculated by subtracting the initial measurements from the final measurements.

Polyp Activity and Behavioral Observation

Polyp activity was visually monitored throughout the study period. The degree of polyp extension was recorded daily as an indicator of coral health and feeding behavior. Behavioral changes such as reduced polyp expansion, mucus secretion, and discoloration were considered signs of physiological stress.

Assessment of Coral Bleaching

Visual assessment of bleaching was conducted weekly. Coral fragments under identical lighting conditions. Changes in coral coloration were compared among treatment groups to identify bleaching intensity associated with microplastic exposure.

Antioxidant and Oxidative Stress Analysis

Tissue Extraction

At the end of the exposure period, coral tissues were carefully removed using an air brush technique with phosphate buffered saline (PBS). Tissue homogenates were prepared and centrifuged at 4°C for 15 minutes at 5000 rpm. The supernatant obtained after centrifugation was used for antioxidant enzyme analysis.

Reactive Oxygen Species (ROS) Analysis

Reactive oxygen species (ROS) production was determined using 2′,7′-dichlorofluorescein diacetate (DCFH-DA) reagent following the method described by (Downs *et al.*, 2002). Briefly, coral tissue homogenates were mixed with DCFH-DA solution and incubated in darkness for 30 minutes at room temperature. Fluorescence intensity was measured using a UV visible spectrophotometer. Increased fluorescence intensity indicated elevated oxidative stress levels in coral tissues.

Superoxide Dismutase (SOD) Activity

Superoxide dismutase (SOD) activity was measured using a commercial SOD assay kit according to the manufacturer's instructions. The absorbance of the reaction mixture was measured spectrophotometrically, and enzyme activity was expressed as units per milligram protein. SOD activity was analyzed as an indicator of antioxidant defense against oxidative stress (Lesser, 2006).

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Catalase (CAT) Activity

Catalase (CAT) activity was determined using a catalase assay kit based on the decomposition rate of hydrogen peroxide (H_2O_2). Changes in absorbance were recorded using a spectrophotometer, and CAT activity was expressed as units per milligram protein.

Chlorophyll Content Analysis

Chlorophyll content was analyzed to evaluate the condition of symbiotic zooxanthellae associated with coral tissues. Approximately 1 mL of coral tissue homogenate was mixed with 90% acetone and centrifuged at 5000 rpm for 10 minutes. The absorbance of the supernatant was measured at wavelengths of 630 nm and 664 nm using a spectrophotometer following the method described by (Muscatine and Porter, 1977). Reduced chlorophyll concentration was considered indicative of bleaching stress.

Statistical Analysis

All experimental data were expressed as mean ± standard deviation (SD). Statistical analysis was performed using SPSS software version 25. One way analysis of variance (ANOVA) was applied to determine significant differences among treatment groups. Tukey's post hoc test was used for multiple comparisons between groups. Differences were considered statistically significant at $p < 0.05$.

RESULTS

The present study evaluated the effects of different concentrations of microplastics on the physiological and antioxidant responses of *Pocillopora damicornis* under controlled laboratory conditions for six weeks. Coral fragments exposed to increasing concentrations of microplastics exhibited gradual physiological disturbances and oxidative stress responses compared with the control group. The responses among treated groups were not completely uniform, and slight variations among replicates were observed during the experiment, indicating natural biological variability.

Water Quality Parameters

Water quality parameters remained relatively stable throughout the experimental period. Minor fluctuations were recorded among aquaria but remained within acceptable ranges for coral maintenance.

Table 1. Water Quality Parameters Maintained During Experimental Exposure of *Pocillopora damicornis* to Microplastics

Parameter	Control	10 mg/L	50 mg/L	100 mg/L
Temperature (°C)	26.1 ± 0.5	26.3 ± 0.4	26.4 ± 0.6	26.2 ± 0.5
Salinity (ppt)	33.2 ± 0.7	33.5 ± 0.6	33.1 ± 0.5	33.4 ± 0.8
pH	8.1 ± 0.1	8.0 ± 0.1	8.0 ± 0.2	7.9 ± 0.2
Dissolved Oxygen (mg/L)	5.8 ± 0.3	5.7 ± 0.4	5.5 ± 0.5	5.4 ± 0.4

No significant differences ($p > 0.05$) were observed in water quality parameters among treatment groups.

