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## Microbial and physico-chemical assessment of seawater in fishing locations on the Tripoli Coast, Libya: Potential risks to marine animal life and public health

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### ABSTRACT

**Background:** Seawater quality is critical to maintaining ecological balance and ensuring the safety of fish consumed by people. However, untreated wastewater discharge along the Tripoli coast threatens marine animals and public health, especially in fishing areas.

**Aim:** This study aims to evaluate seawater quality by analyzing microbial, physical, and chemical parameters across three selected locations along the Tripoli coastline characterized by intensive fishing activities, in order to assess the potential impacts of water quality on the health of marine animals and the safety of consumers.

**Methods:** Seawater samples were collected from three various fishing locations along the Tripoli coastline. Using a composite sampling method, the collected seawater samples were subjected to laboratory analysis to assess both physical and chemical properties, including pH, electrical conductivity, dissolved oxygen, nitrate and phosphate (PO<sub>4</sub>) were measured following standard protocols (e.g., APHA). Microbiological analyses focused on total aerobic microbial count (TAMC), total coliform bacteria, and fecal coliform *Escherichia coli* (*E. coli*) using standard laboratory methods. The findings were compared with national and international permissible limits to assess seawater quality.

**Results:** The results of physico-chemical analysis of seawater from all selected locations met permissible limits, except for the PO<sub>4</sub> concentration, which exceeded the acceptable values in some regions. Microbiological analysis showed the *E. coli* and total coliform were within permissible limits, whereas TAMC values exceeded standard thresholds in certain regions, indicating microbial contamination.

**Conclusion:** The present study reveals that the quality of seawater in regions with high fishing activity along the Tripoli coastline shows signs of chemical and microbial contamination, which may impact marine animals' health and pose threats to consumers. These results highlight the need for ongoing monitoring and effective wastewater management to ensure safe fishing practices and protection of consumers' health.

**Keywords:** Physio-chemical analysis, Composite sampling, Fishing points, Seawater quality, Tripoli coastline.

### Introduction

Seawater plays a crucial role in sustaining ecological balance. It regulates the thermal exchange between the atmosphere and aquatic systems, shapes weather patterns, and supports overall environmental stability (Braira *et al.*, 2016). However, pollution of the marine environment has become a growing global concern. Many Mediterranean countries, including Libya, continue to discharge untreated wastewater into coastal waters (Al-Harir *et al.*, 2022; Bukha *et al.*, 2023). By 2020, approximately 75% of the global population

resided within 60 km of the coastline, intensifying anthropogenic pressure on marine environments (El Zrelli *et al.*, 2018).

The marine environment of Libya is vital for both ecological and economic reasons, particularly for sectors as fishing and tourism (Al-Omari *et al.*, 2018). Coastal zones like Tajoura, Al-Shaab Port, and Hay Al-Andalus are widely used by both commercial and recreational fishers due to their accessibility and proximity to rich marine resources (Shakman and Kinzelbach, 2012). However, increasing fishing activities in these areas

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coincide with environmental stressors, including direct discharge of untreated municipal wastewater, which can negatively affect both public health and marine biodiversity (Saad *et al.*, 2025).

Wastewater pollution exposes the public to health risks through direct contact with contaminated waters (e.g., swimming) and indirectly through the consumption of contaminated seafood (Altohame Jalgaif *et al.*, 2018). Studies estimate that around 2.4 million tons of wastewater are produced annually worldwide, with nearly 1.8 million tons improperly discharged, leading to major ecological impacts (Al-Omari *et al.*, 2018). Wastewater may originate from domestic use, agricultural runoff, maritime activities, industrial discharges, healthcare facilities, and surface wash-off. It disrupts food chains in marine ecosystems and threatens fish health (Yahya *et al.*, 2016; Samarasekera, 2017; Dashti and Al-Haddad, 2019). Moreover, it contains pathogenic and non-pathogenic microorganisms linked to gastrointestinal disorders, skin infections, and respiratory problems (Samarasekera, 2017; Hassan *et al.*, 2021).

