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The Impact of Sewage, Human Activity, Fishing, and Storms on the Coral Reef Ecosystem in Benghazi, Derna, and Tobruk areas, Northeast Libya

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ABSTRACT

Coral reefs along the Libyan coastline, particularly near Benghazi, Derna, and Tobruk, play a vital role in supporting marine biodiversity and contributing to the local economy. However, these ecosystems face significant threats due to a combination of anthropogenic pressures and natural events. Sewage discharge, unregulated human activity, unsustainable fishing practices, and the increasing frequency of catastrophic storms all contribute to the degradation of these critical habitats. Recent studies have revealed a concerning shift in the structure of the reefs, with many coral-dominated areas being replaced by algal reefs. This transition is exacerbated by plastic pollution, which not only physically harms coral structures but also hinders their ability to recover. Furthermore, the effects of climate change, including rising sea temperatures and ocean acidification, are intensifying the vulnerability of these reefs. This paper investigates the extent of these environmental stressors, with a particular focus on the role of pollution, overfishing, and climate change in coral decline. We provide a detailed analysis of the implications of these factors and propose recommendations for mitigating further damage, emphasizing the urgent need for effective conservation strategies to preserve these vital ecosystems.

تأثير مياه الصرف الصحي والأنشطة البشرية والصيد والعواصف على النظام البيئي للشعاب المرجانية في مناطق بنغازي ودرنة وطبرق، شمال شرق ليبيا

بالقاسم خميس[1] محمد مسعود 2

تلعب الشعاب المرجانية على طول الساحل الليبى، ولا سيما بالقرب من بنغازي ودرنة وطبرق، دورًا حيويًا في دعم التنوع البيولوجى البحري والمساهمة في الاقتصاد المحلى. ومع ذلك، تواجه هذه النظم البيئية تحديات خطيرة نتيجة تداخل الضغوط البشرية مع العوامل الطبيعية. إذ يسهم تصريف مياه الصرف الصحى، والأنشطة البشرية غير المنظمة، وممارسات الصيد غير المستدامة، إضافة إلى تزايد وتيرة العواصف الكارثية، في تدهور هذه الموائل الحساسة. وقد كشفت دراسات حديثة عن تحول مقلق في بنية الشعاب، حيث استُبدلت العديد من المناطق التى كانت تهيمن عليها الشعاب المرجانية بتجمعات طحلبية. ويتفاقم هذا التحول بسبب التلوث البلاستيكى، الذي لا يسبب أضرارًا مباشرة لهياكل الشعاب فحسب، بل يعيق أيضًا قدرتها على التعافي. علاوة على ذلك، تؤدي آثار التغير المناخى، بما في ذلك ارتفاع درجات حرارة مياه البحر وزيادة تحمّض المحيطات، إلى زيادة هشاشة هذه الشعاب. تتناول هذه الورقة البحثية مدى تأثير هذه الضغوط البيئية، مع تركيز خاص على دور التلوث والصيد الجائر والتغير المناخى في تراجع الشعاب المرجانية. كما تقدم تحليلًا مفصلًا لآثار هذه العوامل، وتقترح مجموعة من التوصيات للحد من المزيد من الضرر، مؤكدة على الحاجة الملحّة إلى اعتماد استراتيجيات فعالة للحفاظ على هذه النظم البيئية الحيوية وصونها للأجيال القادمة.

INTRODUCTION

Coastal ecosystems play a fundamental role in maintaining marine biodiversity, regulating global climate, and supporting economic activities such as fisheries and tourism. However, these fragile environments are increasingly threatened by pollution, habitat destruction, and climate change. Coastal water contamination, in particular, has emerged as a significant concern due to its far-reaching consequences for marine organisms, human health, and regional economies, as you see in figure 1.

The primary sources of coastal pollution include untreated sewage discharge, industrial effluents, agricultural runoff, and hydrocarbon contamination from shipping activities. These pollutants introduce heavy metals, synthetic chemicals, microplastics, and organic waste into marine environments, leading to profound ecological disruptions. Libya's coastal waters, which form a crucial part of the Mediterranean marine ecosystem, are no exception, as rapid urbanization, industrial expansion, and unsustainable fishing practices continue to exert pressure on these habitats (Khameiss, Zubi, 2024).