Growth Performance of Coral Fragments

The growth rate of *Pocillopora damicornis* decreased progressively with increasing concentrations of microplastics. Coral fragments in the control group exhibited comparatively better growth throughout the experimental period.

Table 2. Growth Performance of *Pocillopora damicornis* Exposed to Different Concentrations of Microplastics

Treatment Group	Initial Wet Weight (g)	Final Wet Weight (g)	Weight Gain (g)
Control	12.4 ± 0.8	14.1 ± 1.0	1.7 ± 0.4
10 mg/L	12.7 ± 0.9	13.8 ± 1.1	1.1 ± 0.3
50 mg/L	12.6 ± 1.0	13.1 ± 0.9	0.5 ± 0.2

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

100 mg/L	12.5 ± 0.7	12.7 ± 0.8	0.2 ± 0.1

A significant reduction ($p < 0.05$) in weight gain was observed in the 50 mg/L and 100 mg/L groups compared with the control. Similarly, linear extension measurements indicated reduced skeletal growth under higher microplastic exposure.

Table 3. Linear Growth Response of *Pocillopora damicornis* Under Microplastic Exposure

Treatment Group	Initial Length (cm)	Final Length (cm)	Growth Increment (cm)
Control	4.1 ± 0.3	4.8 ± 0.4	0.7 ± 0.2
10 mg/L	4.2 ± 0.4	4.6 ± 0.3	0.4 ± 0.1
50 mg/L	4.0 ± 0.3	4.2 ± 0.4	0.2 ± 0.1
100 mg/L	4.1 ± 0.2	4.2 ± 0.3	0.1 ± 0.1

Polyp Activity and Behavioral Responses

Corals in the control group maintained normal polyp extension and feeding behavior during most of the study period. In contrast, microplastic treated corals exhibited irregular polyp activity, reduced feeding responses, and occasional mucus secretion. Behavioral stress signs became more pronounced during the fourth week onward, particularly in the 100 mg/L treatment group.

Table 4. Polyp Activity Scores of *Pocillopora damicornis* Following Microplastic Exposure

Treatment Group	Polyp Activity Score (0–3)
Control	2.8 ± 0.2
10 mg/L	2.3 ± 0.3
50 mg/L	1.7 ± 0.4
100 mg/L	1.2 ± 0.5

Coral fragments exposed to the highest concentration occasionally showed partial tissue retraction and slight discoloration near branch tips.

Coral Bleaching Observations

Visual observations revealed mild bleaching responses in microplastic exposed corals. No obvious bleaching was observed in the control group. The 10 mg/L treatment group showed only slight paling in some coral fragments after the fifth week. Moderate discoloration was observed in the 50 mg/L group, whereas corals exposed to 100 mg/L displayed noticeable fading of pigmentation and reduced brightness. Complete bleaching or mortality was not observed during the experimental period.

Reactive Oxygen Species (ROS) Production

ROS production increased with increasing microplastic concentration, indicating elevated oxidative stress in exposed corals.

Table 5. Reactive Oxygen Species (ROS) Production in *Pocillopora damicornis* Exposed to Microplastics

Treatment Group	ROS Level (Fluorescence Units)
Control	118 ± 11
10 mg/L	146 ± 14
50 mg/L	191 ± 18
100 mg/L	243 ± 21

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

The highest ROS activity was recorded in the 100 mg/L treatment group and was significantly different ($p < 0.05$) from the control.

Superoxide Dismutase (SOD) Activity

SOD activity showed an increasing trend with rising microplastic exposure. Moderate elevation of SOD activity was observed in low and medium treatment groups, suggesting activation of antioxidant defense mechanisms.

Table 6. Superoxide Dismutase (SOD) Activity in *Pocillopora damicornis* Under Microplastic Stress

Treatment Group	SOD Activity (U/mg protein)
Control	18.5 ± 1.7
10 mg/L	22.1 ± 2.1
50 mg/L	27.8 ± 2.5
100 mg/L	31.4 ± 3.2

The increase in SOD activity was statistically significant ($p < 0.05$) in the 50 mg/L and 100 mg/L groups.

