Applied Food Research 6 (2026) 101934

Contents lists available at ScienceDirect

Applied Food Research

journal homepage: www.elsevier.com/locate/afres

Dietary exposure to micro- and nanoplastics in the Arab Region, a narrative review

Hussein F. Hassan [a], Roa Echtay [a], Hanin El Hajj [a], Sonel Lahdo [a], Tala Jaafar [a], Aya Fakhr El Dine [a], Elias Akoury [b], Maya Bassil [c], Layal Karam [c], Mohamed Abdelfatah [d], Christelle Bou-Mitri [e], Ioannis Zuburtikudis [f,*], Nisreen Alwan [g,*]

[a] Department of Nutrition and Food Science, School of Arts and Sciences, Lebanese American University, Beirut, Lebanon
[b] Physical Sciences Department, School of Arts and Sciences, Lebanese American University, Beirut, Lebanon
[c] Department of Nutrition Sciences, College of Health Sciences, QU Health, Qatar University, Doha, Qatar
[d] Faculty of Medical and Health Sciences, Liwa College, Abu Dhabi, , United Arab Emirates
[e] Faculty of Nursing and Health Sciences, Notre-Dame University-Louaize, Zouk Mozbeh, Lebanon
[f] College of Engineering, Abu Dhabi University, Abu Dhabi, United Arab Emirates
[g] College of Health Sciences, Abu Dhabi University, Abu Dhabi, United Arab Emirates

ARTICLE INFO

Keywords:
Microplastics
Nanoplastics
Dietary exposure
Food safety
Arab region

ABSTRACT

Background: : The widespread presence of microplastics (MPs) and nanoplastics (NPs) emerged as a global health concern. These particles have been detected in different components of the food chain, raising increasing concern regarding their potential effects on human health. This narrative review examines the existing body of literature on dietary exposure to MPs and NPs within the Arab region. Despite the growing use of plastics and escalating environmental pollution, research on dietary exposure to MPs and NPs in this region remains limited.
Methods: : This narrative review screened multiple databases and identified 30 published research articles related to the presence of MPs and NPs in food and drinking water across the Arab countries. These articles were analyzed to examine key parameters, including particle type, size, shape, color, and the specific food or water sources affected.
Results: : MPs are prevalent across the Arab region, including Lebanon, Kuwait, Oman, Egypt, Algeria, Sudan, UAE, Saudi Arabia, Morocco, and Tunisia. Numerous food products, including bottled water, salt, meat and poultry have been reported to be heavily contaminated. Marine ecosystems, particularly in the Mediterranean and Red Seas, have shown substantial plastic pollution, contributing to the presence of MPs in marine species such as fish, mollusks, and crustaceans. These contaminated products enter the human food chain, leading to adverse health effects.
Conclusion: : The presence of MPs and potential NP infiltration is due to the region's high rates of plastic waste mismanagement, limited wastewater treatment infrastructure, and increasing plastic consumption. The findings underscore the need for comprehensive monitoring efforts and policy interventions to mitigate plastic pollution and its impact on food safety and public health in the Arab world.

1. Introduction

Global plastics production has reached >390 million tons per year, with a steady increase in demand due to the diverse properties and applications of plastics (Dokl et al., 2024; Plastics Europe, 2022). The amount of plastic produced annually that ends up in the oceans is approximately 10 %, with an estimated 8 million pieces of plastic escaping from land-based sources every day. In marine environments, plastic degradation can take hundreds of years and is driven by factors such as oxygen, moisture, heat, and sunlight (Bajt, 2021). Plastic

* Corresponding authors.
E-mail addresses: hussein.hassan@lau.edu.lb (H.F. Hassan), roa.echtay@lau.edu (R. Echtay), hanin.elhajj@lau.edu (H.E. Hajj), sonel.lahdo@lau.edu (S. Lahdo), tala.jaafar@lau.edu (T. Jaafar), aya.fakhreldine@lau.edu (A.F.E. Dine), elias.akoury@lau.edu.lb (E. Akoury), bassil.maya@qu.edu.qa (M. Bassil), lkaram@qu.edu.qa (L. Karam), mohammed.abdelfatah@lc.ac.ae (M. Abdelfatah), cboumitri@ndu.edu.lb (C. Bou-Mitri), ioannis.zuburtikudis@adu.ac.ae (I. Zuburtikudis), nisreen.alwan@adu.ac.ae (N. Alwan).

https://doi.org/10.1016/j.afres.2026.101934
Received 17 November 2025; Received in revised form 20 February 2026; Accepted 25 March 2026
Available online 25 March 2026

degradation through sunlight exposure (photodegradation) is considered the most significant driver. It changes the plastic's characteristics, including color and physical properties, and leads to the formation of cracks, visible defects and the release of volatile organic compounds (VOCs). In addition, photodegradation results in plastic breakage into smaller particles, resulting in the formation of microplastics. Moreover, biodegradation, a natural process involving microorganisms, further breaks down plastics into microplastics. This process depends on various factors, including environmental conditions, substrate characteristics, and the types of microorganisms involved (Bajt, 2021). Different types of plastics are currently in commercial use, including polypropylene (PP), polyethylene terephthalate (PET), polyurethane (PU), polystyrene (PS), polyethylene (PE), polycarbonate (PC), and polyvinyl chloride (PVC) (Kannan & Vimalkumar, 2021).

In 2008, the National Oceanic and Atmospheric Administration (NOAA) proposed defining Microplastics (MPs) as particles with a diameter of <5 mm, revising the earlier definition from 2004, which categorized MPs as particles approximately 20 µm in size (Hartmann et al., 2019). Based on their source of environmental release, MPs are classified as either primary or secondary (Kannan & Vimalkumar, 2021). Primary MPs are deliberately manufactured at microscopic sizes, such as microbeads, and are typically used in cosmetics, facial cleansers, air blasting media, and as vectors for drug delivery (Cole et al., 20ll). Secondary MPs, on the other hand, are formed from the breakdown of larger polymers through normal weathering processes, including corrosion, erosion, abrasion, photo- and biodegradation (Cole et al., 2011; Kannan & Vimalkumar, 2021). In addition, the physicochemical properties of MPs can be used to classify them. These include microfibers (from textiles), fragments, nurdles, foams and microbeads (Kannan & Vimalkumar, 2021). MPs persist in the environment for hundreds to thousands of years, posing not only an environmental pollution but also a chemical hazard by releasing the additives and performance-enhancing compounds used during their production (Rashid et al., 2025; Kannan & Vimalkumar, 2021).

Nanoplastics (NPs) are the result of further microplastic degradation into smaller particles (Cai et al., 2021). The definition of nanoplastics is still under debate with no clear and definite consensus (Cai et al., 2021). The current definition of NPs follows the threshold commonly used in nanotechnology and nanomaterials, which is smaller than 100 nm. However, Hartman et al. (41Hartmann et al., 2019) proposed that NPs range from 1 to 1000 nm. NPs may be more harmful than MPs due to their smaller size and higher potential for penetrating biological members (Cai et al., 2021). However, there is no clear effect of NPs yet as research in this field is limited and data is scarce (Cai et al., 2021).

The ingestion of MPs in marine organisms may lead to reduced feeding rates, energy depletion, and inflammation (Wright et al., 2013). In addition, MPs may act as a route for chemical hazards, including polycyclic aromatic hydrocarbons (PAH), bisphenol A (BPA), and heavy metals, all of which lead to toxic effects on marine life (Teuten et al., 2009). These effects include impaired reproductive health, reduced swimming performance, neurotoxicity, and oxidative stress (Barboza et al., 2018). The reported findings pose a significant concern for humans who rely on seafood as a primary source of protein and essential micronutrients.

MPs and NPs are transferred to humans through chemical (toxic additives), biological (microorganisms), and physical (inhalation and ingestion) pathways (Rashid et al., 2025; Blackburn & Green, 2022). Cox et al. (Cox et al., 2019) reported that the average annual intake of MPs through food consumption ranges from 39,000 to 52,000 particles. Several studies have assessed the dietary exposure to MPs and NPs worldwide, including the Arab region, where high levels of MPs and NPs in the ecosystem (ocean, seas, and land) have been reported. Therefore, the aim of this review is to assess the dietary exposure to MPs and NPs in the Arab region, with a focus on their different characteristics including size, color, shape, and polymer type.

2. Methods

This narrative review aims to explore the occurrence of MPs and NPs in food and drinking water in the Arab region.

2.1. Inclusion criteria

Studies that investigated the presence of NPs and/or MPs in food and/or drinking water in Arab countries between 2000 and 2025 were included.

2.2. Exclusion criteria

Studies examining NP and MP contamination in non-edible products were excluded.

2.3. Data extraction

A total of 30 published articles in English were found through searches on several online databases, including ScienceDirect, PubMed, and Google Scholar. The search strategy involved keywords of each of the 22 Arab countries (Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates, Yemen) and microplastics or nanoplastics, separately (for example: for Lebanon, "Lebanon AND microplastics", and "Lebanon AND nanoplastics") (Fig. 1). Only those pertaining to food products and drinking water were assessed. A summary of these results is presented in the summary table.

Fig. 2 and Table 1.

2.4. Analysis

No quality assessment of the studies was performed. Relevant data were extracted from each study to identify the types, sizes, shapes, and colors of NPs and MPs found in food and water across the Arab countries. The data were grouped and synthesized by country to highlight the regional trends and differences. Among the 30 identified studies, none assessed NPs as shown in the summary table.

3. Results and discussion

3.1. Lebanon

Recent studies in Lebanon have revealed alarming levels of microplastic contamination in commonly consumed items, such as table salt and bottled water. Tests detected high levels of up to 10,134 microplastic particles per liter in bottled water samples, with most particles measuring between 1 and 5 $^{\mu m}$ in size, small enough for the human body to absorb (Malak, 2021). Additionally, 81.3 % of salt brands tested were contaminated, leading to an estimated annual intake of 2372 microplastic particles per adult (Nakat et al., 2023). These findings indicate a concerning level of dietary exposure to MPs in Lebanon, likely due to inadequate waste management, marine pollution, and a lack of regulatory controls.

3.2. Kuwait

Recent research in Kuwait has confirmed the presence of microplastics in commercial marine fish species, raising concerns about dietary exposure through seafood. Polyethylene microplastics were identified in the digestive tract of three commonly consumed fish species: *Acanthopagrus latus, Lutjanus quinquelineatus*, and *Eleutheronema tetradactylum* (Al-Salem et al., 2020). The findings suggest that ingestion occurs via exposure to contaminated habitats, such as muddy lagoons, and as a result of net-fishing activities. Consistently, Saeed et al. (Saeed

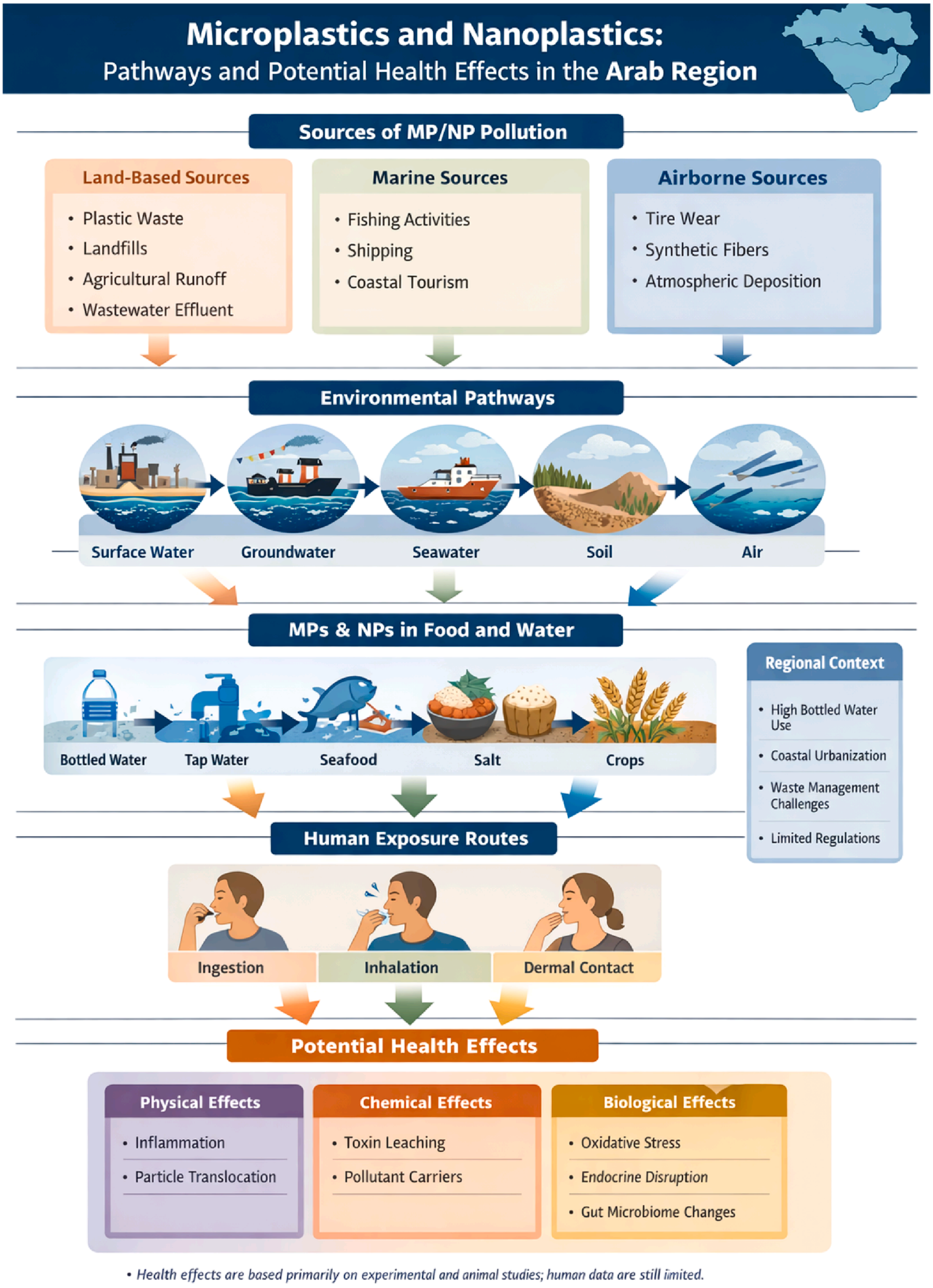

Fig. 1. Sources of MP/NP contamination, transmission routes to humans, and potential health effects.

et al., 2020) reported polyethylene microplastic particles in beach sediments and seawater across Kuwait, indicating widespread marine contamination. Both studies highlight a growing dietary exposure risk in Kuwait and emphasize the need for environmental monitoring and regulatory measures to address marine plastic pollution (Al-Salem et al., 2020; Saeed et al., 2020).