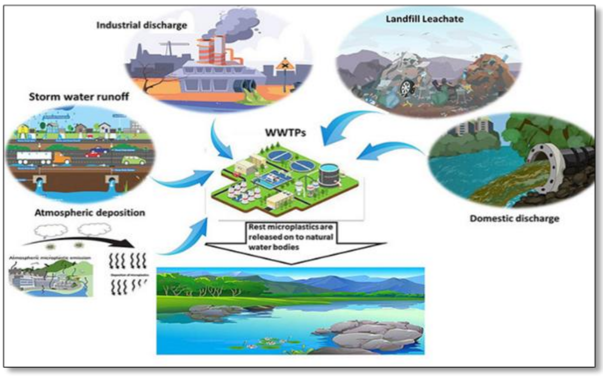

Fig. 1. various sources, including atmospheric deposition, stormwater runoff, industrial and domestic discharges, as well as landfill leachates. (Talukdar et al., 2024).

The geochemical and biological integrity of coastal waters is particularly crucial for coral reef ecosystems, which provide essential habitat for a diverse range of marine species. Corals are highly sensitive to changes in water quality, making them valuable bioindicators of environmental health (Khameiss et al., 2016). Pollution, particularly from hydrocarbons, microplastics, and heavy metals, can disrupt the delicate symbiotic relationship between corals and their algal partners, leading to bleaching and eventual reef degradation. Additionally, bottom trawling and overfishing contribute to reef destruction by physically damaging coral structures and disrupting marine food webs (Nizamuddin,1981,1988,1991; Nizamuddin, and Menez,1979). Studies conducted in Libya have documented alarming levels of marine contamination in key coastal cities, including Benghazi, Derna, and Tobruk. These regions exhibit high concentrations of pollutants, ranging from polycyclic aromatic hydrocarbons (PAHs) to heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd), which exceed international safety standards and pose severe risks to both marine and human populations(Aghow et al., 2018; Shaltami et al., 2020; Masoud et al., 2021; Masoud et al., 2022; El Werfalli et al., 2022; El-Ekhfifi et al., 2022; Ojaley et al., 2022; Masoud, Khameiss,2024).

The catastrophic flooding in Derna, triggered by the collapse of two dams during Mediterranean storm Daniel in September 2023, further exacerbated marine pollution by introducing vast amounts of freshwater, sediment, and contaminants into the coastal environment. This sudden influx of debris, sewage, and industrial pollutants has significantly altered the local marine ecosystem, leading to extensive coral bleaching, changes in salinity, and potential long-term shifts in nutrient cycling (Normand, and Heggy, 2024). The destruction of coral reefs and seagrass beds in the aftermath of the flooding raises concerns about the resilience of Libya's coastal ecosystems in the face of extreme weather events and anthropogenic stressors. Given the increasing frequency of such climate-induced disasters, it is imperative to assess the cumulative impacts of pollution and environmental disturbances on marine biodiversity.

This study aims to characterize the geochemical composition of surface coastal waters in Libya, with a particular focus on understanding pollution sources and their impacts on coral reef ecosystems. By analyzing sediment and water samples from Benghazi, Derna, and Tobruk, this research seeks to identify key contaminants, assess their ecological implications, and contribute to the broader discourse on marine conservation and sustainable coastal management. The findings of this study will provide valuable insights for policymakers, environmental agencies, and marine scientists working to mitigate the effects of pollution and enhance the resilience of Libya's coastal environments.

MATERIALS AND METHODS

The study area was selected based on its high sediment contamination, significant human activity, and natural hazards. The selected locations include the coastal area of Benghazi, the eastern section of the coastline from Benghazi Harbor to the Alkwayfiah area, the Derna region, and the coastal area near Tobruk Harbor, as you see in figure 2.

Fig.2. The location of the study areas.

METHODOLOGY:

Twenty-two samples were collected from the coastal regions of Benghazi, Derna, and Tobruk for a comprehensive analysis. Both water and sediment samples were examined to assess the extent of damage to coral and other marine organisms. The study aimed to quantify the percentage of affected coral populations and identify the specific types of contamination influencing coral reef degradation in these areas, as you seen in figure 3.

Fig. 3. Samples collected from the Tobruk region.