Catalase (CAT) Activity

Catalase activity also increased in response to microplastic exposure. However, variations among replicates were observed, particularly in the highest treatment group.

Table 7. Catalase (CAT) Activity in *Pocillopora damicornis* Exposed to Different Microplastic Concentrations

Treatment Group	CAT Activity (U/mg protein)
Control	11.6 ± 1.2
10 mg/L	13.4 ± 1.5
50 mg/L	16.9 ± 2.0
100 mg/L	18.7 ± 2.8

The elevated CAT activity indicated increased antioxidant response against oxidative stress.

Chlorophyll Content

Chlorophyll concentration decreased gradually with increasing microplastic concentrations.

Table 8. Chlorophyll Content of *Pocillopora damicornis* Following Exposure to Microplastics

Treatment Group	Chlorophyll Content (mg/g tissue)
Control	2.41 ± 0.18
10 mg/L	2.12 ± 0.20
50 mg/L	1.74 ± 0.16
100 mg/L	1.39 ± 0.21

The reduction in chlorophyll content suggested impairment of zooxanthellae photosynthetic performance under microplastic stress. The present findings demonstrated that exposure to microplastics adversely affected the physiological condition and antioxidant responses of *Pocillopora damicornis*. Corals exposed to higher microplastic concentrations showed reduced growth, altered behavior, elevated oxidative stress, increased antioxidant enzyme activities, and reduced chlorophyll content. The observed responses were gradual rather than extreme, and complete mortality was not recorded during the experimental period. These findings suggest that chronic microplastic exposure may weaken coral health and increase physiological stress even under sublethal conditions.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

DISCUSSION

The present study investigated the effects of microplastic exposure on the physiological and antioxidant responses of *Pocillopora damicornis* under controlled laboratory conditions. The findings demonstrated that increasing concentrations of microplastics negatively affected coral growth, polyp activity, chlorophyll content, and antioxidant responses. Although complete mortality was not observed during the experimental period, corals exposed to higher concentrations of microplastics exhibited clear signs of physiological stress and oxidative imbalance. The reduction in coral growth observed in the present study indicated that microplastic exposure interfered with normal metabolic functioning and energy allocation in Pocillopora damicornis. Coral fragments exposed to higher concentrations showed significantly lower weight gain and skeletal extension compared with the control group. Similar findings were reported by (Chapron *et al.*, 2018) who observed reduced feeding activity and impaired growth in cold-water corals exposed to microplastics. Likewise, (Hall *et al.*, 2015) demonstrated that corals ingest microplastic particles, which may obstruct feeding structures and reduce nutrient uptake. Reduced energy acquisition may therefore explain the slower growth observed in the present investigation. Behavioral changes recorded during the experiment, including reduced polyp extension and increased mucus secretion, further suggested stress related responses caused by microplastic exposure. Similar behavioral disturbances have previously been described by (Rotjan *et al.*, 2019) who reported altered feeding behavior and tissue irritation in corals exposed to plastic particles. In contrast, some studies have suggested that short term exposure to lower microplastic concentrations may not immediately affect coral behavior (Reichert *et al.*, 2018). The slight differences between studies may be associated with variations in coral species, exposure duration, particle size, and environmental conditions. The present study also demonstrated gradual bleaching and reduction in chlorophyll content in microplastic treated corals. Decreased chlorophyll concentration suggested impairment of zooxanthellae photosynthetic efficiency and disruption of coral algal symbiosis. These findings are in agreement with (Okubo *et al.*, 2018) who reported that microplastics disturb the symbiotic relationship between corals and zooxanthellae, leading to reduced photosynthetic performance. Similarly, (Tang *et al.*, 2021) observed decreased chlorophyll levels and bleaching responses in corals subjected to plastic associated stress. Here, the bleaching observed in the current study remained partial rather than severe, possibly because the exposure duration was limited and environmental conditions remained otherwise stable. One of the major findings of the present study was the significant increase in reactive oxygen species (ROS) production in microplastic exposed corals. Elevated ROS levels indicated oxidative stress caused by microplastic contamination. Oxidative stress occurs when excessive ROS production exceeds the antioxidant defense capacity of the organism, resulting in cellular damage (Downs *et al.*, 2002). Similar increases in oxidative stress markers have been reported in previous coral stress studies involving pollutants and environmental disturbances (Lesser, 2006). The elevated ROS production observed in the present investigation therefore confirmed that microplastics can function as physiological stressors in reef-building corals. Antioxidant enzyme activities, including superoxide dismutase (SOD) and catalase (CAT), increased progressively with rising microplastic concentrations. This response likely represented an adaptive defense mechanism against oxidative damage. Similar findings were reported by (Tang *et al.*, 2021) who observed enhanced antioxidant enzyme activities in corals exposed to microplastics. Increased SOD and CAT activities have also been documented in marine invertebrates exposed to environmental contaminants, suggesting activation of protective antioxidant pathways (Lesser, 2006). Nevertheless, excessive or prolonged oxidative stress may eventually overwhelm antioxidant defense systems and result in tissue damage and bleaching. Although the present findings generally agreed with previous studies, some variability among coral fragments was observed during the

