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Assessment of Plastic Pollution and Its Impacts on Human Health and Marine Life along the Coast of Tobruk Eastern Libya

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Abstract
This study investigates plastic pollution along the coastal zone of Tobruk City in eastern Libya, a region strongly influenced by both natural drainage systems and intense human activities. Field surveys were conducted along major wadis, urban beaches, and port areas, combining on-foot and boat-based observations to document the distribution, types, and density of plastic debris. The findings reveal that plastic bottles are the dominant waste category, accounting for approximately 40% of the total pollution, followed by containers, bags, and plastic sheets, which together represent nearly 25%. Styrofoam fragments, fishing gear, and household plastics also contribute significantly, particularly in harbor areas and densely populated zones.
The spatial distribution of plastic debris correlates closely with drainage outlets, indicating that wadis act as major transport pathways carrying inland waste into the marine environment. The persistence of polyethylene terephthalate (PET) and low-density polyethylene (LDPE) reflects inadequate waste collection systems and low levels of community awareness regarding proper plastic disposal. These materials readily fragment into microplastics, posing serious risks to marine organisms and potentially entering the human food chain.
Overall, the study highlights that Tobruk's coastline is experiencing escalating plastic pollution as a result of uncontrolled waste discharge and urban expansion. Addressing this issue requires integrated coastal management strategies, strengthened waste management policies, and continuous monitoring to protect marine biodiversity and sustain local livelihoods.
Keywords: Plastic pollution; marine life; human health; environmental impact.

تقييم التلوث البلاستيكي وتأثيراته على صحة الإنسان والحياة البحرية على طول ساحل طبرق شرق ليبيا

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الملخص

تبحث هذه الدراسة التلوث البلاستيكي على طول المنطقة الساحلية لمدينة طبرق، شرق ليبيا، وهي منطقة تتأثر بشدة بكل من أنظمة الصرف الطبيعية والأنشطة البشرية المكثفة. أجريت مسوحات ميدانية على طول الوديان الرئيسية والشواطئ الحضرية ومناطق الموانئ، حيث تم الجمع بين الملاحظات التي تمت سيرًا على الأقدام، والملاحظات التي تمت بالقوارب لتوثيق توزيع ونوع وكثافة النفايات البلاستيكية. تكشف النتائج أن الزجاجات البلاستيكية هي الفئة السائدة من النفايات، حيث تشكل حوالي 40٪ من إجمالي التلوث، تليها الحاويات، والأكياس، والأغطية التي تمثل مجتمعة حوالي 25٪. كما تساهم شظايا الستايروفوم ومعدات الصيد والبلاستيك المنزلي بشكل كبير، لا سيما بالقرب من مناطق الموانئ والمناطق المكتظة بالسكان. يرتبط التوزيع المكاني للبلاستيك بمنافذ الصرف؛ مما يشير إلى أن الأودية تعمل كمسارات نقل رئيسية تنقل النفايات الداخلية نحو البيئة البحرية. يعكس استمرار وجود مواد البولي إيثيلين تيريفثاليت (PET) والبولي إيثيلين منخفض الكثافة (LDPE)عدم كفاية أنظمة جمع النفايات، وضعف وعي المجتمع بشأن التخلص من البلاستيك. تتفتت هذه المواد إلى جزيئات بلاستيكية دقيقة، مما يشكل مخاطر جسيمة على الكائنات البحرية، ويحتمل أن تدخل في سلسلة الغذاء البشرية. بشكل عام، تسلط الدراسة الضوء على أن ساحل طبرق يواجه تلوثًا متزايدًا بالبلاستيك؛ بسبب تصريف النفايات غير المنضبط والتوسع الحضري. تتطلب معالجة هذه المشكلة إدارة ساحلية متكاملة، وسياسات محسنة للنفايات، ومراقبة مستمرة لضمان السلامة.

الكلمات المفتاحية: التلوث البلاستيكي، صحة الإنسان، الحياة البحرية والتأثير البيئي.

Introduction

Plastic pollution silently infiltrates coastal sands and waters, altering ecosystems and imperiling marine life. Recent fieldwork in Hawaii revealed that **91%** of retrieved plastic fragments were buried deeper than **two centimeters** beneath beach surfaces, highlighting how traditional surveys can drastically underestimate actual pollution levels (1). Advances in remote sensing, such as the Beached Plastic Debris Index, leverage shortwave infrared spectral features to accurately identify plastics even when they occupy less than 30% of a satellite image pixel, demonstrating significant potential for scalable monitoring.