RESULTS AND DISCUSSION

RESULTS

Benghazi Area:

Ten samples were collected, as you see in figures 4 and 5, These samples exhibit a high concentration of coral fragments, many of which show signs of bleaching. Additionally, they contain significant quantities of foraminiferal fragments, including deformed specimens. The collected materials also include fragments of both invertebrate and vertebrate remains, pollutants, along with microplastics and plastic debris. Furthermore, the samples contain a mixture of sediments and mud, likely transported by freshwater inflow from nearby sources, and you see in figure 6.

Fig. 4. Plastic and sewer contamination in the Benghazi coastal area,

Fig. 5. Coral replacement by algae.

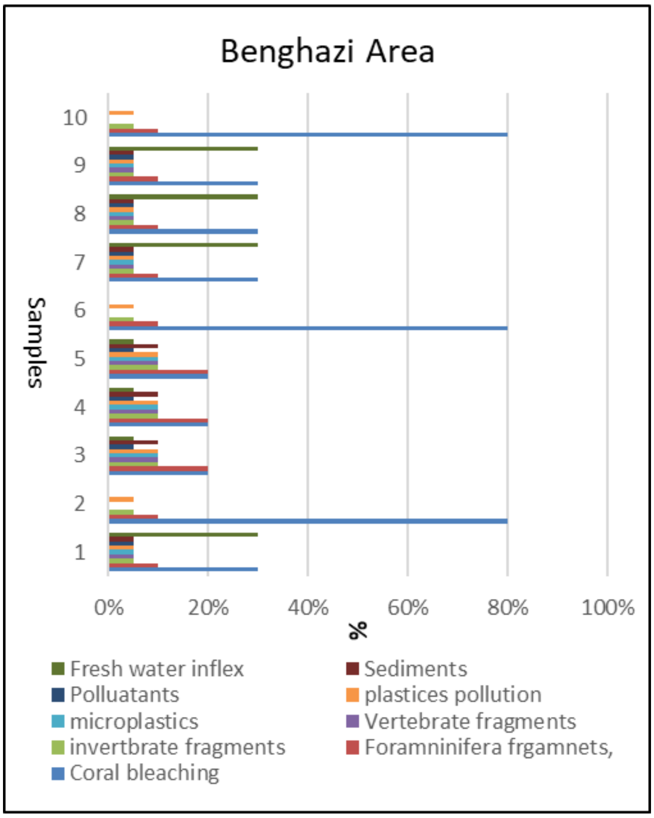

Fig. 6. Percentage and oxygenation content, and their impact on corals, and other organisms.

Derna Area:

Seven samples were selected one month after the catastrophic storm to assess its long-term impact on the area, as you see in figures 7 and 8. These samples reveal significant effects on coral species, including extensive coral bleaching and a high abundance of coral fragments. They also contain numerous foraminiferal fragments, many of which exhibit deformation. Additionally, the samples include remnants of both invertebrate and vertebrate fauna, microplastics, plastic debris, and various pollutants. Notably, traces of sewage, human waste, and other discarded materials were detected. Furthermore, the samples contain a substantial amount of mud, likely transported by freshwater inflow into the area, as you see in figure 9

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Fig. 7. Collapse of the sewer system after the storm.

Fig. 8. Mud suspension and trash contamination.

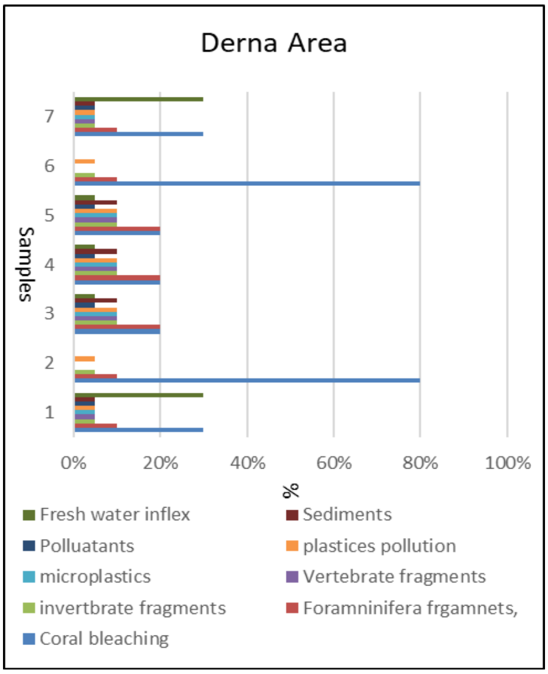

Fig. 9. Percentage and oxygenation content, and their impact oncorals, and other organisms