3.3. Oman

According to two studies conducted in the Northern Gulf of Oman, a

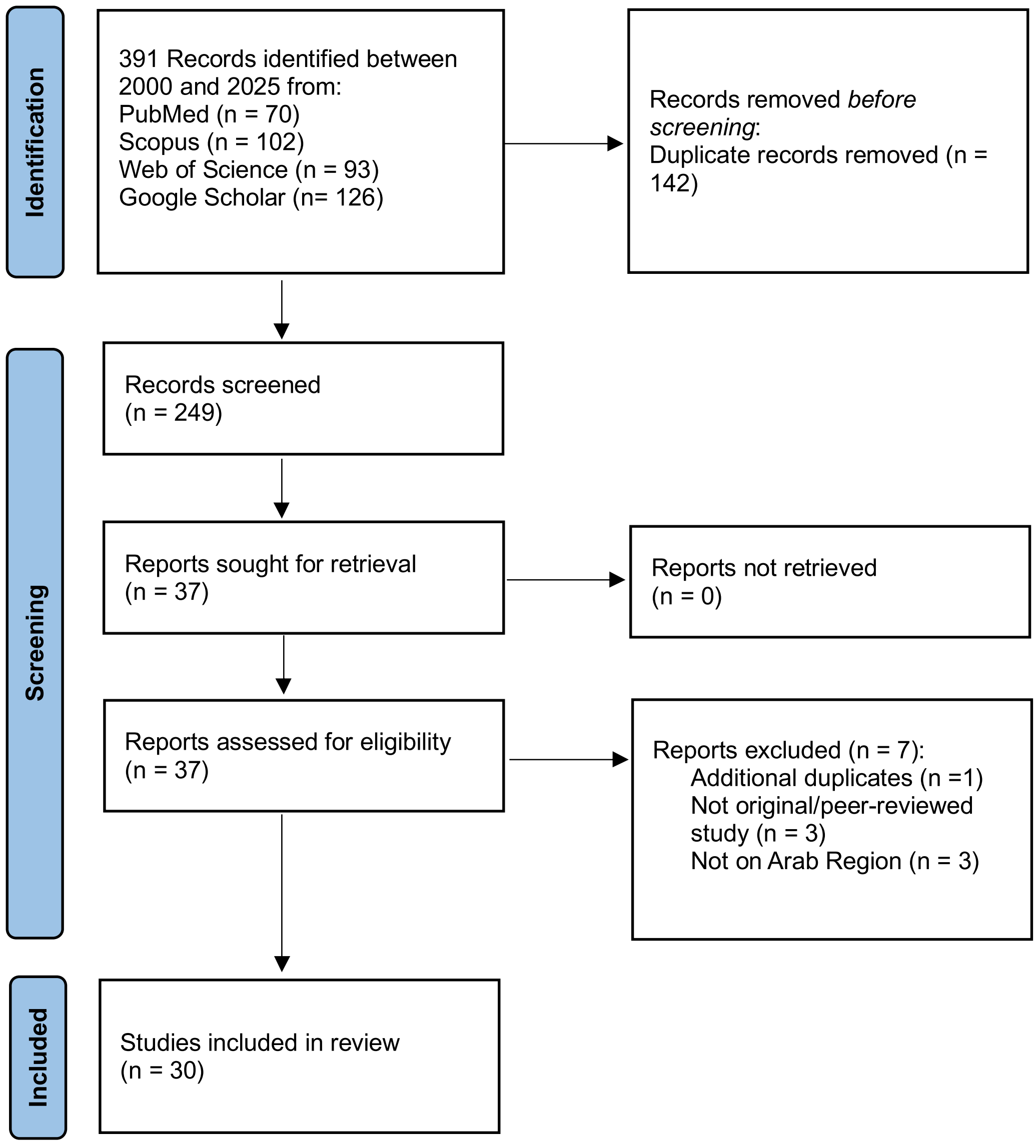

Fig. 2. Flowchart of study selection process.

significant presence of MPs in marine biota was revealed, suggesting that various habitats are widely contaminated. In the study focused on mangrove habitats, MPs were detected in finfish, crabs, and oysters, with crabs showing the highest prevalence (41.6 %). Contamination was slightly higher in planted mangroves, indicating links to human activity (Kor et al., 2023). The detected MPs were mainly fibers and fragments, composed primarily of polyethylene and polypropylene. In addition, Abbasi et al. (Abbasi et al., 2023) reported MPs in 100 % of two commercially important fish species- *Otolithes ruber* and *Acanthopagrus latus,* with ingestion rates reaching up to 43 particles per fish. Fibers dominated again, particularly in dark colors, and most MPs measured under 1 mm. Both studies indicate widespread MP pollution in Oman's coastal ecosystems, likely stemming from fishing, tourism, and urban waste.

3.4. Egypt

MPs are highly prevalent across different areas of Egypt, from the Red Sea to the Mediterranean Sea (Abd-Elkader et al., 2023; Hamed et al., 2023; Lourenço et al., 2017; Shabaka et al., 2020; Shobier et al., 2024). Studies conducted in fish markets, intertidal zones, and coastal waters confirm the widespread occurrence of MPs in all studied organisms, including fish, invertebrates, and shorebirds (Osman et al., 2023). These results highlight the consistent exposure to MPs across species or habitats, and mirror the global trend of MP infiltration into marine ecosystems (Tang et al., 2023). The dominant type of MP detected in marine environments was fiber, followed by fragments, indicating the majority of MPs originate from natural (linen, cotton, wool) and synthetic textiles (polyamide, polyester), released through wastewater from washing machines (Carney Almroth et al., 2018). In addition, the composition of MPs detected in marine environments often reflects the polymers used in plastic products. The frequent detection of polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET) polymers suggests common MP sources such as plastic packaging, water bottles, fishing gear, and personal care products (Li et al., 2023; Ramos et al., 2025). Also, the colors and sizes of MPs play an important role in understanding their environmental behavior, their sources of contamination and stages of plastic degradation, as well as the probability of ingestion by marine organisms. In Egypt, most detected MPs were larger than 500 µm, which are likely released from plastic products, car tires, and fishing gear (Osman et al., 2023). In addition, black and transparent were the dominant MP colors in the studied samples, which further proves that synthetic textiles and fishing gear are likely the sources of contamination (Santini et al., 2022). Black MPs are more

Table 1
Summary of studies on micro and nanoplastics from the Arab Region.