Wastewater discharge, whether treated or untreated, introduces high concentrations of phosphorus and nitrogen into coastal waters, stimulating algal blooms that dissolved oxygen (DO) and create hypoxic zones detrimental to aquatic life (Dashti and Al-Haddad, 2019). The survival of marine organisms depends on good water quality (Hamuna *et al.*, 2019), particularly in relation to key parameters such as temperature, salinity, pH, DO, nitrogen, nitrate (NO<sub>3</sub>), and phosphate (PO<sub>4</sub>) concentrations (Altohame Jalgaif *et al.*, 2018). Regular monitoring of these parameters is essential to assess pollution levels and guide remediation efforts (El Zrelli *et al.*, 2018).

The Tripoli coast is subject to significant environmental pressure due to years of unregulated sewage discharge, with an estimated 37 million cubic meters released annually (Brika, 2018). Nevertheless, research studies on seawater quality in Tripoli Coast remain scarce and lacks proper organization, with monitoring programs being virtually absent. Notably, many of these polluted coastal regions are heavily used for fishing. However, little is known about the actual chemical and microbial safety of seawater in these active fishing zones. The results will help evaluate the safety of these locations for fishing activities and assess potential risks to marine animals' lives and public health.

## Material and Methods

### Sampling location

Seawater samples were collected from three active fishing locations along the Tripoli coastline in Libya:

- Location 1 - Tajoura: (32°54'01.3"N 13°18'53.3"E): situated near a densely populated area, this location is close to a known sewage discharge point. It is heavily used by recreational and small-scale fishermen.

- Location 2 - Al-Shaab Port: (32°53'45.7"N 13°11'39.3"E): this port region is characterized by heavy marine traffic, moderate fishing activity, and potential industrial discharge.
- Location 3 - Hai Al-Andalus: (32°52'48.0"N 13°08'32.4"E): this region is located near visible wastewater discharge pipes; however, it is considered relatively less effected compared to the other sampling locations. Traditional fishing activity is still observed in this region.

The sampling locations were selected based on the presence of recreational fishermen, human activities, and commercial fishermen, with varying levels of anthropogenic influence, including the presence of untreated wastewater discharge and recreational marine traffic (Fig. 1). The study was designed to evaluate spatial trends in seawater quality among locations frequently used for fishing activities and seafood is potentially harvested for consumption. A control location, typically characterized by minimal pollution sources, was not included in this preliminary study, as it was difficult to identify a coastal region along Tripoli's coastline that was free from anthropogenic effects. Therefore, the focus of the present study was to assess the quality of seawater in active fishing regions to evaluate potential risks to marine animals' lives and consumers' health.

### Sample collection

To obtain a representative analysis of the location, a composite sampling method was employed (Rainwater and Thatcher, 1960; Bowers and Windom, 1982; Csuros, 2018), with sub-samples collected from various points within each location as follows:

- The present study represents a preliminary assessment based on samples collected in a single month (January 2025). Sampling was conducted during daylight hours between 9:00 AM and 2:00 PM to control for diurnal shifts in microbial populations. The need for extended seasonal sampling in future investigations is to reflect broader pollution trends.
- Number of points: Three points were selected at each location.
- Distances between points: The three points were arranged with 500 m apart, with 1 km between the first and third points.

### Sampling preparation

The seawater samples were collected from the surface, and 50 ml of seawater was gathered from each sub-point. After that, the samples were pooled and mixed into a 1.5-l sterile polyethylene bottle to obtain a composite sample from each location for physico-chemical analysis according to the methods of Parsons (2013). Additionally, three sterile test tubes from each location were used to collect seawater samples for bacteriological analysis according to the methods of Grasshoff *et al.* (2009).



Fig. 1. The sampling locations.

### Sample transportation

The collected seawater samples were stored at 4°C in an icebox during transportation to the Almadina Laboratory in Tripoli under controlled conditions. Analyses were initiated within 2–4 hours of sampling to ensure the reliability of chemical measurements and microbial counts.

### Laboratory analyses

#### A - Physico-chemical parameters

All analyses were conducted at Almadina laboratory according to standardized methods (Grasshoff *et al.*, 2009; Parsons, 2013).

- DO analyzed using the DO membrane method (Katznelson, 2004).
- Electrical conductivity (EC) method and salinity: EC was determined using a portable EC meter, and salinity was calculated accordingly.
- pH: determined using a calibrated pH meter after standardized with buffer solutions (pH 4.0 and 7.0).
- PO<sub>4</sub> concentrations: measured spectrophotometrically at a wavelength of 660 nm.
- NO<sub>3</sub> concentrations: measured using UV spectrophotometry at a wavelength of 275 nm.