Tobruk Area:

The five selected samples exhibit the lowest percentage of coral bleaching and coral fragments compared to other areas as you see in figures 10 and 11. However, they show a high occurrence of foraminiferal deformation and fragmented specimens. The samples also contain significant amounts of invertebrate and vertebrate fauna remains, microplastics, and plastic debris. Additionally, they reveal a high concentration of pollutants, including wastewater, sewage, and oil residues. The presence of sediments transported by freshwater inflow further indicates ongoing environmental disturbances in the area, as you see in figure 12.

Fig. 10. Sewer remains and sediment deposition in the coastal area

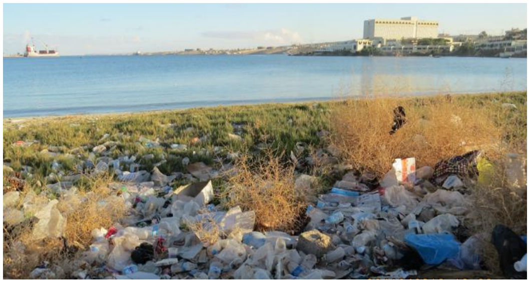

Fig. 11. Plastic and trash accumulation in the coastal area.

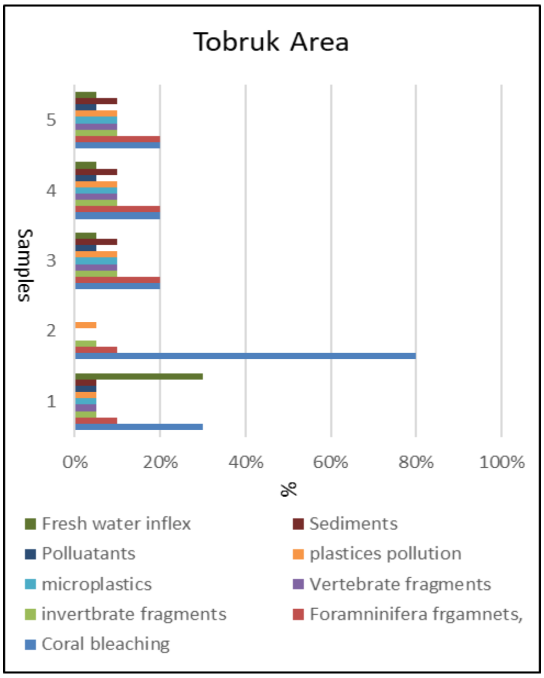

Fig. 12. Percentage and oxygenation content, and their impact on corals, and other organisms..

Discussion

The present study highlights the severe impact of environmental stressors on coral reefs and marine ecosystems across the Benghazi, Derna, and Tobruk coastal regions. The analysis of sediment and water samples revealed varying degrees of coral bleaching, foraminiferal deformation, and the presence of pollutants, including microplastics, sewage, and industrial waste. Notably, the catastrophic flooding in Derna further exacerbated these issues by introducing substantial amounts of freshwater, debris, and contaminants into the marine environment. The observed degradation of coral reef health in these areas underscores the urgent need for conservation efforts and pollution mitigation strategies to preserve marine biodiversity.

In Benghazi, the high concentration of coral fragments, coupled with significant foraminiferal deformation, suggests ongoing stress from both natural and anthropogenic sources. The presence of pollutants such as plastic debris and microplastics further indicates the detrimental effects of human activities on these ecosystems. The influx of freshwater carrying sediments and organic matter may have altered the local water chemistry, contributing to coral bleaching and the decline of reef-associated organisms. The degradation observed in this area highlights the vulnerability of coral reefs to multiple environmental pressures, necessitating continuous monitoring and management strategies to prevent further deterioration.

The situation in Derna presents a more drastic scenario due to the impact of Storm Daniel, which introduced an unprecedented influx of sediment, pollutants, and human waste into the marine environment. The extensive coral bleaching and the deformation of foraminiferal specimens indicate severe physiological stress on marine organisms. The introduction of sewage and other contaminants poses additional risks by promoting the proliferation of harmful bacteria and reducing oxygen levels in the water, potentially leading to hypoxic conditions. Furthermore, the destruction of reef structures and seagrass beds diminishes essential habitats for marine species, disrupting food webs and reducing biodiversity. The long-term consequences of this disaster may include persistent contamination, reduced coral recruitment, and shifts in local marine ecology.