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
Zeina nakat, 2023	Lebanese market	the aims of this study were to assess the occurrence and exposure to microplastics through the consumption of edible salt available in Lebanon and to identify the types of plastic and other physical contaminants.	$n = 16$, salt samples	MPs	MP contamination was analyzed using Fourier Transform Infrared (FTIR) spectroscopy.	81.3 % of the assessed brands ($n = 16$), and 55 % of the total assessed samples ($n = 27$) were contaminated with microplastics	Range of MP MPs.kg−1 : 0–635 Average MP MPs. kg−1± STD: 159.6 ± 157.6	Microplastics detected in several salt samples in Lebanon, indicating contamination in food products. - 55.6 % of the total assessed samples ($n = 27$) were contaminated with microplastics while 100 % of the evaluated samples and their replicates ($n = 81$) were contaminated with either microplastics or other physical contaminants.	Limited sample size; only certain brands and regions were tested.
Hassan malak, 2021	Lebanon	This study aims at producing much needed data pertaining to the size, amount, and type of MPs	$n = 17$, salt samples	MPs	microplastic contamination was analyzed using Fourier Transform Infrared (FTIR) spectroscopy.	around 50 % of the total particles detected are plastics. the amount of MPs/L was 86.6 times greater than the study done by (Schymanski, Goldbeck, Humpf, & Fürst, 2017) that reported 118±88 MPs/L.	min= 14,835 particle/L to max= 26,673 particle/L with an average of 20,348 particles/L.	All plastic water bottles samples contained micro-particles	Sampling bias as the selection of brands may not represent all available products
Talat Saeed et al., 2022	Kuwait coastal areas	This study was undertaken to assess the severity of this problem in Kuwait.	$n = 87$, fish and mussels	MPs	Microplastics were characterized by Raman spectroscopy.	10 % of the total samples contained only one MP, while about 14 % had 2 MPs, with a single sample with 3 MPs. Four and five MPs were detected in 2 and 1 samples	0–3 particles/m3 with an average of 0.7 particle/m3.	First survey of microplastics in Kuwait's marine environment reveals significant contamination. The results of the sediment examination indicated that out of the 44 locations MPs were found on only 15 locations. The actual numbers of MPs in these 15 locations were quite low (Table 2). 10 % of the total samples contained only one MP, while about 14 % had 2 MPs, with a single sample with 3 MPs. Four and five MPs were detected in 2 and 1 samples, respectively. Raman spectroscopic analysis showed that	Study did not account for all possible sources of microplastic pollution in the region.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								polypropylene was present in 7 samples.	
S.M. Al-Salem et al., 2020	State of Kuwait (of the Arabian/ Persian Gulf)	Evidence of microplastics (MP) in gut content of major consumed marine fish species in Kuwait	$n = 8$ different fish species of market size, were acquired	MPs	the specimens were subjected to Micro Raman and Micro Fourier Infrared Spectroscopy (FTIR) in Attenuated Reflective Mode (ATR)	54 % of studied fish stomach contents contained MP		Microplastics found in the digestive tracts of commonly consumed fish species.	The study did not explore the sources of microplastics in fish or quantify their effects on fish health.
Kamalodin Kor et al., 2023	northern Gulf of Oman	The purpose of this study was to evaluate MP pollution in finfish and shellfish from two mangrove swamps (i. e., natural and planted) in the northern Gulf of Oman.	$n = 200$ Fish and crab	MPs	Extracted particles were assessed using a micro-Raman spectrometer	The highest MP prevalence was recorded in crabs (41.65 %) followed by fish (33.89 %) and oysters (20.8 %).	mean number of 230 and 214 MP particles/kg	Study reveals microplastic presence in finfish and shellfish in the Gulf of Oman.	Limited sampling in terms of species diversity and geographical location
Ali Abbasi et al., 2023	Oman Sea	characterization of microplastics in digestive tract of commercil fish species from the oman Sea	$n = 25$ of fish species, ruber and the tigertooth croaker and larus, the yellowfish seabream ($n = 20$)	MPs	Raman spectra analyses were performed using a confocal Raman microscope (HORIBA Scientific, France) with a 785 nm laser.	The results confirmed the ingestion of MPs by 100 % of these two commercially important fish species	tigertooth croaker: 25–106 with an average of 43.16 ± 8.23 MPs/Ind and 4.27 ± 1.34 MPs/g WW yellowfin seabream: 4–52, with an average of 29.9 ± 2.73 MPs/Ind and 2.10 ± 0.89 MPs/g WW	Commercial fish species in Oman contain microplastics in their digestive tracts.	Lack of long-term data on microplastic accumulation and the health implications for fish
Abidli et al., 2019	Northern Tunisia: the lagoon of Bizerte	To assess the occurrence, amount and typology of MPs in six commonly consumed mollusc species from the lagoon of Bizerte, and their risk for consumers of seafood.	Six economically valuable mollusc species (three commercial bivalves Mytilus galloprovincialis, Ruditapes decussatus and Crassostrea gigas, two gastropods Hexaplex trunculus and Bolinus brandaris and the cephalopod Sepia officinalis). Mytilus galloprovincialis: 3 replicates, 5 individuals used in pooled sample. Ruditapes decussatus: 3 replicates, 8 individuals used in pooled sample. Crassostrea gigas: 3 replicates, 1 individual used in pooled sample (each	MPs	The extraction method and analysis of MPs from all molluscs were based on H.X. Li et al. (2018): - Soft tissues were rinsed with bidistilled water. - Samples were placed in 1 L bottles with 200 mL of 10 % KOH and incubated at 65 °C, 80 rpm for 24 h. - Further digestion occurred at room temperature for 24–48 h if needed. - A 140 g/L NaCl solution was prepared and after digestion, 800 mL of filtered NaCl solution was added to float MPs while tissue settled at the bottom. - The overlying water was filtered after 24 h of flotation using a Millipore vacuum pump	Microplastics were detected in all six mollusc species.	Total concentration: 703.95±109.80 items kg−1 wet weight in Hexaplex trunculus and 1482.82±19.20 items kg−1 wet weight in Crasso streagigas. Mean concentration: 1031.10 ± 355.69 items kg−1 wet weight. Statistically significant differences were observed among the mollusc species, except between the bivalve species Ruditapes decussatus and Crassostrea gigas (THSD: $F = 2.23$, $P = 0.98$) and the group Mytilus galloprovincialis, Hexaplex trunculus, and Sepia officinalis (THSD: $F = 8.54$, $P = 0.4$).	Types, colours, sizes and polymers of microplastics in mollusc species: - Three types: fibres, fragments and films. Fibres were the most abundant type (91.30 %) followed by fragments (5.47 %) and films (3.23 %). - Seven diverse colours; the predominant colours are black > blue > clear > red > green white > yellow for fibres, blue > red > black > green for fragments and red > black > blue > clear > white for films. Predominant colours: black (56.18 %) followed by blue (18.45 %), red (10.79 %), clear (9.54 %), green (2.58 %), white (1.50 %) and yellow (0.96 %). - Sizes:	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
			individual was treated as a replicate). Hexaplex trunculus: 3 replicates, 3 individuals used in pooled sample. Bolinus brandaris: 3 replicates, 3 individuals used in pooled sample. Sepia officinalis: 3 replicates, 1 individual used in pooled sample (each digestive tract was treated as a replicate).		onto 1 μm Whatman GF/C filters (47 mm diameter). - Filters were dried overnight at room temperature and analyzed under a ZEISS KL1500 LCD stereomicroscope. - Images were captured using a Casio (14 MP) camera. - Contamination control was done. FTIR polymer identification: The characterization of plastic polymer particles was performed in a group of 30 MPs (10 fibres, 10 fragments, 10 films) using Fourier transform infrared spectroscopy in attenuated total reflectance mode (FTIR-ATR).			0.05–5 mm (0.05–0.1 mm, >0.1–1 mm, >1–5 mm). Average sizes ±SD for collected fibres: 1.09 ± 0.31 mm, fragments: 0.21 ± 0.15 mm, and films: 0.5 ± 0.68 mm. Size class 0.1–1mm: most abundant, 55.93 % in Mytilus galloprovincialis, 96.55 % in Bolinus brandaris. - Two polymer types: poly propylene (PP, 70 %) and polyethylene (PE, 30 %). Fibres: PP polymer. Fragments: 60 % PP polymer and 40 % PE polymer. Films: 50 % PE polymer and 50 % PP polymer. Dietary intake of microplastics via mollusc consumption: - Mean quantity of molluscs consumption among the Tunisian population: 80 g/person/year, among fishermen and shellfish harvesters from Bizerte: 9000 g/person/year. - Annual MP dietary intake per capita by the Tunisian population: Mytilus galloprovincialis: 24.50 items/person/year Ruditapes decussatus: 43.73 items/person/year Crassostrea gigas: 40.33 items/person/year Hexaplex trunculus: 27.59 items/person/year Bolinus brandaris: 22.73 items/person/year - Annual MP dietary intake per capita by fishermen and shellfish harvesters from Bizerte: Mytilus	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								galloprovincialis: 2756.76 items/person/ year Ruditapes decussatus: 4919.83 items/person/year Crassostrea gigas: 4537.44 items/person/ year Hexaplex trunculus: 3104.45 items/person/year Bolinus brandaris: 2557.67 items/person/ year	
Belgacem et al., 2025	Northern Tunisia: the Sejenane Stream	To assess the level of MP contamination in three fresh water mussel species of similar average size, found in northern Tunisia: Unio ravoisieri, Unio gibbus, and Unio durieui. To determine the accumulation and size distribution of MPs in specific tissues, particularly the gills and digestive gland.	Three fresh water mussel species: Unio ravoisieri, Unio gibbus, and Unio durieui. 24 individuals (8 individuals per species).	MPs	Following the methodology described by Phuong et al. (2018) and Zitouni et al. (2020), a two-step filtration process was used to isolate MPs from Unio spp. species. Tissues from eight mussels were pooled and weighed, and then each pool was digested separately in a 10 % potassium hydroxide solution (KOH 10 %; density: 2.044 g/cm3; molarity: 1.8 M,). The digestion process involved heating at 60 °C under continuous agitation for 24hr. The digested solution was then transferred into a separation funnel (250 ml) for 4hr at room temperature. Subsequently, the second separation step involved the recovery of dense MPs with 50 % potassium iodide solution KI (density: 1.55 g cm-3). The retained solutions were filtered on cellulose nitrate filters (diameter = 47 mm, Healthcare GE Life Science, UK) with pore sizes of 3 µm,	Total concentrations observed in each sample indicated a relative similarity across all three species. Average abundance in the digestive gland: 9 ± 1.80–11.5±.5 items/g wet weight tissue. Mean abundance in gills: 8.33 ±1.52–13±2.64 items/ g wet weight tissue. Unio ravasoiri: highest abundance (average uptake of 13±2.64 items/g wet weight tissue). Unio gibbus: lowest abundance (8.33 ±1.52 items/g wet wt tissue).	Size distribution of MPs in tissues: - Three size categories: S1 (<1.2–.45 µm), S2 (<3–1.2 µm), and S3 (≥3 µm). - Digestive gland: S1 (<1.2–.45 µm) predominant, followed by S2 (<3–1.2 µm) and S3 (≥3 µm). Over 50 % of the S1 class in Unio gibbus. - Gills: S3 (≥3 µm) predominant. Over 60 % of the S3 class in Unio durieui, followed by S2 (<3–1.2 µm) and S1 (<1.2–.45 µm). Shape of MPs: - Two shapes: fragments and filaments (fibers). - Predominant in both organs: fragments (69.4 %), followed by filaments (fiber; 20 %). Chemical composition of MPs: - Six polymer types: polyethylene terephthalate (PET), polyethylene-vinyl-acetate, low-density polyethylene, polyethylene, high-density polyethylene, and polypropylene. - Predominant: PET (up to 59.37 %), then polypropylene, polyethylene, and polyethylene-vinyl-		