Spectral analyses of both weathered and virgin marine plastics over sandy substrates indicate that specific polymers can be detected at surface cover levels as low as 2–8%, with detection performance varying by polymer type. These findings inform the development of more sensitive and reliable retrieval tools. As beaches continue to receive persistent debris inputs from both terrestrial and marine sources, coordinated efforts to enhance detection capabilities are essential for validating cleanup strategies and supporting policies aimed at mitigating coastal plastic pollution (2).

Pollution in Tobruk Bay is strongly linked to the discharge of untreated wastewater and solid waste from the city, which enters the coastal zone and accumulates in the sediments. The bay's sediments exhibit elevated concentrations of heavy metals compared with background levels, a pattern attributed to both natural mineral inputs and anthropogenic activities. Marine ecosystems within the bay are therefore subjected to significant ecological stress, as fine-grained sediments retain contaminants more efficiently than coarse sands, increasing the persistence and bioavailability of pollutants. The study concludes that continuous monitoring of sediment composition and pollution indicators is essential to protect coastal habitats and reduce environmental risks in Tobruk (3).

Water and sediment pollution along the Tobruk coastline emerges in Mohamed Masoud's work as a coupled problem driven by urban effluents, port and shipping activities, and nearshore industrial pressures. His studies of Tobruk Bay identify multiple pollution pathways, including municipal sewage discharge points, harbor operations, shoreline construction activities, and accumulations of wastewater on beaches. Together, these sources create a mosaic of stressors that alter seawater chemistry and contaminate bottom sediments.

The coastal setting—characterized by a semi-enclosed bay geometry and variable water depths ranging from approximately 5 to 16 meters—promotes the trapping of contaminants and enhances their interaction with fine particles and organic matter, thereby amplifying ecological risk. Across these investigations, Masoud evaluates classical water quality indicators such as pH, electrical conductivity, and major ions, alongside bacteriological loads, and links these parameters to land-based pollution sources and wastewater treatment efficiency.

His study of well water in Tobruk further assesses physicochemical parameters before and after treatment and screens for *Escherichia coli*, illustrating how inadequate infrastructure and poor well conditions can perpetuate human health risks even when nominal treatment processes are in place. This groundwater perspective complements the marine studies by demonstrating how contamination pathways connect inland water resources with the coastal zone (4).

Tobruk Bay also suffers from significant heavy metal contamination in its sediments. Samples collected from eight stations revealed elevated concentrations of iron (Fe), manganese (Mn), zinc (Zn), cadmium (Cd), and lead (Pb), exceeding permissible limits and indicating that the bay is polluted (5). Sediments receive particular attention as both sinks and potential secondary sources of heavy metals. Masoud's sediment surveys report concentrations of Fe, Mn, Zn, Cd, and Pb alongside grain-size fractions (sand, silt, and clay), carbonate content, and organic matter, all of which govern metal retention. By comparing measured levels with previous regional studies, these works highlight spatial variability among sampling stations and the tendency of fine, organic-rich sediments to host elevated metal burdens, with important implications for benthic habitats and for contaminant resuspension during storms or dredging activities (6).

Extending this body of work, subsequent studies integrate paired water–sediment measurements and interpret their implications for human health. By applying contamination and risk indices, these studies evaluate exposure pathways and identify elements of concern in the Gulf of Tobruk, strengthening the evidence that nearshore communities may face non-negligible health risks where heavy metal inputs persist. The synthesis of metal profiles across environmental media—water and sediments—demonstrates that effective management must address both the water column and the depositional environment in order to reduce long-term exposure.

Taken together, these publications present a coherent picture: coastal water quality in Tobruk is closely linked to land-based discharges and harbor activities; sediments function as critical archives and potential secondary sources of heavy metals; and assessments of both groundwater and seawater quality underscore the need for systematic monitoring, improved wastewater control, and sediment-focused remediation in identified hotspots. Future monitoring frameworks, as implied by Masoud's datasets and site maps, should integrate routine seawater chemistry, microbial indicators, and sediment grain-size and organic matter analyses with risk-based thresholds to inform local policy and protect public health (7).