In contrast, the Tobruk area exhibited a lower degree of coral bleaching but still showed significant signs of environmental stress, particularly through foraminiferal deformation and the presence of pollutants such as oil residues and sewage. The high occurrence of plastic debris and microplastics within these samples suggests an ongoing influx of pollution, which may gradually impact coral health over time. The combination of sediment transport, pollutant accumulation, and habitat degradation indicates that even in regions with relatively less direct damage, coral reef ecosystems remain at risk. Given these findings, proactive measures, such as reducing pollutant discharge, enhancing waste management practices, and implementing marine protected areas, are essential for safeguarding coral reefs and associated biodiversity in these coastal regions.

CONCLUSION

The findings of this study provide critical insights into the extent of environmental degradation affecting coral reef ecosystems in the Benghazi, Derna, and Tobruk coastal areas. The results indicate that sewage discharge, plastic pollution, hydrocarbon contamination, and extreme climatic events significantly contribute to coral bleaching, foraminiferal deformation, and ecosystem destabilization. The catastrophic flooding in Derna following Storm Daniel exacerbated these impacts by introducing large quantities of freshwater, sediments, and pollutants into marine environments, disrupting biogeochemical cycles, and increasing stress on coral populations. The documented increase in algal overgrowth and sediment deposit further highlights the progressive deterioration of coral-dominated reefs, suggesting an ecological transition that threatens biodiversity and marine resource sustainability. Comparative analysis across the three regions reveals that while Tobruk exhibits lower coral bleaching rates than Benghazi and Derna, it remains vulnerable to chronic pollution from microplastics, oil residues, and sewage discharge. The persistence of these stressors without intervention will likely accelerate coral degradation, leading to further loss of reef-associated species and weakening of marine food webs. Given the crucial role of coral reefs in supporting fisheries, coastal protection, and biodiversity, immediate conservation efforts are necessary to mitigate further damage and enhance reef resilience against both anthropogenic and climatic stressors.

Recommendations for Coral Reef Protection in Northeast Libya:

1.Implementation of Wastewater Treatment Facilities; Establish and upgrade sewage treatment plants to prevent the direct discharge of untreated sewage into coastal waters and enforce stringent regulations on industrial and municipal waste disposal to reduce nutrient loading and contamination of marine ecosystems.

2-Microplastic and Solid Waste Management; Develop and enforce policies for reducing plastic waste, including bans on single-use plastics and improved waste collection infrastructure, and conduct community-based cleanup initiatives to remove plastic debris from coastal areas and promote awareness of marine pollution.

3-Monitoring and Regulation of Fishing Practices; Ban destructive fishing techniques such as bottom trawling, which physically damages coral structures and disturbs benthic ecosystems, and establish no-take marine protected areas (MPAs) to allow coral recovery and enhance biodiversity conservation.

4-Climate Adaptation and Resilience Building; Monitor Sea surface temperature fluctuations and ocean acidification trends to assess climate-related threats to coral reefs, and restore damaged reefs using coral transplantation and artificial reef structures to promote habitat recovery and enhance resilience.

5-Post-Storm Environmental Recovery Plans; Develop emergency response protocols for mitigating marine pollution following extreme weather events, such as sediment management and pollutant removal initiatives, and assess long-term ecological impacts of flood-induced pollution and implement restoration strategies to enhance reef ecosystem recovery.

6-Legislative and Policy Framework for Marine Conservation;Establish and enforce environmental laws to protect coral reef ecosystems from urbanization, industrial expansion, and unregulated coastal development, and foster international collaborations to integrate Libya's marine conservation efforts with regional and global initiatives for sustainable ocean management.

7-Scientific Research and Community Engagement;Conduct long-term ecological monitoring of coral reef health using geochemical and biological indicators to track environmental changes, and engage local communities, fishers, and stakeholders in conservation programs to promote sustainable marine resource use and stewardship.

By implementing these measures, Libya can protect and restore its coral reef ecosystems, ensuring their ecological integrity and economic value for future generations. The urgency of these actions cannot be overstated, given the increasing frequency of anthropogenic and climate-induced stressors threatening.

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