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					1.2 μm, and 0.45 μm. Finally, the filtered samples were transferred into a glass petri dish for further analysis. Precautions were carefully applied during sample processing to minimize airborne contamination. Raman microspectroscopy μRaman (Xplora, HORIBA, Scientific, UK) and microscopy was used to examine and identify microparticles with size ranges under 5000 μm.		acetate. - In Unio dureui, PET predominant in both the digestive gland (up to 55 %) and the gills (up to 59 %).		
Ben Hassine et al., 2024	Northern coast of Tunisia: Tabarka, Bizerte, La Goulette, and Kelibia	To extend the examination of MPs in Tunisia's most-consumed fish species, Sardina pilchardus, collected from the northern coast at Tabarka, Bizerte, La Goulette, and Kelibia and to investigate the presence, quantity, and typology of MPs in two organs of the sardine: the digestive tract and gills.	40 adult Sardina pilchardus specimens purchased from local fishermen (10 specimens per sampling site).	MPs	The extraction method and analysis of MPs from all fishes were based on Li et al. (2018): - Digestive tracts and gills were removed and placed in an opaque glass falcon. - Two-thirds of the falcon's volume was filled with 10 % KOH solution. - Digestion occurred at room temperature for 48 h. - A 140 g/L NaCl solution was prepared and after digestion, 1 L of filtered NaCl solution was added to float MPs while tissue settled at the bottom. - The overlying water was filtered after 24 h of flotation using a Millipore vacuum pump onto 0.22 μm Whatman GF/C filters (47 mm diameter). - Filters were dried and analyzed under a ZEISS KL1500 LCD stereomicroscope. - Contamination control was done. Control	Majority accumulate MPs in their tissues (digestive tracts + gills). 37/40 (92.5 %) in digestive tracts, and 29/40 (72.5 %) in gills.	Highest concentration in coast of Bizerte, total concentration: 5.86 ± 3.39 items/individual in the digestive tract and 4.00 ± 3.67 items/individual in the gills. Then Kelibia, concentrations: 4.43 ± 3.55 items/individual (digestive tract) and 2.21 ± 1.69 items/individual (gills). Then La Goulette, concentrations: 3.6 ± 2.37 items/individual (digestive tract) and 1.1 ± 1.45 items/individual (gills). Tabarka lowest concentrations, 1.1 ± 0.99 items/individual in the digestive tract and 1.2 ± 2.25 items/individual in the gills. The comparison of MPs concentration (the total MPs found in the gills and digestive tract of each individual) between sites showed statistically significant differences between Tabarka and Bizerte	Types of microplastics: - Types: fibres, fragments, and films. Fibres: most prevalent. Among the 117 MPs detected in the digestive tract: fibres 81.20 %, fragments 16.24 %, and films 2.56 %. Among the 90 MPs detected in the gills: fibres 53.33 %, fragments 38.89 %, and films 7.78 %. - All 3 types found in Tabarka, La Goulette, and Kelibia. Only fibres and fragments at the Bizerte stations. Microplastic colors: - Colors: black, clear, blue, red, green, and white. - Fibres: four colors in the digestive tract black > clear > blue > red, five colors in the gills black > blue > clear > red > green. Predominant: black clear blue - Fragments: four colors in the digestive tract and gills, red > blue > black > green. - Films: two	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					dishes showed an average of two fibres per blank (range: 0–3). To account for atmospheric contamination, two fibres were subtracted from each fish's MP count.		(THSD: $F = 1.55$, $P = 0.0002$), Tabarka and Kelibia (THSD: $F = 1.55$, $P = 0.02$), and Bizerte and La Goulette (THSD: $F = 1.55$, $P = 0.009$). Statistical analysis demonstrated significant differences in MP concentrations between the digestive tract (THSD: $F = 3.43$, $P = 0.004$) and gills (THSD: $F = 0.25$, $P = 0.018$) of sardines collected from Tabarka and Bizerte, as well as in the gills of sardines collected from Bizerte and La Goulette (THSD: $F = 0.25$, $P = 0.013$). Between the two tissues within each site, despite a slight increase in MPs in the digestive tract compared to the gills (excluding Tabarka), a significant difference was observed only in the fish collected from La Goulette (THSD: $F = 4.08$, $P = 0.01$).	colors in the digestive tract clear > red, and in the gills red > white. Microplastic sizes: - Sizes: 0.033–5 mm (0.033mm-0.5 mm; >0.5mm-1 mm; >1mm-3 mm; >3mm-5 mm). Predominant <0.5 - Digestive tract: size class 0.033–0.5 mm predominant (42.85–73.17 %), >0.5mm-1 mm (12.19–33.93 %), >1mm-3 mm (13.04–17.85 %), >3mm-5 mm (exclusively observed in Kelibia 4.35 % and La Goulette 5.36 %). - Gills: size class: 0.033–0.5 mm predominant (44.83–87.09 %), then >0.5mm-1 mm (4.83–33.33 %), >1mm-3 mm (8.06–31.03 %), >3mm-5 mm was missing.	
Belgacem et al., 2025	Northern Tunisia: the Sejenane Stream	To assess the level of MP contamination in three fresh water mussel species of similar average size, found in northern Tunisia: Unio ravoisieri, Unio gibbus, and Unio durieui. To determine the accumulation and size distribution of MPs in specific tissues, particularly the gills and digestive gland.	Three fresh water mussel species: Unio ravoisieri, Unio gibbus, and Unio durieui. 24 individuals (8 individuals per species).	MPs	Following the methodology described by Phuong et al. (2018) and Zitouni et al. (2020), a two-step filtration process was used to isolate MPs from Unio spp. species. Tissues from eight mussels were pooled and weighed, and then each pool was digested separately in a 10 % potassium hydroxide solution (KOH 10 %; density: 2.044 g/cm3; molarity: 1.8 M,). The digestion process involved heating at 60 °C under continuous agitation for 24hr. The		Total concentrations observed in each sample indicated a relative similarity across all three species. Average abundance in the digestive gland: 9 ± 1.80–11.5±.5 items/g wet weight tissue. Mean abundance in gills: 8.33 ±1.52–13±2.64 items/g wet weight tissue. Unio ravasoiri: highest abundance (average uptake of 13±2.64 items/g wet weight tissue). Unio gibbus: lowest abundance (8.33 ±1.52 items/g wet wt tissue).	Size distribution of MPs in tissues: - Three size categories: S1 (<1.2–.45 μm), S2 (<3–1.2 μm), and S3 (≥3 μm). - Digestive gland: S1 (<1.2–.45 μm) predominant, followed by S2 (<3–1.2 μm) and S3 (≥3 μm). Over 50 % of the S1 class in Unio gibbus. - Gills: S3 (≥3 μm) predominant. Over 60 % of the S3 class in Unio durieui, followed by S2 (<3–1.2 μm) and S1 (<1.2–.45 μm). Shape of MPs: - Two shapes: fragments and filaments (fibers). -	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					digested solution was then transferred into a separation funnel (250 ml) for 4hr at room temperature. Subsequently, the second separation step involved the recovery of dense MPs with 50 % potassium iodide solution KI (density: 1.55 g cm-3). The retained solutions were filtered on cellulose nitrate filters (diameter = 47 mm, Healthcare GE Life Science, UK) with pore sizes of 3 μm, 1.2 μm, and 0.45 μm. Finally, the filtered samples were transferred into a glass petri dish for further analysis. Precautions were carefully applied during sample processing to minimize airborne contamination. Raman microspectroscopy μRaman (Xplora, HORIBA, Scientific, UK) and microscopy was used to examine and identify microparticles with size ranges under 5000 μm.			Predominant in both organs: fragments (69.4 %), followed by filaments (fiber; 20 %). Chemical composition of MPs: - Six polymer types: polyethylene terephthalate (PET), polyethylene-vinyl-acetate, low-density polyethylene, polyethylene, high-density polyethylene, and polypropylene. - Predominant: PET (up to 59.37 %), then polypropylene, polyethylene, and polyethylene-vinyl-acetate. - In Unio dureui, PET predominant in both the digestive gland (up to 55 %) and the gills (up to 59 %).	
Zitouni et al., 2020	Six sites along the Tunisian coast: Bizerte Beach (BB), Bizerte channel (BC), Hergla (H), Chott-Mariem (CM), coastal area of the city of Monastir (M), and Sfax (S)	Identify the possible presence and size distribution of small MPs in the gastrointestinal tract and muscle of the painted comber from six different sites along the Tunisian coast and assess the potential ecotoxicological risk they pose to this species. Evaluate a battery of biomarkers commonly used to	Adults Serranus scriba (L.1758) were sampled. 20 pools (made of 2 fishes each) per site of each tissue.	MPs	Tissues digestion and MP isolation: The MP extractions from painted comber tissues were performed as described by Phuong et al. (2018). Approximately, based on the weight of tissues, each pool of 5 tissue were placed into clean 250 ml glass bottles and digested separately in 10 % potassium hydroxide solution	MPs were found in every replicated tissue sample from all sampling sites (100 %).	Average abundance in the GI tract: 3.63 ±0.35–6.11±0.48 items/g of tissue. Highest abundance: in Hergla (6.11±0.48 items/g of tissue), followed by BC (5.27 ±0.33 items/g of tissue) and M (4.93±0.4items/g of tissue). Lowest abundance: in CM (3.63 ±0.35 items/g of tissue). Average abundance in muscle: 1.78±0.26–6.03	Size distribution of MPs in tissues: - Three size classes: ≥ 3 μm (T3), <3–1.2 μm (T2), and < 1.2–0.45 μm (T1). - >30 % of T3 and 40 % of T2 size classes in the GI tract, and the H site contained MPs with a significantly larger diameter. - T1 size class (∼60 %) more frequent in the muscle. And T2 Shape: Majority were fragments. Chemical	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
		screen oxidative stress, neurotoxicity, and biotransformation in the gastrointestinal tract tissue. Shed light on the possible interaction between small particles and fish tissue alterations using a correlation matrix and principal component analysis (PCA).			(KOH 10 %; molarity: 1.8 M, density: 2.044 g/cm3) with a heating time (60 C) of 24 h under agitation. The use of a volume of 50 ml of KOH per gram of tissue was chosen according to Dehaut et al. (2016). For each replicate, the content obtained after the digestion step was transferred to a 250 ml funnel in order to remove and separate the floating particles (polyethylene (PE), polypropylene (PP)) from the denser (especially sand, poly-vinyl-chloride (PVC) and polyethylene terephthalate (PET)). After 4 h, a sedimentation step, using a 50 % potassium iodide (KI 50 %; density: 1.55 g cm-3) solution was then required to separate the dense MPs from the mineral particles. The resulting solution was filtered through three Whatman cellulose nitrate filters with pore diameters of 3 mm, 1.2 mm and 0.45 mm successively (filters Diameter = 47 mm, Healthcare Life Science, UK). Thus, MPs were placed within a closed glass Petri dish and identified directly on the filter by Raman microspectroscopy (Xplora® Raman spectrometer from Horiba provided with a fully automatic high sensitivity Raman		±0.47 items/g of fish tissue. Highest abundance: in BB (average of 6.03±0.47 items/g of tissue). Lowest abundance: in CM (mean 1.78±0.26 items/g of tissue).	composition of MPs: - Types: polyethylene-vinyl acetate (PEVA), high-density polyethylene (HD-PE), low-density polyethylene (LD-PE), polyamide derivatives (PA) or nylons (11), and poly (ethylene-co-methyl acrylate) (PEMA). - Plastic polymer additives: 1-tetradecanol, IGEPAL® Co-890, p-Methyl-Laurate, and ivory black. A-C® 617 A, Advalube® B-3202, and Besno® 20 TL were found as polyethylene photopolymer-wax, PVC (poly-vinyl-chloride) pipes, and polyamide. - PEVA: most common (up to 33.45 %), followed by HD-PE (17.33 %) and polyamide (16.18 %). Various MP types were generally found in the BC. Biochemical assessment in the gastrointestinal tract of fish: - CAT activity: significant difference between sites; highest from BB (up to 535.4 ± 68.9 mmol min 1 mg 1 of protein) and then BC (up to 386.5 ± 45.5 mmol min 1 mg 1 of protein). Low from Sfax (S): 86.9 ± 16.3 mmol min 1 mg 1 of protein. Negative correlation with T3 size class (r ¼ 0.2, $P < 0.05$). - GST activity: response profile similar to the CAT activity at the different sampling sites, except from H (activity	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					confocal microscope with a spatial resolution <1 mm). Precautions were carefully applied during sample processing to minimize airborne contamination. Biochemical analyses: To assess the toxic effects of plastic particles on Serranus scriba, the study focused on biochemical analyses associated with cellular toxicity in the GI tract. Examined: Metallothionein (MTs) content (by a spectrophotometric method), antioxidant enzyme activities of catalase (CAT), the detoxification enzyme activity of glutathione-S-transferase (GST), malondialdehyde accumulation levels (MDA), and acetylcholinesterase (AChE). The total protein concentration in GI fractions was quantified according to Bradford (1976) using Coomassie Blue reagent.			was significantly increased with 262.4 ± 57.3 mmol min 1 mg 1 of protein). Positive correlation with MT levels (r ¼ 0.5, $P <$ 0.05). - Lipid peroxidation (MDA accumulation): not significantly different between the sampling sites except from BC (highest level with 2.4 ± 0.5 mmol mg 1 of protein). Positive correlation with T2 MPs (r ¼ 0.8, $P < 0.05$) and AChE activity (r ¼ 0.72, $P < 0.05$). - AChE activity: not significantly different among the sampling sites except from BC and BB where it was significantly higher (227.8 ± 76.4 and 199.1 ± 88.8 mmol min 1 mg 1 of protein, respectively). Negative correlation with T3 MPs (r ¼ 0.4, $P < 0.05$). Significant negative correlation with T1 size class MP. - MT levels: significantly higher from H (51.1 ± 12.8 µgmg 1ofprotein), CM (44.9 ± 8.7mgmg 1ofprotein), and BC (43.2 ± 8.8 mgmg 1 of protein) than in those caught in S (24.6 ± 3.8 mgmg 1 of protein). - The PCA indicated a clear separation between the six selected sites and the MP size classes associated with biomarker responses, and the biomarkers also revealed that two axes explain over 65 % of	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								total variance in the data matrix. The first axis (40.27 %) was mainly influenced by GST, MDA accumulation, MT levels, T1, and T2, while CAT, AChE, and T3 mainly comprised the second axis (25.08 %). There is a clear separation of BC and H from the other sites. GI tracts of fish caught from BC were mainly characterized by high activity of CAT, MDA, and AChE biomarkers, which is correlated with the T2 size class MP ingested. H was characterized by high GST activity and MT levels, which correlates with the T3 size class of MP ingested.	
Hassen et al., 2023	The beach above the waterline in the Gulf of Gabes on the Zarat coast (the southeast coast of Tunisia)	To determine the abundance, identity, and composition of microplastics in the Gulf of Gabes (the southern Mediterranean side of Tunisia) by using PO litter and PO sea balls, by stereomicroscopy and NMR spectroscopy, and with two different protocols of extraction.	*Posidonia oceanica* sea balls (egagropili (EG)) and lost leaves of PO (500–1000 g). Eight samples of EGs. For the loose leaves of the PO, four samples of 100 g were taken.	MPs	The preparation of EG and PO loose leaf samples followed a modified version of Sanchez-Vidal et al. (2021). The samples were dried at room temperature (25 °C) for 10 days. EG samples were weighed, measured, disentangled, and sieved at 5 mm, 0.36 mm, and 0.2 mm, while PO samples (100 g each) were similarly disentangled. For EGs, two extraction protocols were used. For the first series, glass Petri dishes were solubilized by adding 4–6 ml of 30 % hydrogen peroxide (H2O2) and oven-dried at 60 °C for 12 h. This	PO loose leaf extract: no microplastic traces in the four samples under magnification (×2; ×5). EG: plastic debris found in 14/16 samples tested on stereomicroscopes under (×2; ×5) magnification.		Three size categories: macroplastics (>25 mm), mesoplastics (5–25 mm), and microplastics (1 μm–5 mm). Biometric parameters: - PO loose leaves samples: total length of the plant 53–60 cm, average 56.375, standard deviation 2.77 cm. - EGs: total weight of a ball 12.85–15.18 g, average weight 12.55 g, standard deviation 3.23. - Axis 1 and axis 2 varied between 4 and 6 cm, with an average length of 5125 cm and a standard deviation of 0.739, and between 2 and 4.5 cm, with an average length of 3.25 cm and a standard deviation of 0.9,	Technology employed