Plastic pollution has also rapidly emerged as a major global threat to marine ecosystems and human health, particularly in coastal regions where human activity is intense and waste management systems are often inadequate. The growing accumulation of plastics—especially microplastics—in aquatic environments poses serious risks to marine biodiversity and raises significant concerns regarding food safety and public health. Coastal areas worldwide, including regions in Southeast Asia, South America, and South Korea, are heavily impacted by plastic debris. This pollution disrupts marine ecosystems, with effects cascading through the food web and ultimately affecting communities that depend on these systems for their livelihoods and nutrition (8).

Microplastics, defined as plastic particles smaller than 5 mm, are now ubiquitous in marine environments. They originate from multiple sources, most notably the fragmentation and degradation of larger plastic debris, and are of particular concern because of their capacity to adsorb and transport harmful pollutants. These contaminants can subsequently enter the food chain. Numerous studies have documented the presence of microplastics in commercially important species, including fish and shellfish, raising concerns about human exposure through seafood consumption (9).

Despite growing evidence of their prevalence, the complex interactions between microplastics and marine organisms remain insufficiently understood, underscoring the urgent need for comprehensive research to clarify the ecological and human health implications of plastic pollution. In this context, the present study investigates the distribution, types, and density of plastic pollution along the coastal zone of Tobruk City in eastern Libya and assesses its potential impacts on marine ecosystems and human health. The study further aims to identify the primary sources and transport pathways of plastic debris—particularly those associated with natural drainage systems (wadis) and anthropogenic activities—and to propose mitigation strategies to address this escalating environmental threat.

Materials and Methods

Study area and Samples collections:

The study was conducted along the coastal zone of Tobruk City, located in eastern Libya on the Mediterranean Sea. The city lies approximately between 32°05′–32°10′ N latitude and 23°50′–24°05′ E longitude. Tobruk is one of the most important urban and economic centers in the region, characterized by its strategic port and the presence of several valleys (wadis) that discharge directly into the sea.

The coastal strip includes multiple locations where plastic pollution has been observed. To the west of the city, the main wadis include Wadi Um Khail, Wadi Elmgarrun, Wadi Bo Hager, Wadi Elhwuat, Wadi Hasouha, and Wadi Toburag. Within the urban zone, key sites comprise Wadi Elaoda, Wadi Abd Elrasol, Wadi Amerera, the Corniche, and the Port of Tobruk. Further east, the surveyed sites extend to Al Zagam, Port Ludo, Wadi Boawuna, the Oil Company area, Wadi Um Elshawsh, and Wadi Halmy (Fig. 1).

These locations represent the principal drainage outlets and zones of intense human activity where land-based waste, including plastic debris, is discharged into the marine environment. Accordingly, the study area reflects the combined influence of natural inputs via wadis and anthropogenic pressures associated with urbanization, industrial operations, and port activities (Fig. 1).

Figures1. Locations of the study area

Samples and Collection

The assessment of plastic pollution along the Tobruk coast was conducted through systematic field visits. Surveys were carried out both on foot and by boat, depending on site accessibility. Walking surveys allowed careful examination and direct documentation of shoreline plastic debris. Boat surveys reached areas inaccessible by land and gave a broader view of pollution spread in the marine environment. During each visit, photographs were taken to document visible plastics on beaches and in nearshore waters. Evidence was collected to identify types of plastic waste present, including bottles, bags, fishing gear, and fragments. Each debris type was recorded separately for detailed inventory and classification. The exact locations of pollution sites were documented to provide spatial data linked to specific valleys, urban areas, and human activities along the coast. This combined approach—direct observation, photographic documentation, and classification—enabled a comprehensive evaluation of plastic pollution in Tobruk's coastal environment. See Plates 1 to 9.

Plate 1. A general view of Wadi Um Khail beach shows scattered plastic and fishing waste. (B): Close-up view reveals degraded plastic and ropes at Wadi Um Khail. (C)Wadi Um Elmgarrun beach displays a dense accumulation of plastic and mixed debris. (D): Researcher documents coastal litter at Wadi Um Elmgarrun.