#### B - Bacteriological analysis

- Total aerobic microbial count (TAMC)

The total aerobic microbial analysis was assessed using Heterotrophic Plate Count on Plate Count Agar, which is incubated at 37°C for 24 hours. Serial dilutions were performed prior to plating according to the methods of Reasoner (2004).

- Total coliform bacteria

Coliform bacteria were detected using the most probable number method with Lactose broth medium, which is incubated at 37°C for 24 hours. Concentrations were tested using (0.1, 1.0, 10 ml) according to the methods of Chigbu and Sobolev (2007).

- Fecal coliform *Escherichia coli* (*E. coli*)

*E. coli* was detected using M-FC medium, which is incubated at 37 °C for 24 hours according to the methods of Chigbu and Sobolev (2007).

### Ethical approval

Not needed for this study.

### Results

The results of microbial, physico-chemical properties of seawater for each location are summarized in Table 1 and compared to established environmental standards (Marine, 1999; Nordin *et al.*, 2009; Brenner and Hoekstra, 2012).

### Comparison of seawater quality across the three locations

#### A- Comparison of physico-chemical properties

The pH values remained relatively stable across all locations, ranging from 8.12 to 8.14. EC (salinity) was notably lower at Hai Al-Andalus (57,900 µs/cm) compared to the other locations, while Tajoura and Al-Shaab port showed similar EC (salinity) levels (58,300 µs/cm). In contrast, Tajoura (9.62 mg/l) showed a higher level of DO compared to the other locations, while Al-Shaab port (6.65 mg/l) and Hai Al-Andalus (5.80 mg/l) showed similar levels of DO. However, NO<sub>3</sub> concentrations remained relatively stable across all locations, ranging from 0.5 to 0.6 mg/l. PO<sub>4</sub> concentrations were notably higher at Tajoura (14.2 mg/l) compared to the other locations, while Al-Shaab port (2.2 mg/l) and Hai Al-Andalus (3 mg/l) showed similar PO<sub>4</sub> concentrations.

#### B- Comparison of microbial load

Significant variations in microbial pollution were observed among the study locations. Al-Shaab port (1,660 CFU/ml) exhibited the highest TAMC, exceeding the levels observed at the other locations. In

**Table 1.** Results of microbial, physico-chemical parameters of seawater at three locations of the Tripoli coastline.

Measured parameters	Location 1 (Tajoura)	Location 2 (Al-Shaab port)	Location 3 (Hai Al-Andalus)	Permissible limits
pH	8.12	8.13	8.14	7.5–8.5
EC Salinity	58,300 $\mu\text{s/cm}$	58,300 $\mu\text{s/cm}$	57,900 $\mu\text{s/cm}$	$\leq 60,000$ $\mu\text{s/cm}$
$\text{NO}_3$	0.6 mg/l	0.5 mg/l	0.6 mg/l	$\leq 0.5$ mg/l
$\text{PO}_4$	14.2 mg/l	2.2 mg/l	3 mg/l	$\leq 0.1$ mg/l
DO	9.62 mg/l	6.65 mg/l	5.80 mg/l	$\geq 5$ mg/l
TAMC	1,000 CFU/ml	1,660 CFU/ml	1,320 CFU/ml	$\leq 500$ CFU/100 ml
Total Coliform Bacteria	7.30 CFU/100 ml	75 CFU/100 ml	43 CFU/100 ml	$\leq 500$ CFU/100 ml
<i>Escherichia coli</i> ( <i>E. coli</i> )	10 CFU/100 ml	12 CFU/100 ml	8 CFU/100 ml	$\leq 126$ –250 CFU/100 ml

The pH value ranged from 8.12 to 8.14. The EC ranged from 57,900 to 58,300  $\mu\text{s/cm}$ . DO levels ranged from 5.80 to 9.62 mg/l.  $\text{PO}_4$  concentrations ranged from 2.2 to 14.2 mg/l.  $\text{NO}_3$  concentrations ranged from 0.5 to 0.6 mg/l. TAMC ranged from 1,000 to 1,660 CFU/ml. Total Coliform Bacteria ranged from 7.30 to 75 CFU/100 ml. *Escherichia coli* (*E. coli*) count ranged from 8 to 12 CFU/100 ml.

contrast, Tajoura (1,000 CFU/ml) showed the lowest TAMC. Likewise, Total Coliform Bacteria levels were notably higher at Al-Shaab port (75 CFU/100 ml), while Tajoura (7.30 CFU/100 ml) showed the lowest Total Coliform Bacteria level. Also, Al-Shaab port (12 CFU/100 ml) showed the highest *E. coli* concentrations compared to other locations.