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					process was repeated until no more organic matter remained in the sample, so the plastics were observed and extracted. For the second series, H2O2 (30 %) and hydrogen chloride (HCl) 10 % were added to remove most of the organic matter and calcium carbonate and were oven-dried at 50 °C for >24 h. PO samples were treated with 30 % H_2O_2, 10 % HCl, and 10 % KOH, then oven-dried at 50 °C and sieved at 1.25 mm, 1 mm, and 0.63 mm. Plastic particles were extracted using tweezers and examined under a Leica M60 stereomicroscope (Leica Microsystems AG, Glattbrugg, Switzerland). Nuclear Magnetic Resonance (NMR) spectroscopy was conducted on four PO samples using a Bruker Avance AV-500 spectrometer (Bruker Group, Fällanden, Switzerland) in DMSO to determine polymer structures. Infrared (IR) spectra were recorded with a Bruker Vertex 70v (Bruker, Germany), for additional chemical characterization.			respectively. Microplastic analysis by stereomicroscope: - Pellets (68.8 %; $n = 11$ items/16 samples), fragments (6.3 %; $n = 1$ item/16 samples), and threads (6.3 %; $n = 1$ item/16 samples) of different sizes and were intertwined in 87.5 % of the EGs examined. - Colors: blue (46.2 %) and black (23.1 %). - The first series of EGs were solubilized by using 30 % hydrogen peroxide (H2O2), and the microplastic items found comprised pellets ($n = 8$) and thread ($n = 1$) in only four samples tested, with blue (five pellets and one thread) and black (three pellets) colors. For the second series, EGs were solubilized at 30 % H2O2 and 10 % hydrogen chloride (HCl), and the microplastic items found comprised pellets ($n = 3$) and fragments ($n = 1$) on the four samples tested, with blue (two pellets), black (one pellet), and pink (one fragment) colors. Microplastic analysis by NMR spectroscopy: - Characteristic peaks of plastic polymers that vary slightly from one to another from the four PO loose leaf extract samples (S1–S4). - Protons of the polystyrene (PS) aromatic group: appear in a single peak at ≈1.13 ppm, other	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								polymer protons: appear at a peak at ≈1.56 ppm and a peak at ≈3.55 ppm. - Protons of bis(2-ethylhexyl) phthalate (DEHP): appear in two low-intensity peaks at ≈6.2 ppm and 7.54 ppm. This shows their reliable concentration in the samples and that it can be classified as a trace element. - Last peak: represents one proton of the polyethylene polymer (PE) aromatic groups at ≈8.4 ppm. For S2, background noise hides behind the third peak of polystyrene (PS).	
Djekoun et al. (2024)	•Eastern Algerian coastline: 3 sampling sites along the coast of Annaba city°Ain Achir:unexposed to pollution sources and relatively remote°Saint-cloud: receives untreated urban discharges and rainwater runoff°Sidi Salem: in an industrial zone, receives discharge waters from anthropogenic effluents and Asmidal complex	To assess the ability of investigated organisms (fish and mussels) to serve as enviormental vectors of MP	• *Commodity: 3 edible wild fish species (Liza aurata, Sparus aurata, and Sarpa salpa) and mussels (Mytilus galloprovincialis).* • *Sample size: 80 specimens per sampeling site (20 specimens for each of the 4 species studied) = Total 240 specimens*	MP	MP's chemical composition of the isolated MP was determined using Raman microspectroscopy (RMS), based on a spectral matching with a similarity of ≥70 % and comparison with other refrence spectra.	Found in all investigated organisms (100 %)	•Lowest MPs concentration in all organisms selected is from Ain Achir station. •Highest MPs concentration: in all organisms selected from Sidi Salem station •Overall mussels tissues showed lower MP concentration compared to all studied fishes	• MP sizes range between 0.45 μm and 1.22 μm.° The highest number of large-sized MP particles (>3 μm) was found in Sarpa salpa (fish) compared to other species, and the highest number of small-sized MP particles (0.45–1 μm) was detected in Mytilus galloprovincialis (mussels) compared to other fish. •Six polymer types were identified: polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polyethylene-vinyl acetate (PEVA), high-density polyethylene (HDPE), and low-density polyethylene (LDPE).° Dominant polymer type is PE (34.77 %) •MP colors :12 colors were detected. The most	•Various analytical methods used across studies made comparison difficult. •The link between MP contamination in fish and environmental concentration can not be made •The extent of human exposure to MP particles in edible fish tissues is not known.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								prominent ones are black or transparent, followed by red and blue, in all fish species except Red Mullet.° Fish were more contaminated with transparent MPs than bivalves. •In fish: 57.81 % of MP were detected in the digestive tracts, 21.03 % and 21.15 % were found respectively in the liver and muscles tissues. •In mussels: highest number of MPs was found in soft tissues	
Saad and Alamin (2023))	Sudan, khartoum	To assess the presence and characteristics of MP in Nile Tilapia fish	*30 Nile Tilapia fish (Oreochromis niloticus) bought from Al-Mawrada fish market along the River Nile in Omdurman, Khartoum, in (Aug 2021).*	MP	•Physical examination/ measurments/ observations: Stereomicroscopy •MP's surface texture: Scanning electron microscopy (SEM) •To identify MP's polymer types: Raman spectroscopy	100 %	•Mean abundance: 72.02 ± 62.06 particles/ kg •Mean intensity: 18.90 ± 9.17 MPs/fish •Minimum: 5 MPs/fish •Maximum: 47 MPs/fish	•MPs abundance: ranged between 04.33 to 236.84 particles/Kg° Total of 567 particles identified as MP°Significant negative correlation between fish size and MP abundance: Higher MP contamination in smaller fish •MPs sizes: ranged between 0.04 to 4.94 mm •Shapes: Fibers (85 %), fragments (9.5 %), films (4.6 %), foams (0.35 %), and pellets (0.35 %) •Colors: Green (26.63 %), black (18.69 %), blue (14.29 %) and transparent MPs (16.40 %) ° Coloured, small sized (<1 mm) and fibrous shaped MP were the most prominent •Two polymer types: high-density polyethylene (HDPE) and polypropylene (PP) •Surface examination detected signs of fragmentation (pits, pores and cracks) •Potential MP sources: domestic discharge,	Due to the lack of data on MPs contaminations of the Nile river, innacurate association can be made between the ingestion of MP by Tilapia to the actual abundance of MP in the Nile river. Taking into consideration biotic factors (such as feeding habits) and the shape of MPs which may influence the fish's prey perception

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								recreational activities, wastewater effluent (from poor waste management practices)	
Al Salem et al. (2020)	Countries reviewed are in the Persian/ Arabian gulf region (Iran, Oman, Qatar, Kuwait)	Summarize the available data on MP	*Sediments, seawater and biota*	MP	N/A	Varied across studies	N/A	•Saeed et al. (2020) : Found 37 particles in sediment samples and 3 particles in the gut content of Orange-spotted grouper (kuwait) •Akhbarizadeh et al. (2018) found 5.66 ± 1.69 to 18.50 ± 4.55 MP particles/ 10 g of fish muscles in Iran •Abayomi et al. (2017) found MP abundance 4.38×104 to 1.46×106 particles.km offshore of Eighty beaches and four surface stations(Qatar eastern coast) •Higher abundance of MP contamination on Iranian shores •Most common identified polymer types are polypropylene (PP) and polyethylene (PE) •MP contaminate various marine organisms (Possible trophic transfer)	•Inconsistency in standardized sampling/ identification method, and reporting unit •Primary sources of MP are not well determined •Lack of data/ understanding on MP contamination in marine organisms, movements, and degradation rates of microplastics across different environments
Uddin et al. (2020)	Countries reviewed are in the Persian/ Arabian gulf region (kuwait, Qatar, Iran,UAE)	Summarizes multiple studies conducted to assess the abundance, presence, distribution, characteristics of MP in seawaters, sediments and biota	*•Seawater: Sample sizes varied, sampling was done using plankton/ neuston nets with varying dimensions and mesh sizes. •Sediments:◦Samples per location varied (ranging from one to multiple replicates across various studies/ sites). ◦Collected from beaches / intertidal zones using frames of different depths and sizes. •Biota:◦Sample sizes varied◦Includes diverse fish species,*	MP	N/A	Varied across studies.	N/A	•MP concentration varies across the Gulf region, with the highest reported on the Iranian coast. •MP concentrations are higher in areas near industrial activities, wastewater treatment plants, and low-energy depositional environments. •Types of MPs: Fibers, fragments, PE, PP, nylon, PET, and PS. •Most MPs, except for LDPE and PP, are denser than the Gulf's	•Different methodologies: Sampling techniques, identification methods. •Different data reporting units:◦In seawater, particles per cubic meter ($m-3$) and particles per square meter ($m-2$).◦ In sediments, particles per gram ($g-1$) and particles per square meter ($m-2$).◦In biota, the number of particles per sample and particles per gram ($g-1$) of tissue.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
			molluscs (mussels, gastropods, clams), shrimp. °Collected from markets or trawling.					water; they sink and accumulate in the sediments.°Biofouling increases MP's density, causing them to sink into the sediments.°The settling velocity of MP depends on its size, shape, and material °Denser polymers such as PET, PVC, polyester, nylon, etc., settle rapidly into the sediments and are found in marine organisms. °KI solution is better used as a separation method for higher-density plastics than NaCl solutions	•Human error when relying on visual examination (bio-fouled particles/ degraded may be discarded as non-plastic debris) •Efficacy of density separation using NaCl: NaCl solution has a density of 1.2 g cm−3, which is lower than the density of many MP polymers reported. •A limited number of MP particles are identified using spectroscopy due to sample size requirements. •Limited studies/data on MP concentration in the terrestrial environment
R.Z. Habib et al. (2022)	United Arab Emirates (UAE) and Kuwait	•To investigate MP contamination in fish and chicken meat bought from Kuwait and UAE markets •To determine the MP contamination source •To study the effect of food prepartion on MP and analyze the mechanical properties of plastic cutting boards (possible MP source)	• *6 chicken samples (one from Kuwait and 5 from UAE) each sample was analyzed in triplicates. •7 cut fish (One from Kuwait and six from UAE)°6 samples were analyzed in triplicate° 1 King mackerel sample was used to assess the effect of washing and grilling on MP content (analyzed in triplicate)*	MP	•Digestion: MP were isolated using aqueous potassium hydroxide (KOH), dichloromethane (CH_2Cl_2) and chloroform ($CHCl_3$, Aldrich) were used without purification. •Filtration: using filter paper •Microscopic analysis: To count, identify and determine the shape and size of MP •Fourier Transform Infrared (FT-IR) spectroscopy:to identify the MP's polymer composition	•Chicken: 100 %, all 6 samples •Fish: 5 from UAE and 1 from Kuwait (6 out of 7)	•Chicken:°Maximum number (1.19 ± 0.72 particles)°Minimum number(0.03 ± 0.04 particles)°Highest mass (0.29 ± 0.25 mg/g meat)° Lowest mass (0.01 ± 0.02 mg/g meat) •Fish:°Maximum number (2.60 ± 2.80 particles/g fish)°Highest mass (2.47 ± 0.4 mg/g in King mackerel fish)° Average weight of MP in all fish is 0.0942 ± 0.1 mg/g fish.	°Samples cut on a wooden bamboo board were not contaminated with MP. •Chicken: °Average MP size 104.2 ± 84.33 µm,°MP sizes ranging from 8.24 to 1454.5 µm. ° Contamination level ranged from 0.03 ± 0.04 to 1.19 ± 0.72 particles per gram of meat in chicken • Fish:° Average MP size 129.1 ± 138.2 µm°MP sizes ranging from 15.6 to 1151.1 µm. °Contamination level: 0.014 ± 0.024 to 2.60 ± 2.80 particles per gram in fish°Washing King mackerel fish: reduced MP concentration from 1.17 ± 0.57 MP/g to 0.03 ± 0.03 MP/g, but did not eleminate all MP.°Grilling King mackerel: caused MP to	Not mentioned

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								change shape into spherical bubbles after melting and partially fusing. Average MP size of grilled fish (316.7 ± 116.4 μm) compared to the average MP size in fish before grilling (192.0 ± 89.1 μm)° When cutting 1 kg of king Mackerel : 2.47 g of plastic will be found in wastewaters, compared to 33 mg MP released from washing with a MP containing rinse - off cosmetic •Plastic cutting boards are made of low-density polythene (LDPE), with a melting temperature below 115 °C and density below 1 g/cm3. •Sources of MP contamination: polythene-based plastic cutting boards, match the color and polymer types of detected MP. •50 % of MP generated from cutting, persist on the cutting board and are lost in wastewater after washing the cutting boards	
R.Z. Habib et al. 2022	United Arab Emirates (UAE)	•To investigate if plastic cutting boards are a source of MP contamination in meat •To study the effect of washing, cooking, and frying on MP content in meat.	*Total of 9 cut meat samples (8 samples purchased and 1 scrapped off at the end of the working day) available, from butcher shops and supermarkets in the Middle East*	MP	•Digestion: MP were isolated using aqueous potassium hydroxide (KOH) •Filtration: filter paper •Microscopic analysis: To count, identify and determine the shape and size of MP •Fourier Transform Infrared (FT-IR) spectroscopy: To identify MP's polymer composition •Differential Scanning Calorimetry (DSC) and density measurements : Characterize the	7 out of 9 samples are positive	•Maximum number of MP: 68.9 ± 12.1 MP/g (scrapped off meat) •Minimum number of MP: 0.07 MP/g (washed goat meat) •Maximum weight of MP: 220.4 ± 50.1 mg MP/g)scrapped off meat) •Minimum weight of MP: 0.07 ± 0.05 mg MP/g (washed goat meat)	•MP sizes:°Ranges between 14.8 μm to 13,089.8 μm°Mean average size of 1279.2 ± 835.0 μm° 35 % of plastic particles had a size < 500 μm°0.7 % of particles extracted had a size larger than 5000 μm •Plastic cutting boards made of polythene are source of MP •Number of MP particles meat cooked in a pressure cooker (7.2 ± 4.5 MP/g) but smaller size distribution	Not mentioned