Plate .2 (A): Wadi Bo Hager beach covered with mixed plastic litter and containers along the shoreline.(B): Floating marine debris observed near Wadi Bo Hager, consisting mainly of plastic bottles and fragments.(C): Wadi Elhwuat beach showing large amounts of discarded bottles, crates, and packaging materials.(D): Extensive accumulation of plastics and nets at Wadi Elhwuat, indicating severe coastal pollution.

Plate.3. (A): Wadi Hasoha beach showing extensive plastic and household waste accumulation on sandy deposits.B): Closer view at Wadi Hasoha highlighting mixed litter including bottles, foams, and fishing materials.(C): Wadi Toburag coastal zone covered with scattered plastic bottles and containers along the shoreline.(D): Inland area near Wadi Toburag showing waste accumulation around coastal vegetation and ponds.

Plate .4 (A): Wadi Elaoda coastal site showing large amounts of plastic bottles and garbage bags scattered on rocky terrain.(B): Sandy beach of Wadi Elaoda containing dispersed plastic litter and debris along the shoreline.(C): Wadi Abd Elrasol beach covered with seagrass remains and mixed plastic waste.(D): View of Wadi Abd Elrasol coastal area with accumulated debris near local fishing houses and boats.

Plate.5. (A): Wadi Amrera site showing mixed waste including plastic bottles, construction debris, and dry vegetation near the shoreline.(B): Extensive solid waste accumulation at Wadi Amrera, with burnt and mixed municipal litter.(C): AlZagam Shore showing large piles of construction and plastic waste with a researcher conducting field documentation.(D): Coastal zone at AlZagam Shore covered by dispersed debris and rocky waste deposits extending toward the sea.

Plate. 6. (A): Ludo beach showing scattered plastic waste, tires, and organic debris along the high-tide line.(B): Rocky shoreline of Ludo with concentrated plastic bottles and construction remnants.(C): Floating litter accumulated near the harbor wall at the Port of Tobruk, including plastic bottles and other debris.

Plate .7 (A): Corniche (1) showing scattered plastic bottles and mixed waste among coastal vegetation near the shoreline. (B): Concentrated accumulation of plastic and packaging waste at Corniche (1) adjacent to the urban waterfront. (C): Corniche (2) coastal zone displaying marine debris and remnants of old structures along the rocky beach. (D): Inland area of Corniche (2) showing piles of mixed household waste and plastic bags near vegetation patches.

Plate.8 (A): Port of Toruks showing large quantities of floating plastic bottles and waste materials accumulated along the harbor edge. (B): Wadi Boawuna site showing stagnant water with scattered waste and vegetation along the banks. (C): Lower section of Wadi Boawuna illustrating mixed litter, including plastics and tires, deposited along the wetland channel.

Plate .9 (A): Oil Company site showing mixed industrial and household waste accumulated near the shoreline below the vegetated slope.(B): Wadi Um Elshawsh coastal area displaying scattered plastic debris among coastal vegetation along the sandy beach.(C): Wadi Halmy site with extensive plastic waste and containers spread across the dry valley floor.

Results and Discussion

The analysis of plastic pollution along the Tobruk coastline indicates a clear predominance of plastic bottles, which account for approximately 40% of the total observed plastic debris. These bottles—commonly transparent, green, or blue—are widely distributed across both sandy and rocky coastal environments, reflecting high levels of single-use plastic consumption and inadequate waste management and disposal practices.

Plastic containers and plastic bags or sheets constitute the next major categories of debris, accounting for approximately 15% and 10%, respectively. These materials are primarily associated with domestic and commercial activities, particularly household packaging and retail use. Owing to their lightweight nature, they are easily dispersed by wind and tidal processes, leading to their accumulation along coastal areas and near drainage outlets.