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

experiment. Certain coral fragments maintained moderate polyp activity even under higher microplastic exposure, whereas others showed earlier signs of stress. Such variability may reflect natural biological differences in stress tolerance among coral colonies. Similar variability has also been reported in coral stress physiology studies by (Hughes *et al.*, 2017). In comparison with previous international studies, the present research provides important baseline information regarding the physiological and antioxidant responses of *Pocillopora damicornis* under microplastic exposure conditions relevant to controlled laboratory environments. Furthermore, studies related to coral microplastic toxicity remain extremely limited in Pakistan and surrounding regions. So, this study contributes valuable preliminary data for understanding the ecological risks of microplastic pollution to coral reef ecosystems associated with the Arabian Sea region. The present study had certain limitations. The experimental duration was relatively short, and only polyethylene microplastics of a single particle size range were used. In natural marine environments, corals are exposed to mixed pollutants, variable environmental conditions, and different plastic polymers over longer periods. Future studies should investigate chronic exposure effects, combined environmental stressors, and molecular responses of corals under field conditions.

CONCLUSION

The present study evaluated the effects of microplastic exposure on the physiological and antioxidant responses of *Pocillopora damicornis* under controlled laboratory conditions. The findings demonstrated that increasing concentrations of microplastics adversely affected coral health, even during relatively short term exposure. Coral fragments exposed to microplastics showed reduced growth performance, decreased polyp activity, mild bleaching responses, and lower chlorophyll content compared with the control group. These observations indicated that microplastic contamination interfered with normal physiological functioning and negatively affected the coral zooxanthellae symbiotic relationship. The reduction in chlorophyll content further suggested impairment of photosynthetic efficiency in symbiotic algae associated with coral tissues. The study also revealed a significant increase in reactive oxygen species (ROS) production and elevated antioxidant enzyme activities, including superoxide dismutase (SOD) and catalase (CAT), in microplastic exposed corals. The increase in oxidative stress biomarkers indicated that microplastics induced cellular stress and activated antioxidant defense mechanisms in *Pocillopora damicornis*. Here, prolonged or continuous exposure to elevated oxidative stress may eventually compromise coral health and survival. Although complete mortality was not observed during the experimental period, the gradual physiological disturbances recorded in this study suggested that chronic exposure to microplastics could have long-term ecological consequences for reef-building corals. The findings are consistent with previous international studies reporting harmful effects of microplastic pollution on coral reef organisms. Importantly, the present research provides preliminary baseline data regarding microplastic induced stress responses in corals under laboratory conditions relevant to the regional context. Since studies concerning coral microplastic toxicity remain limited in Pakistan and nearby coastal regions, this work contributes valuable scientific information for future marine pollution monitoring and coral reef conservation strategies. So, the study concluded that microplastic pollution poses a significant threat to the physiological stability and antioxidant balance of *Pocillopora damicornis*. Therefore, effective management of plastic waste and reduction of marine pollution are essential to protect coral reef ecosystems and maintain marine biodiversity in the future.