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					material of plastic cutting boards used			•Number of MP particles in fried meat (3.8 ± 2.6 MP/g) •Number of MP particles in raw goat meat (2.2 ± 0.6 MP/g) •0 MP particles were found in meat cut on bamboo tray and meat grinder • Washing meat:°Washing meat for 10 s was found to have a minimal effect on reducing MP content°Washing for 3 min reduced MP content more significantly from (1.19 ± 0.41 mg of MP/ g of meat) to (0.07 ± 0.05 mg of MP/g of meat), but it does not eliminate it. •Goat meat retain higher MP content •Plastic cutting board loses 875 g of polythene after cutting 400 kg of meat, accounting for 2.2 mg of plastic/ g of cut meat. •50 % of MP from cutting board remains in meat, the other half is drained into the wastewaters	
Al Hammadi et al. (2022)	United Arab Emirates (UAE) along the northern shores of (Sharjah, Ajman, Umm Al Quwain)	To assess MP contamination levels in sediments and oysters in 5 sites along UAE coastal waters	•*15 sediments* •*47 oysters.*	MP	•MP extraction: Digestion with filtered KOH and H2O2 (oysters) •Visual characterization: microscope (Dino-Lite Edge Digital) •MP analysis: Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR)	51 % of the oysters samples	•Oysters (accounting to only samples with MP):° Average abundance: 182.7 ± 110.2 MP/ Kg°Maximum MP contamination:357.1 ± 243.2 MP/Kg (site 5)	•MP contamination oysters compared to sediments:°High MP contamination in oysters aligns with the high MP contamination in sediments in site 5° In sites 2 and 4, high MP contamination in oysters does not align with the MP levels in sediments° No significant correlation between MP concentration in sediments and oysters •Inverse relationship	The actual total MP count may be underestimated as smaller particles are not counted: this study is only asses MP sized ≥ 0.1 mm.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								between the oyster's mass and MP contamination: the smaller the oyster mass the higher is the MP contamination (site 2,4,5) • Maximum MP size in oysters is relatively smaller than the ones found in sediments with a size ranging 0.146 mm to 3.172 mm •Prominent MP shapes/ colors : fibers (93 %) and fragments in various colors but black (53 %) was the most abundant followed by blue. •Most abundant MP type: Polyethylene fibers	
Ouheddou et al. (2025)	Morocco, Atlantic Ocean off the Moroccan coast	To investigate microplastic pollution in marine fish species from the Moroccan Atlantic	*12 fish species; 240 samples*	MPS	• Initially examined using a trinocular stereomicroscope for preliminary identification and quantitative evaluation • Subsequently analyzed by scanning electron microscopy coupled with energy dispersive X-ray (EDX) troscopy to determine their surface morphology and elemental composition. • Lastly, used total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR) to identify the chemical acteristics of the plastic particles.	100 %	• Mean abundance of ingested microplastics ranged from 0.24 to 4.36 MPs/g across the different species • Min and max not mentioned	• Total of 18,295 microplastics (MPs) were identified across all 12 edible fish species sampled, with an ingestion frequency of 100 %. • Demersal species presented the highest microplastic counts, ranging from 62.15 to 133.2 MPs/ individual, with totals of 1243 and 2664 MPs, respectively. • Pelagic-neritic species followed, with 66.5 to 82.7 MPs/ individual. • Benthopelagic species presented the highest ingestion rates, ranging from 20.6 to 37.25 MPs/individual, totaling 412 and 745 MPs, respectively. • Correlation between fish size or weight and microplastic uptake revealed a positive correlation between MP abundance and fish length/body weight. •	• Challenges in quantification and risk assessment of MPs • Variability in exposure estimates • Lack/ limited knowledge on MPs long term health effects • General lack of information on pathways of exposure, the toxicological impacts of different MP types, and the cumulative risks posed by their presence in the food chain.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								Microplastic abundance by tissue: o highest levels found in the gonads ranging from 12.88 to 51.46 MPs/g o followed by the gills 18.63 to 45.71 MPs/g o gastrointestinal tract (8.76 to 22.82 MPs/g) • The most abundant MPs were the fragments being 60 % of the total, followed by fibers which constituted 30 % and films 8 % of the total • Classified into four main color groups: black, white, transparent, and colored. o Color group included five colors: blue, red, yellow, green, and purple. Red MPs were the most abundant (27 %), followed by blue (24 %), black, and transparent (17 %). • Most abundant sizes were 0.5–1 mm and <0.5 mm, representing 84 % of the total MPs.	
Bouzekry et al. (2023)	Morocco, three locations at Moroccan Mediterranean Sea	To detect, quantify and characterize MPs in three edible species: the two fish species *Colaptes auratus* and S. pilchardus and the bivalve species C. chione; and to evaluate the poly hazard index (PHI) in order to obtain information about the danger of any polymer for the marine environment and human health	*131 specimen of edible marine organisms*	MPs	Raman spectroscopy to randomly select and analyze MPs. Statistical methods were used for data interpretation such as PHI, Kruskal–Wallis test, and Pearson's Chi-squared.	Frequency of occurance FO (%): Chelon auratus 100 % (35/35), Sardina pilchardus 72 % (32/50), Callista chione 100 % (46/46)	• Mean abundance MPs/ind: o Chelon auratus = 16.82 o Sardina pilchardus = 9.64 o Callista chione = 19.19 • The highest occurrence of MPs (100 %) was found in C. chione and *C. auratus*, followed by S. pilchardus (72 %). • Min and max not mentioned	• Results showed that 1.954 suspected items were ingested/ accumulated by the three species: 883 in C. chione, 589 in *C. auratus*, and 482 in S. pilchardus. • No significant differences in the number of ingested MPs among the three species (Kruskal–Wallis test) • Highest MP contamination: C. chione (bivalve) had the highest MP abundance, particularly in the Martil station (22.52 MPs/ individual). Other	• Low percentage of MPs analyzed by Raman spectrometry • Restricted sampling period, which does not consider seasonal variations, and the lack of comparative studies, which prevents the investigation of correlations between MP abundance in biota and in water and sediments.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								locations showed lower but still significant levels M'diq station: 18.37 MPs/individual and Fnideq station: 16.28 MPs/individual. • S. pilchardus (European pilchard): Fnideq station had the highest contamination (15.85 MPs/ individual). M'diq station had a lower level (9.06 MPs/ individual) • No significant differences in MP characteristics across species: The percentage of MPs, along with their size, shape, and color, did not significantly differ among the three species ($p > 0.05$). • Fibers were the most common MP shape 80.60 % overall: o Fish species (*C. auratus* & S. pilchardus): 93–95 % fibers o Bivalves (C. chione): 65 % fibers • Fragments constituted 31 % in bivalve samples and between 5 and 7 % in fish samples • Foams were only observed in C. chione specimens sampled in the M'diq (1.31 %) and Fnideq stations (10.20 %). • More than half of MPs were found to be black (56.34 %), followed by yellow (12.43 %), blue (11.05 %), red (8.80 %), transparent (4 %), grey (2.91 %), violet (1.07 %), green (0.61 %), and orange (0.10 %). The black color was predominant in all three species. • Most	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								represented MP size category was the 0.5–1 mm range, with a percentage of 71.18 % in *C. auratus*, 69.08 % in S. pilchardus, and 63.95 % in C. chione • Raman spectroscopy identified five types of plastic polymers PP (39.14 %), followed by PET (26.08 %), PVC (17.40 %), PE (8.69 %), and PC (8.69 %)	
Maaghloud et al. (2021)	Morocco, Moroccan Atlantic coastal area located between Larache (35.30. N) and Boujdour (26.30. N)	To investigate the ingestion of Polyamide, Acrylic and Polystyrene by Atlantic horse mackerel, in the Moroccan Atlantic coastal area located between Larache (35.30. N) and Boujdour (26.30. N). The objective is to map the spatial distribution of horse Mackerel containing microplastics (MPs) in their stomachs and identify hot spot areas. Also aim to verify the most ingested polymer by this fish characterized by significant daily vertical migrations.	*147 individuals of Atlantic horse mackerel*	MPs	• Particle polymer type was identified by Fourier transform infrared spectroscopy (FTIR) • Statistical analysis were used: Chi-Square Tests (SPSS software, version 23) and the Cramer's V test to check the probability of association between polymers and verify the link between the ingestion of MPs with depth of each station, the size of the individuals, and the stage of sexual maturity	73 % of the 147 Atlantic horse mackerel specimens examined had MPs in their stomachs	• Mean = 0.46 ingested MPs/fish. • Min and max not mentioned.	• 73 % of the fish (107 out of 147) had MPs in their stomachs. • Quantitative analysis performed on 65 % (96 individuals) of the samples. Forty individuals had MPs in their stomach contents (42 %). • A total of 45 microparticles (26 fibres and 18 fragments and 1 film) were sorted visually from the stomach contents. • The most common MPs colour found in the stomach of fish was blue (33 %). • Three polymer types detected in the stomach contents of horse mackerel samples: Acrylic (73 %), polystyrene (32 %) and Polyamide (86 %) • Among the 30 stations analysed, the association acrylic - polystyrene and polyamide - polystyrene were present in 20 % of samples, while acrylic - polyamide were identified in 47 % of stations.The triplet acrylic - polystyrene - polyamide was detected	Not explicitly mentioned.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								in 30 % of cases. • The spatial distribution of specimens with MPs in their stomachs shows high concentrations in the area situated between 35 and 30 N The specimens collected in the zone between 30 and 26 N did not show the presence of MPs in their stomach contents • There was no significant correlation between the fish size and the presence of MPs in their stomachs. • Among mature individuals, 83 % contained MPs, whereas 67 % of immature individuals had MPs in their stomachs.	
Ahmad et al. (2025)	Riyadh, Saudi Arabia	To investigate the abundance of MPs in 112 drinks and food products purchased from local markets in Riyadh, Saudi Arabia.	*112 drinks and food products*	MPs	• For the identification and quantification of MPs, visual inspection methods were followed • To measure the particle size of the MPs, ImageJ software was employed to microscope images • The MPs particles were analyzed qualitatively to identify the types of polymers by Fourier transform infrared spectroscopy	100 % of the samples (All of the samples exhibited MPs contamination to some extent regardless the type of the sample.)	• No mean mentioned • The highest contamination is observed in tea bags, with an average of 622 particles per teabag. • The lowest contamination is observed in disposable containers, with 14.80 particles per container.	•All tested food and drink samples were contaminated with microplastics (MPs). • The dominant shapes of MPs found were fragments (49.45 % to 92.05 %) and fibers (4.82 % to 35.17 %). Lines (up to 13.08 %) and spheres (6.59 %) were found in smaller amounts. • The common colors observed were black, blue, red, and pink. •Tuna fish, noodles, bottled water, and disposable containers had a dominant size fraction in the range of 101–250 µm (38–49 % of the particles). • Honey, tea bags, and sugar samples showed dominance in the 251–500 µm range	Not explicitly mentioned.

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								(40–55 % of the particles). • Salt, juices, and soft drinks samples showed a dominant size range of 501–1000 μm (39–51 % of the particles). • Presence of several polymers, including PP (Polypropylene), PE (Polyethylene), PET (Polyethylene Terephthalate), PVC (Polyvinyl Chloride), and PC (Polycarbonate). • Tea bags showed the highest average of MPs at 622 particles per teabag for fragments, followed by fibers (32.57), spheres (15.71), and lines (5.43). Bottled water contained 77.55 particles $L-1$ of fragments, 12.45 particles $L-1$ of fibers	
Baalkhuyura et al. (2018)	Saudi Arabia, the Saudi Arabian Red Sea coast	To describe and compare the types of microplastic ingested by fish across different habitats, while testing for possible differences in the frequency of microplastics ingestion among these habitats.	*Red Sea fish, including 178 individuals from 26 species from 4 different habitats*	MPs	• Visually inspected for the presence of microplastic under a binocular stereoscope • Particles were counted, photographed, and measured using ImageJ software • Fourier-transform infrared spectroscopy (FTIR) for the characterization of plastic polymer particles • To confirm the polymer type, all spectra were compared with Hummel Polymer (Thermo Fisher Scientific, USA) • Since FTIR could not analyze very fine fibers, a hot needle test was used to confirm plastic composition	14.6 % (26/178 individuals) had microplastic fragments	• Mean prevalence of plastic fragments within species = 14.4 % ± 0.3 SE • Mean microplastic particles per fish (Approximate) Coral reef: ~7; Demersal: ~8; Mesopelagic: ~1; Seagrass: ~10 • Minimum and Maximum Values (Approximate): Coral reef: Min ~0, Max ~15–18; Demersal: Min ~0, Max ~20–25; Mesopelagic: Min ~0, Max ~3–4; Seagrass: Min ~3–4, Max ~25–30	• 18 out of 26 fish species examined contained plastic fragments. • Average prevalence of microplastic fragments per species: 14.4 % (±0.3 SE). • The highest prevalence of microplastic ingestion (> 20 % of individuals) was found in the following species: Parascolopsis eriomma, Epinephelus chlorostigma, Plectorhinchus gaterinus and Lipochelius carnolabrum. • The highest number of ingested microplastics was observed in Parascolosps eriomma,	Not explicitly mentioned.

(continued on next page)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								of the 5 individuals analysed, 3 individuals (60 %) had ingested plastic particles • Size of microplastic particles: 1–3 mm (mean: 2.39 ± 0.28 mm SE). • Most common microplastic type: fibers, followed by film and fishing thread. Colors: Blue, black, green, white, and red. • Polymers identified: Polypropylene, polyethylene, polystyrene, polyvinyl chloride, and polyacrylonitrile. • 77 % of fibers (37 out of 48) were confirmed as plastic using the hot needle test. • Demersal, seagrass, and coral reef fish had significantly higher microplastic ingestion than mesopelagic fish • Microplastic particles per fish increased with fish length • No significant difference in microplastic ingestion between commercial and non-commercial fish	
Almaiman et al. (2021)	Saudi Arabia	To This study investigate the presence and the quantity of microplastics in bottled and tap water from five regions in Saudi Arabia and estimate the dietary intake of microplastics.	*30 samples of drinking water were collected from the retail markets in Saudi Arabia which included plastic bottled drinking water, 2 glass bottles, and 2 samples of tap water to represent ground water and desalinated seawater*	MPs	• Aliquot of the sample was filtered through a Whatman Anodisc filter (47 mm diameter, 0.2-µm pore size) using a vacuum system. • Fourier Transform Infrared (FTIR) spectrometry was used to characterize plastic particles larger than 25 µm • The total number of particles confirmed as polymers of interest was then counted using	56.7 % (17/30) contained microplastics	• Mean for all samples = 1.9 pcs/L for LB and 4.67 pcs/L for UB. • In the positive samples, the total amounts of microplastic particles ranged from 0.99 to 26 pcs/L (min and max) • Mean for men and women exposure = 0.1–0.2 pcs/Kg bw/day for LB and UB.	• Most contaminated sample (C3): 26 pcs/L (significantly higher than others). • Glass bottle samples: < LOQ (below the limit of quantification). • PC plastic container sample had no quantifiable microplastics detected. • Most frequent plastic types identified: PE (38 %), PS (25 %), PET (22 %). Other identifie plastic types were PP,	• Size range restriction: the study only quantified microplastics in the 25–500 µm size range, meaning smaller microplastics and nanoplastics were not analyzed. This could lead to an underestimation of total microplastic exposure. • Need for improved detection methods for better analytical techniques