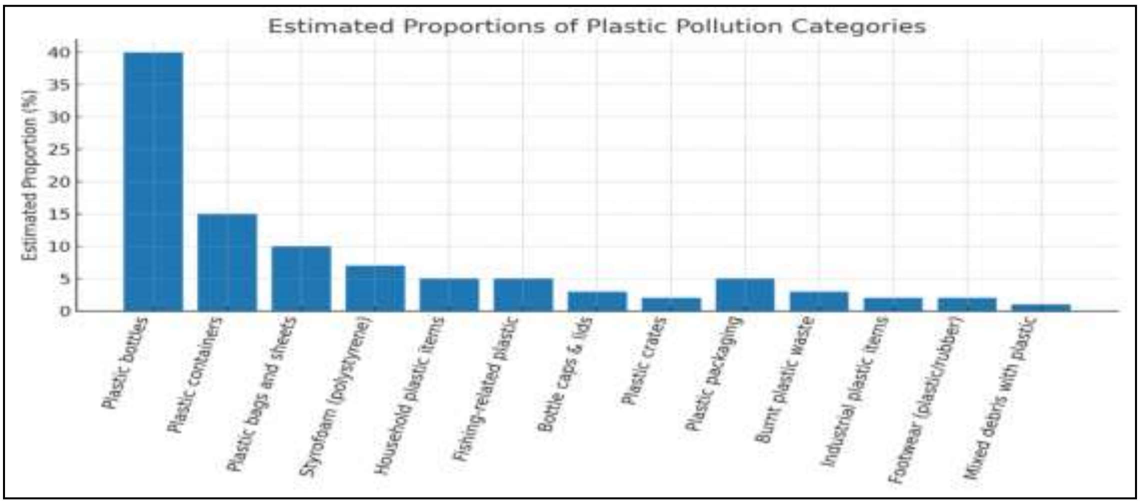
Styrofoam fragments (7%) and fishing-related plastics (5%) also make substantial contributions to the overall pollution profile. The occurrence of foam blocks and fragments of fishing nets indicates the influence of maritime activities, including fishing operations and harbor-related practices. In addition, household plastics (5%) and plastic packaging materials (5%) reflect the continued input of residential waste, especially in densely populated or recreational coastal zones.

From an environmental perspective, the dominance of polyethylene terephthalate (PET) bottles and low-density polyethylene (LDPE) bags represents a significant ecological concern. These materials are highly persistent in the environment and degrade slowly, fragmenting into microplastics that can be ingested by marine organisms. Such ingestion may disrupt marine food webs and facilitate the bioaccumulation of harmful chemicals. Furthermore, although less prevalent (3%), burnt plastic waste poses additional risks by releasing toxic compounds, including dioxins and furans, into the coastal atmosphere and surrounding soils.

Overall, these findings demonstrate that plastic bottles are the most widespread and environmentally hazardous form of plastic waste along the Tobruk coastline. Their persistence underscores the urgent need for improved waste management systems, enhanced public awareness initiatives, and stricter enforcement of anti-littering regulations to safeguard coastal and marine ecosystems.

Table 1. Types of Plastic Pollution Observed along the Tobruk Coast.

Category	Examples Observed	Estimated Proportion
Plastic bottles	Transparent, green, blue bottles scattered in large quantities across all images	≈40% (most dominant across all images)
Plastic containers	Blue jerrycan, detergent bottles, white and colored containers, food boxes	15%
Plastic bags and sheets	Thin transparent bags, torn sheets, fragments spread on sand and rocks	≈10%
Styrofoam (polystyrene)	White foam blocks, packaging fragments, broken pieces	≈7%
Household plastic items	Pink sponge, cups, containers, plastic chair parts, footwear	≈5%
Fishing-related plastic	Orange nylon ropes, fishing net fragments entangled with debris	≈5%
Bottle caps & lids	Colored caps (red, blue, white) scattered with bottles	≈3%
Plastic crates	Black broken crate, blue crate parts	≈2%
Plastic packaging	Wrappers, food-related packaging films, six-pack rings	≈5%
Burnt plastic waste	Melted and charred plastics observed in open dump area	≈3%
Industrial plastic items	Blue drums/cans, large scattered industrial containers	≈2%
Footwear (plastic/rubber)	Black slippers, sandals, rubber shoes among waste	≈2%
Mixed debris with plastic	Wood, cloth, cardboard, organic material mixed with plastic waste	≈1%



Figures 2 Types and Distribution of Plastic Pollution Observed along the Tobruk Coast, Eastern Libya

The Impact of Marine Plastic Pollution on Human Health

The pervasive presence of plastic debris—particularly microplastics (<5 mm)—in the marine environment of Tobruk Bay, as documented in this study, represents a significant and direct threat to human health through multiple exposure pathways. The observed categories of pollution, including plastic bottles, containers, packaging materials, and fishing gear, are not merely aesthetic or ecological concerns; rather, they serve as sources of contaminants that can enter the human body.