### Discussion

The quality of seawater is essential to evaluating the environmental quality of coastal waters and their suitability for recreational and fishing activities. In the present study, seawater samples were collected from selected fishing regions along the Tripoli coastline, where anthropogenic activities occur. The findings reflect the influence of urban runoff and untreated sewage and highlighting variations in pollution levels across selected fishing zones.

The pH levels across all locations ranged from 8.12 to 8.14, indicating that Tripoli's seawater is in slightly alkaline conditions, which are typical for seawater and support the survival of most marine animals. These values align with earlier results from the Gulf of Tobruk (Altohame Jalgaif *et al.*, 2018) and Zliten Beach (Algoul *et al.*, 2016). Even small pH changes threaten marine biodiversity, particularly for calcifying organisms like corals and shellfish. Ocean acidification, driven by pollutants, diminishes biodiversity and disrupts ecosystems (Hamuna *et al.*, 2019).

The DO levels ranged from 5.80 to 9.62 mg/l across three locations, meeting the minimum environmental requirement ( $\geq 5$  mg). These values were within permissible limits for marine life survival. The level of DO measured in this study is consistent with the DO levels of the seawater in the Gulf of Tobruk, Libya (Altohame Jalgaif *et al.*, 2018), and another study by Braira *et al.* (2016) has reported the same level of DO on

the Tripoli coast. However, variations across locations may indicate differing levels of organic pollution.

EC serves as an indirect indicator of salinity in seawater, as higher EC values are typically associated with increased concentrations of dissolved salts. In the present study, the EC was ranged from 57,900 to 58,300  $\mu\text{s/cm}$ , reflecting moderately high salinity across the locations. However, our findings were within permissible limits but indicate a higher salinity level, which contradicts the findings of Fitori *et al.* (2022). Their study showed that the EC in Ain Al-Ghazala water was higher, measuring 62,500  $\mu\text{s/cm}$ . Reporting salinity in  $\mu\text{s/cm}$  provides context for ionic concentrations, which is vital in interpreting nutrient dynamics and pollution impact.

$\text{NO}_3$  concentrations ranged from 0.5 to 0.6 mg/l, with Hai Al-Andalus and Tajoura exceeding the upper permissible limit ( $\leq 0.5$  mg/l). These values are only slightly elevated; they may indicate agricultural runoff. These results contradict Emara *et al.* (2015) and Al-Omari *et al.* (2018), who reported elevated  $\text{NO}_3$  concentrations exceeding the acceptable levels in the Northwestern Gulf of Suez and Eastern Beaches of Tripoli, respectively. However,  $\text{PO}_4$  concentrations showed concerning results, particularly in Tajoura (14.2 mg/l), exceeding national guidelines. This suggests potential contamination from sewage discharge, industrial waste, or agricultural runoff. This elevation can lead to eutrophication, promoting excessive algal growth and depletion of DO, which can harm marine animals' life. Comparing these findings with environmental benchmarks highlights the extent of pollution at Tajoura. These findings contradict Fitori *et al.* (2022), who reported elevated  $\text{PO}_4$  concentrations ranging from 0.18 to 0.14 mg/l, exceeding the acceptable levels in the Eastern Coast of Libya.

The results of the microbial analysis indicated that *E. coli* and total coliform bacteria were within permissible limits at all locations. However, the TAMC exceeded the acceptable values. Our findings, with total coliform bacteria count ranging from 7.30 to 75 CFU/100 ml, while *E. coli* count ranging from 8 to 12 CFU/100 ml were below the permissible limits. These values indicate that bacterial contamination is present with varying levels of fecal contamination at selected locations. These findings contradict Al-Omari *et al.* (2018), who reported significantly higher levels of fecal pollution at Easter Beaches of Tripoli, with total coliform counts ranging from 883.3 to 11316.6 CFU/100 ml and *E. coli* ranging from 183.3 to 1166.6 CFU/100 ml. This discrepancy may be attributed to differences in pollution sources, or sampling locations and time.