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
					the Spectrum IMAGE software.			PA, and PU. • In the two investigated tap water samples, a small amount of microplastics made of PE (1.8 pcs/L) was detected in one sample and the second sample of tap water was < LOQ. • No significant difference in microplastic content between underground and desalinated seawater sources. • High exposure was found to be 1.7 and 1.9 pcs/kg bw/day for adults drinking 4.5 L of water per day. Highest exposure came from 5-gallon (15 L) bottled water. • No significant differences in exposure to microplastics were observed between men and women. Additionally, when comparing mean consumers to high consumers, no statistically significant differences were seen. • Annual intake of microplastics of 2550–5100 for mean consumers and 43,400–48,500 particles for high consumers from drinking water only.	to identify and quantify smaller microplastics and nanoplastics in different food and water samples.
Lourenço et al., 2017	Tejo Estuary in Portugal, Banc d'Arguin in Mauritania, Bijagós Archipelago in Guinea-Bissau	Primary: evaluate the prevalence of microplastic pollution in sediments, macroinvertebrates and shorebird faeces in three coastal wetlands for migratory shorebirds in the Eastern Atlantic. Secondary: • Compare species that exhibit	*o Tejo Estuary: • Sediments: 18 samples • Macroinvertebrates: 222 samples o Banc d'Arguin: • Sediments: 12 samples • Macroinvertebrates: 66 samples o Bijagós Archipelago: • Sediments: 18 samples For shorebirds, 809 fecal samples were*	MPs	• Stereoscopy with 10 - 40x magnification • m-FTIR • Kruskal-Wallis and Mann-Whitney tests • ANOVA • GLM • AIC • Linear regression • Chi-squared tests • R 3.1.2	o Macroinvertebrates: • Tejo Estuary: 97 % • Banc d'Arguin: 44 % o Shorebird fecal samples: • Tejo Estuary: 74 % • Banc d'Arguin: 59 % • Bijagós Archipelago: 26 % o Sediments: • Tejo Estuary: 100 % • Banc d'Arguin: 92 % • Bijagós Archipelago: 72 %	o Microfibers in sediments: • Highest contamination in Tejo Estuary with a mean concentration of 7.5 microfibers/mL • Mean concentration at Banc d'Arguin was 4.3 microfibers/mL. • Lowest contamination occurred in Bijagós Archipelago with a mean	o Microfibers in sediments: • Concentration significantly differed among the three wetlands ($p < 0.001$) • Difference is attributed to samples obtained from Tejo Estuary which have highest microfiber concentrations ($p <$	• Difficult to directly compare potential microplastic concentrations reported in this study with other available data due to huge variation in reporting units and in sampling and laboratory methodologies • Since samples used in that

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
		different foraging strategies that may influence their susceptibility to ingest microplastics to infer whether this form of pollution is transferred along intertidal food webs up to the level of key predators. • Determine which environmental or anthropogenic variables may explain the microplastic distribution in intertidal areas by studying their occurrence at a smaller spatial scale in the Tejo Estuary.	*collected across all species from the 3 sites, in addition to 11 shorebirds from the Tejo estuary.*				concentration of 2.2 microfibers/mL o Microfibers in macroinvertebrates: • Higher contamination in Tejo Estuary with a mean concentration of 390 microfibers.g/AFDW • Mean concentration at Banc d'Arguin was 281.8 microfibers.g/AFDW o Microfibers in shorebird faeces: • Mean value varied across different species	0.01) o Microfibers in macroinvertebrates: • Difference in microfiber concentrations was significantly higher in polychaetes than bivalves in the Tejo Estuary ($p < 0.05$). o Microfibers in shorebird faeces: • Individual species variation was significant in Tejo ($p < 0.01$). • In Bijagós, both species and foraging strategies significantly influenced microfiber concentrations ($p < 0.01$ and $p < 0.001$ respectively). o Factors affecting microfiber concentration in Tejo: • Percentage of fine sediments ($p < 0.01$) • Population size of local township ($p < 0.01$) o Composition of microfibers in samples: 34 % PAN, 12 % PET, 6 % other polymers including polyethylene, polypropylene, nylon and polystyrene. o Microfibers are spread along the food chain, with birds apparently ingesting microfibers through the ingestion of contaminated prey.	study were sieved through a 0.25 mm mesh prior to analysis, the possibility that an unknown proportion of the total micro bers present in the sediment were unaccounted for cannot be excluded. • The infrared spectra did not allow for the determination of whether cellulose-based fibres were natural (such as cotton or hemp) or artificial regenerated cellulose (such as rayon) • Given that different measures of microfiber concentration for macroinvertebrates and shorebirds were used, it is impossible to determine if there is bioaccumulation of these debris along the food web
Hamed et al., 2023	Egyptian fish markets: along the Red Sea (Hurghada and Suez) and along the Mediterranean Sea (Alexandria and Port Said)	o Increase knowledge regarding the potential impact of MP as a result of fish consumption at a market from the Mediterranean and Red seas o Determine the extent of MP contamination of fish in the markets and the extent of the difference in the rate of	*6 samples from each fish species (10) at each fish market (4) were collected*	MPs	• FTIR for identification of polymer types • Shapiro-Wilk test and one-way ANOVA + LSD post-hoc test for statistical analysis • BX50F4 OLYMPUS microscope for characterization of MPs • Extraction of MPs based on published methods	• Hurghada: o 66.6 % Epinephelus areolatus o 50 % Epinephelus fasciatus o 33.3 % Variola louti • Suez: o 83.3 % Epinephelus areolatus o 66.6 % Cephalopholis miniata o 33.3 % Nemipterus japonicus • Alexandria: o 66.6 % Nemipterus japonicas o 83.3 % Sargocentron rubrum o	o Abundance of MPs in fish: • Hurghada: o 5.5 ± 1.1 items/individual Epinephelus areolatus o 4.5 ± 0.9 items/ individual Epinephelus fasciatus o 2.4 ± 0.6 items/individual Variola louti • Suez: o 6.33 ± 0.7 items/individual Epinephelus areolatus o 4.6 ± 1.2 items/ individual	•MP contamination is widespread in fishes from the Red and Meditarreanean Seas markets in Egypt. •Higher MP abundance was observed in demersal fish species, most likely due to the sediments acting as microplastic sinks. • Bioaccumulation of MPs may be potentially	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
		contamination from one species to another in the fish markets o Compare the rate of fish contamination with MPs in different markets in different aquatic environments and regions o Characterize microplastics in Egyptian fish on the basis of size, color, shape and polymer o Extraction and identification of MPs from fish to identify the most common types of polymers found in fish in the market				66.6 % Diplodus sargus • Port Said: o 83.3 % Dicentrarchus punctatus o 66.6 % Sparus aurata o 16.6 % solea	Cephalopholis miniata o 1.33 ± 0.2 items/ individual Nemipterus japonicus • Alexandria: o 4.83 ± 0.9 items/ individual Nemipterus japonicas o 3.16 ± 0.6 items/individual Sargocentron rubrum o 2.33 ± 0.4 items/ individual Diplodus sargus • Port Said: o 5.16 ± 0.7 items/individual Dicentrarchus punctatus o 4 ± 0.6 items/ individual Sparus aurata o 0.5 ± 0.07 items/ individual solea • Highest MP concentration was found in fish at the Hurghada site (4.166 items/ individual) qand lowest MP concentration was found in fish at the Suez site (3.22 items/ individual) o Shape distribution of MPs in fish: most common MP shape was fiber in all sites (37.6 % in Hurghada; 48.3 % in Suez; 54 % in Port Said; 54 % in Alexandria), in addition to fragment, pellet and film o Size distribution of MPs in fish: most common size of MPs was categorized as > 5000 μm (26 %) o Color distribution of MPs in fish: the dominant color of MPs in fish in the Red Sea was black (26.5 %) while that in the Mediterranean Sea was transparent (25 %) o MPs polymer composition: dominant polymers of MPs in fish in the Red Sea were PE	due to the transfer of toxic chemicals upon ingestion.	

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
							(59.4 %) followed by PP (24.8 %); whereas that in the Mediterranean Sea were PP (48.5 %) followed by PE (35.9 %)		
Shobier et al., 2024	Gulf of Suez (Suez city and El-Sokhna city)	Determine the levels of multiple pollutants, including emerging pollutants (MPs in terms of quantity and polymeric composition) and persistent pollutants (trace metals, PAHs and OCPs), in economically important bivalve species with high nutritional value collected from the Gulf of Suez as a hotspot region.	233 individuals represented by 3 bivalve species from 2 locations in the Gulf of Suez (Paratapes undulatus, Paphia textile, Tridacna maxima)	MPs	DSC, extraction, Pyris™6 software, ICP-OES, GC/MS, gas chromatography with ECD using a fused-silica HP-5 capillary column	72 %	• Average value of MPs detected was 5.1 ± 4.3 items/ind. • Highest concentration was in T. maxima with an average value of 11 ± 5.1 items/ind and $p =$ 0.00. • Mean concentration of P. textile was 3.7 ± 2.1 items/ind. • Mean concentration of P. undulatus was 3.3 ± 2.0 items/ind.	o Fragments (colored and glossy) and fibers were 2 types of MPs detected with fibers being the dominant type in all species. o Dominant polymers identified were LDPE, PP, PET and PTFE. o Size of extracted MPs: • 1127 ± 1040 μm for T.maxima • 881 ± 769 μm for P. textile • 1150 ± 888 μm for P. undulatus o All examined species contained trace metals at different levels, however, Co was not detected. Al and Fe were predominant in P. undulatus and P. textile, while the highest concentration of Mn was detected in T. maxima. o The average concentration of individual PAHs varied from 1.67 ± 0.02 to 8.57 ± 1.38 ngg− 1 dw o OCPs: Levels of ΣOCPs varied from 10.05 ngg− 1dw in P. textile to 18.31 ngg− 1dw in T. maxima with an average level of 15.36 ± 4.61 ngg− 1dw	The study does not take into account seasonal variations (external factors that affect pollutant intake by bivalves) which might decrease its generalizability.
Abd-Elkader et al., 2023	Red Sea Coast of Egypt (Hurghada city)	To investigate MPs quantity and polymeric composition among invertebrate species with economic value and to define the sources of pollution	110 individuals, from Hurghada City, represented by 11 species belonging to 4 classes (Bivalvia, Gastropoda,	MPs	DSC, stereomicroscopy, PixelPro 3.0 software, one-way ANOVA, post-hoc Tukey test, Pearson's correlation, non-parametric Kruskal-	100 %	• Average abundance of MPs in species ranged from 8.2 to 136.5 items/individual • Among all species, highest abundance per individual was observed	• Higher abundances per gram tissue wet weight were observed in bivalves ($p < 0.05$) which was mainly related to their feeding behavior, where filter	–

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
			Echinodea and Holothuridea)		Wallis test, Statistics program version 12		in A. crassa ($p < 0.05$) • Abundance of MPs per g tissue weight had the highest concentrations in B. pharaonis (18 items/g w) and the lowest concentrations in T. maxima (0.3 items/g w) • Mean concentration of P. undulatus was 3.3 ± 2.0 items/ind.	feeders had the highest MPs abundance ($p <$ 0.05) • A signifcant correlation exists between the tissue wet weight of organisms and the abundance of MPs ($r = 0.31, p < 0.05$) • Types of MPs: fragments were the most abundant type of MPs (65 % of extracted items), followed by fibers (35 %) • Colors of MPs: black fragments were dominant among all species • Size distribution of MPs: Avg size was 797.1 μm and 58 % of all particles ranged between 100 and 500 μm • Polymeric composition of MPs: highest frequency of occurrence was PA, followed by PEVA and PP • Estimated annual intake of MPs for adults through the consumption of bivalves was <0.1 items/kg BW for the three species of bivalves.	
Shabaka et al., 2020	Eastern Harbor of Alexandria, Egypt	Assess MPs contamination in fish digestive tracts from Eastern Harbor using enhanced visual counting technique coupled with combustion analysis and DSC to provide a simple and economic method for MP assessment.	159 fish from 8 species and 6 families	MPs	Enhanced visual counting technique, combustion analysis, DSC	100 %	The average number of MPs was at its highest level in S. rivulatus, D. sargus, and S. aurita (7527, 3593, 1450 MPs sh−1, resp.) and the lowest in Sphyraena viridensis and Atherina boyeri (46 and 28 MPs sh−1, respect.).	o 56 % of all fish samples had < 500 MPs per fish and approx. 30 % had < 100 MPs per fish o 19 % of the samples had large densities of > 5000 MPs per fish, belonging to S. rivulatus, D. sargus, and S. aurita o ANOVA test showed that mean numbers of	• Need for standardized MPs quantification and characterization protocol in order to univocally determine MPs contamination. • Estimation of MPs density based on counting under microscope is highly subjected to human

(*continued on next page*)

Table 1 (*continued*)

Author, year	Country and region(s) within the country	Aim of the study	Commodity assessed and sample size	MPs? NPs? Or both	Analysis method	% of positive samples	Reported mean, min, max	Results	Limitations
								MPs were significantly higher in S. rivulatus than in other species except D. sargus o Pearson's correlation showed a positive correlation between weight of D. sargus and S. rivulatus ($p = 0.023$ and $p = 0.000$ respectively) o The calculated MPs weight was in accordance with the densities of MPs. S. rivulatus and D. sargus, which had larger MPs weight (302 and 62 mg MPs kg−1, resp.) than the other species o DSC analysis revealed several types of polymers: LLDPE and PP were most dominant (38 %), PEVA (16 %), LDPE, HDPE, PET, nylon o Wild fish feeding on seaweeds or having a broader dietary range had the highest number of MPs in their digestive tract	error and creates incomparable results.

frequently found in sediments, while transparent MPs are easily mistaken as food and ingested by a wide range of marine organisms, including zooplanktons, phytoplanktons, corals, fish, etc. (Chatterjee & Sharma, 2019; Cincinelli et al., 2021).