REFERENCES

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin, 62*(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Chapron, L., Peru, E., Engler, A., Ghiglione, J. F., Meistertzheim, A. L., Pruski, A. M., & Lartaud, F. (2018). Macro- and microplastics affect cold-water corals growth, feeding, and behavior. *Scientific Reports, 8*, 15299. https://doi.org/10.1038/s41598-018-33683-6

Downs, C. A., Fauth, J. E., Halas, J. C., Dustan, P., Bemiss, J., & Woodley, C. M. (2002). Oxidative stress and seasonal coral bleaching. *Free Radical Biology and Medicine, 33*(4), 533–543. https://doi.org/10.1016/S0891-5849(02)00907-3

Hall, N. M., Berry, K. L. E., Rintoul, L., & Hoogenboom, M. O. (2015). Microplastic ingestion by scleractinian corals. *Marine Biology, 162*(3), 725–732. https://doi.org/10.1007/s00227-015-2619-7

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., *et al.* (2007). Coral reefs under rapid climate change and ocean acidification. *Science, 318*(5857), 1737–1742. https://doi.org/10.1126/science.1152509

Hughes, T. P., Kerry, J. T., Álvarez-Noriega, M., *et al.* (2017). Global warming and recurrent mass bleaching of corals. *Nature, 543*(7645), 373–377. https://doi.org/10.1038/nature21707

Lamb, J. B., Willis, B. L., Fiorenza, E. A., *et al.* (2018). Plastic waste associated with disease on coral reefs. *Science, 359*(6374), 460–462. https://doi.org/10.1126/science.aar3320

Law, K. L., & Thompson, R. C. (2014). Microplastics in the seas. *Science, 345*(6193), 144–145. https://doi.org/10.1126/science.1254065

Lesser, M. P. (2006). Oxidative stress in marine environments: Biochemistry and physiological ecology. *Annual Review of Physiology, 68*, 253–278. https://doi.org/10.1146/annurev.physiol.68.040104.110001

Muscatine, L., & Porter, J. W. (1977). Reef corals: Mutualistic symbioses adapted to nutrient-poor environments. *BioScience, 27*(7), 454–460. https://doi.org/10.2307/1297526

Okubo, N., Takahashi, S., & Nakano, Y. (2018). Microplastics disturb the anthozoan-algae symbiotic relationship. *Marine Pollution Bulletin, 135*, 83–89. https://doi.org/10.1016/j.marpolbul.2018.07.016

Reaka-Kudla, M. L. (1997). The global biodiversity of coral reefs: A comparison with rainforests. In M. L. Reaka-Kudla, D. E. Wilson, & E. O. Wilson (Eds.), *Biodiversity II: Understanding and protecting our biological resources* (pp. 83–108). Joseph Henry Press.

Reichert, J., Schellenberg, J., Schubert, P., & Wilke, T. (2018). Responses of reef-building corals to microplastic exposure. *Environmental Pollution, 237*, 955–960. https://doi.org/10.1016/j.envpol.2017.11.006

Rinkevich, B., & Loya, Y. (1979). The reproduction of the Red Sea coral *Stylophora pistillata*. I. Gonads and planulae. *Marine Ecology Progress Series, 1*, 133–144.

Rotjan, R. D., Sharp, K. H., Gauthier, A. E., *et al.* (2019). Patterns, dynamics and consequences of microplastic ingestion by the temperate coral, *Astrangia poculata*. *Proceedings of the Royal Society B, 286*(1900), 20190726. https://doi.org/10.1098/rspb.2019.0726

Tang, J., Ni, X., Zhou, Z., Wang, L., & Lin, S. (2021). Acute microplastic exposure raises stress response and suppresses detoxification and immune capacities in

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

the scleractinian coral *Pocillopora damicornis*. *Environmental Pollution*, *289*, 117947. https://doi.org/10.1016/j.envpol.2021.117947