In contrast, the TAMC ranging from 1,000 to 1,660 CFU/ml, which significantly exceeded the permissible limits, with the highest values recorded at Al-Shaab Port (1,660 CFU/ml). This elevated level suggests a high level of microbial and organic pollution, which may be due to untreated wastewater discharge, industrial activities, dense marine traffic, or agricultural runoff. These findings are consistent with Madi *et al.* (2006), who reported that the total coliform bacteria ranging from 26.1 to  $1.1 \times 10^5$  per 100 ml, while TAMC ranging from 10 to  $2.5 \times 10^5$  CFU/ml at Tajoura and Tripoli coasts impacted by untreated wastewater discharges.

However, similar microbial pollution levels indicate persistent untreated wastewater discharge in Tripoli's coastline. Elevated microbial counts suggest potential health risks and a likely rise in heterotrophic bacteria due to organic matter. The discrepancy between coliform counts and TAMC may reflect a dominance of non-fecal heterotrophic bacteria, necessitating further bacterial community identification in future studies.

In comparing the sampling locations along the Tripoli coast revealed that Tajoura exhibited the highest  $PO_4$  concentrations among other selected locations, suggesting substantial pollution possibly from a nearby wastewater discharge point. In contrast, Al-Shaab port showed the highest TAMC, indicates potential organic pollution. These patterns indicate spatial variation in pollution types and sources across the locations. Despite all locations are actively used for fishing, the presence of elevated  $PO_4$  and microbial loads, particularly TAMC raises concerns about the long-term safety of fish harvested from these regions. The present study underscores the need for pollution control strategies and regulatory monitoring programs, and further studies are essential to assess the environmental status along the Tripoli coast.

On the other hand, a potential relationship was observed between high  $PO_4$  concentrations and increased microbial loads, particularly at Tajoura and Al-Shaab port. These associations suggest

that chemical pollutants like  $PO_4$  acts as a nutrient that supports microbial growth, highlighting the interconnected nature of seawater pollution. These findings raise concerns regarding the safety of fishing activities in this region. Therefore, these locations may not currently be suitable for fishing activities without effective pollution control strategies.

Although several studies have investigated the environmental condition of the Tripoli coast (Bairra *et al.*, 2016; Al-Omari *et al.*, 2018; Al-Harir *et al.*, 2022), this study presents a novel approach by highlighting on the relationship between changes in physico-chemical and microbial contamination in selected fishing locations along the Tripoli coast, providing a detailed analysis of contamination patterns in these regions. Differing from earlier studies on the Tripoli coast, the present study employs composite sampling, offering a more complete assessment of seawater quality by combining samples from various locations. Furthermore, this study focusing on potential health risks posed by microbial contamination, emphasizing its potential effect on marine animals' health, human health, fishing activities, and the safety of recreational water activity, in contrast to earlier studies that focused on analysis of seawater.

However, the present study has some limitations. The current study was based on single-month sampling, which limits the ability to assess seasonal variations in pollution. In addition, the absence of a control location prevented comparison with uncontaminated reference conditions and biological assessment of marine animals' species. Therefore, future studies should include seasonal sampling and address these aspects to provide a comprehensive understanding of contamination impacts.

### Conclusion

The findings of this study suggest signs of environmental degradation at Tajoura, Al Shaab port and Hai Al-Andalus, which are characterized by intensive fishing activities, including both recreational and commercial anglers. Elevated levels of  $PO_4$  and microbial load indicate potential risks to seawater quality, which may pose threats to marine animals' life and public health, particularly via recreational exposure and consumption of seafood. While the current study did not directly assess marine animals' health, recorded pollution indicators highlight the need for further investigation. These findings serve as a preliminary baseline assessment of the urgency of implementing sewage treatment interventions and improved coastal control strategies.

Future studies should focus on the impact of seasonal variations on microbial pollution levels, explore biological effects on marine animals, and assess correlations between chemical pollution and microbial proliferation.

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### Conflict of interest

The authors declare that they have no commercial or financial relationship that could be construed as a potential conflict of interest.

### Authors' contributions

KKB designed the study and wrote the manuscript. KKB and SAS collected the seawater samples. SJ, EAS, and SAM interpreted the results of study. SAM supervised the study and edited the manuscript. All authors have read, reviewed, and approved the final version of the manuscript.

### Data availability

All data were provided in the manuscript.

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