Primary Exposure Pathways

Seafood Consumption

The most direct pathway of human exposure to marine plastic pollution is through the consumption of contaminated seafood. Microplastics and the chemical pollutants adsorbed onto their surfaces are ingested by a wide range of marine organisms, from filter-feeding shellfish to commercially important fish species. As plastic debris fragments in the marine environment, it is frequently mistaken for food and becomes incorporated into the food web. Given the importance of fisheries and aquaculture activities in Tobruk Bay, locally harvested seafood represents a potential vector for transferring plastic-associated contaminants to the local population (9).

Microplastic Ingestion by Marine Organisms

The fragmentation of polyethylene terephthalate (PET) bottles and low-density polyethylene (LDPE) bags into microplastics poses a substantial ecological hazard, particularly for marine organisms that commonly misidentify these particles as food. Numerous studies indicate that microplastics accumulate in the digestive systems of fish, mollusks, and crustaceans, leading to reduced feeding efficiency, internal tissue damage, and impaired reproductive capacity. These effects extend beyond individual species, influencing entire food webs by disrupting predator–prey interactions and altering nutrient cycling processes (10).

Water Contamination:

While larger plastic items are visually conspicuous, a more critical concern lies in the leaching of plastic additives—such as plasticizers, stabilizers, and flame retardants—and the release of adsorbed pollutants, including heavy metals and persistent organic pollutants (POPs), from plastic debris into the water column. Studies by Masoud et al. (6) in Tobruk Bay have consistently reported elevated concentrations of heavy metals, particularly cadmium (Cd) and lead (Pb), in bottom sediments. Plastic materials can act as effective vectors by adsorbing these metals and subsequently releasing them into the surrounding environment, thereby facilitating their transfer to aquatic organisms and the water column. This process is further intensified by the semi-enclosed nature of Tobruk Bay, which promotes contaminant retention and accumulation (7).

Groundwater and Drinking Water:

The link between land-based waste, coastal pollution, and inland water sources is clearly evident in Tobruk. Masoud's study (5) on well water in Tobruk City revealed inadequate treatment infrastructure and the presence of *Escherichia coli*, indicating fecal contamination. Although the study did not directly address plastic pollution, it underscores how ineffective waste management practices can facilitate broader environmental contamination, potentially allowing microplastic fibers and particles to infiltrate groundwater aquifers through soil and subsurface pathways.

Potential Human Health Effects

The World Health Organization (11) has acknowledged the potential human health risks associated with microplastics in drinking water and the broader environment. Although further research is required to fully understand their long-term impacts, existing evidence highlights several areas of concern. In addition to microplastic exposure, the open burning of plastic waste—particularly in informal settlements or near coastal dumping sites—poses a serious health hazard. Such practices release toxic pollutants, including dioxins, furans, and polycyclic aromatic hydrocarbons (PAHs), which are well-established carcinogens.

These hazardous compounds can contaminate ambient air and surrounding soils, thereby increasing risks to human health and terrestrial ecosystems. The occurrence of burned plastic residues along the Tobruk coastline underscores the urgent need for stricter waste disposal regulations, improved enforcement, and enhanced public awareness campaigns to discourage open burning and mitigate its associated health risks (12).

Chemical Toxicity:

Plastics contain a variety of chemical additives, including bisphenol A (BPA) and phthalates, which are recognized as endocrine-disrupting compounds. The U.S. Centers for Disease Control and Prevention's National Biomonitoring Program (13) has reported widespread human exposure to these substances, which have been linked to adverse developmental, reproductive, and metabolic health effects. When plastics degrade in the environment, these additives can leach into surrounding water and food sources. Ingestion of contaminated seafood or drinking water may result in their accumulation in human tissues, thereby increasing potential health risks.

Vector for Pathogens**:**

Biofilms that form on plastic surfaces—the "plastisphere"—can harbor pathogenic bacteria and viruses. Plastics can thus act as rafts, transporting harmful microorganisms to bathing waters or shellfish beds, thereby increasing the risk of gastrointestinal and other infectious diseases (11).

Physical Damage and Inflammation:

The ingestion of microplastics can cause physical damage to the gastrointestinal tract. Their small size allows for potential translocation across the gut lining, leading to systemic exposure and triggering inflammatory responses (11).

The Impact of Marine Plastic Pollution on Human Health: Risks and Diseases

The pervasive presence of plastic debris in Tobruk Bay extends beyond ecological damage, posing a direct and multifaceted threat to human health. The pathway from plastic waste to human disease involves chemical exposure, microbial pathogens, and physical harm.

Chemical Exposure and Chronic Disease Risks

Plastics leach harmful additives and absorb environmental toxins that can enter the body through contaminated seafood and water. Many plastics contain BPA and phthalates—recognized endocrine disruptors (13). Chronic exposure to these chemicals is linked to infertility, obesity, diabetes, and hormone-related cancers.

Furthermore, plastics act as magnets for persistent organic pollutants (POPs) such as DDT, PCBs, and heavy metals (Pb, Cd), which are already elevated in Tobruk sediments (5). Upon ingestion, these toxins can accumulate in human tissues. The World Health Organization (WHO) (11) classifies many of these substances as carcinogenic or toxic to the liver, kidneys, and nervous system.

Additionally, PET and LDPE are among the most persistent plastic polymers in the marine environment due to their resistance to biodegradation. These materials can remain intact for decades, especially under low-UV, low-oxygen underwater conditions. Their slow degradation contributes to long-term environmental contamination, complicating cleanup efforts and increasing costs. This persistence underscores the need for upstream interventions, such as reducing single-use plastics and promoting biodegradable alternatives (14).

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Vector for Infectious Diseases

The "plastisphere" harbors and transports pathogenic microbes. In Tobruk, where wastewater is discharged untreated, plastics can carry *Vibrio cholerae*, *E. coli*, and *Salmonella*, potentially causing gastrointestinal infections (6).

Additionally, the plastisphere serves as a hotspot for antibiotic-resistant genes (ARGs). If these pathogens enter the human body, they can cause infections that are difficult to treat with antibiotics (15).

Physical Damage and Inflammation

Microplastics can physically damage the gut, causing micro-tears, inflammation, and immune activation, contributing to diseases such as IBD, cardiovascular disorders, and neurodegeneration (11). The combination of documented heavy metal pollution, poor sanitation infrastructure, and plastic debris creates severe public health risks in Tobruk Bay (7). Addressing plastic pollution is therefore a vital public

Conclusions:

The coastal environment of Tobruk is under increasing pressure from plastic pollution, primarily driven by urban waste discharge, ineffective waste management, and human negligence. The prevalence of polyethylene terephthalate (PET) bottles and low-density polyethylene (LDPE) bags highlights the persistence of single-use plastics in both terrestrial and marine zones. These materials not only degrade into harmful microplastics but also pose significant threats to aquatic life and ecosystem balance.

This study emphasizes the urgent need for collective environmental responsibility, stronger regulatory enforcement, and sustainable waste-handling systems. Protecting Tobruk's coastline is essential for maintaining biodiversity, safeguarding public health, and preserving the economic value of marine resources for future generations.

Plastic pollution on beaches can be effectively addressed through an integrated approach that combines source reduction, advanced waste management, and continuous monitoring. The adoption of sustainable materials, strict regulation of plastic production and disposal, and the application of remote sensing alongside field-based assessments can enable early detection and mitigation of plastic accumulation. Furthermore, public awareness, stakeholder engagement, and robust coastal governance frameworks are critical to ensuring long-term beach cleanliness and ecosystem resilience.

Recommendation:

1. Enhance Waste Management Systems: Establish an integrated solid waste management plan focusing on recycling facilities, collection points, and safe disposal near the coastal zone.
2. Implement Public Awareness Campaigns: Launch educational programs targeting schools, local communities, and fishermen to promote responsible plastic use and waste reduction.
3. Strengthen Environmental Legislation: Enforce stricter regulations on littering, illegal dumping, and industrial discharge, supported by regular coastal monitoring and penalties.
4. Encourage Sustainable Alternatives: Promote the use of biodegradable packaging, reusable containers, and eco-friendly materials in local markets and industries.
5. Support Scientific Monitoring and Research: Develop long-term monitoring programs and academic collaborations to assess plastic pollution trends and design evidence-based mitigation strategies.

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