In Egypt, Hamed et al. (Hamed et al., 2023) reported the presence of MPs in the gastrointestinal tract (GIT) of fish, with no detection in the liver or muscles, potentially due to limitations in detection methods that may mask their actual presence. This indicates minimal dietary exposure for humans, as MPs are cleared from the GIT after 24 h without translocation to other organs; however, this does not eliminate the food safety and ecological risks of MP ingestion by fish (De Sales-Ribeiro et al., 2020). The long-term effects of chronic, low-level MP exposure through human dietary exposure remain largely unknown. Emerging evidence suggests that MP ingestion may lead to genetic alterations resulting in infertility, obesity, and cancer (Sharma & Chatterjee, 2017). The bioaccumulation of MPs in sediments, macroinvertebrates, and shorebirds confirms their trophic transfer within food webs from prey to predator, representing a chronic and mobile form of pollution (Lourenço et al., 2017).

Currently, standardized methodologies for the detection and quantification of MPs are lacking, which affects the comparability of reported data across different studies and regions, including Egypt and West Africa. This highlights a crucial need for coordinated action to establish standardized monitoring protocols and to evaluate targeted policies and mitigation strategies addressing MP pollution. In addition, it is essential to implement interventions that target wastewater infrastructure and regulate plastic production to reduce MP infiltration into marine ecosystems (Hamed et al., 2024). Practices such as improving waste management systems, implementing policies that limit single-use plastics, and promoting the use of biodegradable materials may decrease the release of MPs into different environments (Gallo et al., 2018).

3.5. Algeria

Seafood has been found to be highly susceptible to MP contamination, originating from pesticide manufacturing and fishing activities in industrial cities such as Sidi Salem, Algeria. In contrast, in urban cities such as Saint Cloud, Algeria, MPs originate mainly from household waste, personal care products and synthetics fabrics. Fish studied in Algeria were found to be significantly contaminated with MPs, particularly in industrial and urban areas (Djekoun et al., 2024). Fish ingest either intentionally large-sized transparent MPs that resemble prey, such as zooplanktons and minuscule jellyfish, or accidentally through trophic transfer by ingesting contaminated prey (Djekoun et al., 2024). Although MPs are highly prevalent in digestive tracts of fish, human exposure may be limited, as fish viscera are typically removed before consumption. However, meals made with fish offal or whole fish (e.g. sauces) may pose greater exposure risks (Habib et al., 2022). Mussels, being filter feeders, tend to trap small-sized MPs in their gills, making them ideal bioindicators of marine MP contamination. However, they expose humans to MP more significantly than fish, considering they are consumed whole (Djekoun et al., 2024).

3.6. Sudan

Seafood from the Nile River-Egypt in Sudan is exposed to high levels of MPs possibly due to poor waste management practices, recreational activities alongside the river (restaurants, cafes), and effluents from industrial, agricultural and domestic activities, compounded by the lack of legislation and urban planning (Saad & Alamin, 2023).

3.7. United Arab Emirates (UAE)

Gulf countries are highly susceptible to MP contamination due to the generation of plastic waste from the petrochemical sector, combined with extreme climatic conditions (Al-Salem et al., 2020). The Gulf's high summer temperature (reaching up to 50 degrees Celsius), intense UV radiation, and environmental abrasion promote plastic degradation to MPs (Al-Salem et al., 2020). Seafood contamination with MPs depends on species' feeding habits and sensory capacity to detect, catch, and digest food (Saad & Alamin, 2023). Similarly, oysters, also filter feeders, have found to be highly contaminated with MPs in UAE (Al Hammadi et al., 2022).

Wooden cutting boards have been widely replaced by plastic alternatives due to concerns over the microbial retention capabilities of wood (Habib et al., 2022). However, the use of plastic cutting boards, particularly those made from high-density polyethylene (HDPE) and low-density polyethylene (LDPE), has been linked to MP contamination of meat and seafood products (Habib et al., 2022). In a study conducted in Kuwait and the UAE, all chicken samples and 6 out of 7 fish samples that were cut on plastic cutting boards were found to contain MPs (Habib et al., 2022). The highest MP contamination in chicken reached 0.29 ± 0.25 mg/g, which was lower than the MP levels in king mackerel (2.47 ± 0.4 mg of MP/g) (Habib et al., 2022). This discrepancy is attributed to the greater force required to cut king mackerel, which may release more plastic particles due to its dense texture and strong structural features (Habib et al., 2022). Similarly, MPs were detected in 7 out of 9 meat samples cut on plastic cutting boards in the UAE, with MP levels varying based on meat composition. Goat meat, for example, retained more MPs due to its higher fat content and bones (Habib et al., 2022). Furthermore, washing and cooking were found to significantly affect MP levels in food. Washing king mackerel fish for 3 min reduced MP contamination in from 1.17 ± 0.57 MP/g to 0.03 ± 0.03 MP/g. Similarly, washing meat for 3 min reduced MP content from 1.19 ± 0.41 mg of MP/g to 0.07 ± 0.05 mg of MP/g (Habib et al., 2022). In contrast, cooking meat in a pressure cooker (7.2 ± 4.5 MP) and frying (3.8 ± 2.6 MP/g) increased MP levels due to the breakdown of loosely connected MP and abrasion from cooking surfaces. Cooking may also affect food composition, considering MPs, particularly polyethylene, have a low melting point and change forms when exposed to high temperatures (Habib et al., 2022). Once MPs solidify, they might trap food components such as fats. In addition, plastic cutting boards contribute to wastewater pollution as 50 % of the MPs generated during cutting are drained into wastewater, particularly small-sized MPs which can pass easily through wastewater treatment systems, contributing to aquatic environments (R.Z. Habib et al., 2022). MP contamination from plastic cutting boards can be prevented by switching to wooden boards. The study reported no MP contamination in meat products cut on wooden boards. According to the Food Safety and Inspection Service of the US Department of Agriculture, the use of a wooden, non-porous plastic, pyroceramic, or marble cutting board is recommended. Plastic and wooden cutting boards should be replaced routinely (Habib et al., 2022).

The predominant detected MP types are polyethylene (PE), originating from plastics used in agriculture and food packaging, and polypropylene (PP), originating from fishing gears, in addition to the polythene resulting from plastic cutting boards (Djekoun et al., 2024; Habib et al., 2022). Fiber and fragment-shaped MPs were recurrently found in several countries (Saad & Alamin, 2023; Al Hammadi et al., 2022). Moreover, Detected MPs varied in color, which indicates various pollution sources: white and translucent fibers originate from packaging materials and plastic carry bags; transparent or white fibers from fishing robes; colored fibers from textiles; and black fragments from car tires (Saad & Alamin, 2023). The reported MP size varied substantially ranging from as small as 0.45 μm in fish and mussels in Algeria, to as large as 4.94 mm in Nile tilapia fish in Sudan (Al-Salem et al., 2020; Djekoun et al., 2024). Variation in sampling techniques, identification methods, and reporting units made comparing results across studies challenging, necessitating the need for standardized guidelines (Al-Salem et al., 2020).

3.8. Morocco

In Morocco, Ouheddou et al. (Ouheddou et al., 2024) reported that 100 % of the 240 fish samples from 12 edible species analyzed were contaminated with MPs. Similarly, Bouzekry et al. (22) found that two of the three species types they examined (classified as benthic and pelagic fish) showed 100 % MPs ingestion, while the third species type (classified as pelagic fish) showed 72 % ingestion. Both studies highlighted that major determinants of MP ingestion among different species are related to habitat type and feeding strategies (Ouheddou et al., 2024; Bouzekry et al., 2023). Ouheddou et al. (Ouheddou et al., 2024) reported that demersal species (bottom dwellers) presented the highest MPs counts, followed by pelagic-neritic and benthopelagic species. Moreover, Maaghloud et al. (Maaghloud et al., 2021) noted that 73 % of the Atlantic horse mackerel, a semi-pelagic species, ingested MPs in the North and Central Moroccan Atlantic coast. Comparably, Bouzekry et al. (Bouzekry et al., 2023) highlighted that benthic species, which feed through sediment filtration, had higher intake of MPs than the pelagic species analyzed. This suggests that species that inhabit or feed near the seabed are more susceptible to MPs exposure, likely since MPs and NPs tend to sink to the seafloor.

3.9. Saudi Arabia

In Saudi Arabia, Baalkhuyura et al. (Baalkhuyura et al., 2018) examined 178 fish of 26 species from the Red Sea coast, in which 26 (14.6 %) of the fish were found to have MPs fragments. From the 13 commercial fish species inspected, 10 (65 %) were found to have MPs debris. In contrast to the Moroccan studies, They emphasized that coral reef fish had higher MPs ingestion (46.2 %) than demersal (38.5 %) and seagrass (7.7 %) species. Furthermore, Ahmad et al. (Ahmad et al., 2025) examined several commercial foods and found that tuna fish contained 36.74 particles of MPs/kg.

In terms of NPs and MPs occurrence in water, Almaiman et al. (Almaiman et al., 2021) investigated the presence and the quantity of MPs in bottled and tap water from five regions in Saudi Arabia. They found that 17 out of 30 bottled and tap water samples (57 %) contained MPs (Almaiman et al., 2021). The total concentration of MP particles in positive samples ranged from 0.99 to 26 particles/L. The highest MPs concentration detected was detected in plastic bottled water and to a lower extent in tap water, while no MPs were found in glass bottled water (Almaiman et al., 2021). Similarly, Ahmad et al. (Ahmad et al., 2025) found a wide range of MPs shapes in all 22 bottled water samples purchased form local markets in Riyadh, Saudi Arabia. The most abundant shape was plastic fragments that averaged 77.55 particles/L (Ahmad et al., 2025). The annual intake of MPs for average bottled water consumers is estimated to be 2550–5100 particles, while, for high consumers, it ranges between 43,400 to48,500 particles (Almaiman et al., 2021).

Across all studies done in Saudi Arabia and Morocco reviewed here, NPs and MPs were most identified as fibers and fragments (Ahmad et al., 2025; Almaiman et al., 2021; Baalkhuyura et al., 2018; Bouzekry et al., 2023; Maaghloud et al., 2021; Ouheddou et al., 2024). The most common MP size was 0.5 – 1 mm and <0.5 (Ahmad et al., 2025; Almaiman et al., 2021; Bouzekry et al., 2023; Ouheddou et al., 2024). In contrast, Baalkhuyura et al. (Baalkhuyura et al., 2018) reported a mean MPs size of 2.39 mm in their study. In terms of color, the most abundant were black, blue, and red particles (Ahmad et al., 2025; Baalkhuyura et al., 2018; Bouzekry et al., 2023; Ouheddou et al., 2024). Regarding MP type, polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET) were the most abundant (Ahmad et al., 2025; Almaiman et al., 2021; Baalkhuyura et al., 2018; Bouzekry et al., 2023). On the other hand, Maaghloud et al. (Maaghloud et al., 2021) found that the most common polymers in their study were Acrylic (PC), Polystyrene (PS), and Polyamide (PA).

3.10. Tunisia

In Tunisia, MPs were abundant in fish across numerous regions (Abidli, Lahbib & Trigui El Menif, 2019; Abidli et al., 2021; Almaiman et al., 2021; Belgacem et al., 2025; Ben Hassine et al., 2024; Hassen et al., 2024; Zitouni et al., 2020). Specifically, the lagoon of Bizerte has been identified as a major hotspot for MP pollution, having values such as 1482.82±19 items kg/wet weight in *Crasso streagigas* fish samples (Abidli et al., 2019). This might be due to the high levels of plastic pollution in the lagoon of Bizerte, as it is surrounded by cities such as Bizerte, Zarzouna, Menzel Jemil, Menzel Abderrahmane, Menzel Bourguiba and Tinja, which are densely populated with extensive industrial and fishing activities (Abidli et al., 2015; Ameur et al., 2013; Yoshida et al., 2002). Additionally, pollutants from five fishing ports can reach the coastal waters of Bizerte via wind or tidal currents, as it is linked by a natural bottleneck and artificial channel (Ben Hassine et al., 2024). In contrast, areas like the lagoon of Ghar el Melh and Tabarka have lower demographic densities and less industrial activities, contributing to lower plastic contamination and thus lower MP levels (Abidli et al., 2019; Ben Hassine et al., 2024). Fishermen and shefllfish harvesters from Bizerete face an added risk, since their annual MP dietary intake per capita varies between 2557.67 and 4919.83 items/person/year via the consumption of *Bolinus brandaris* and *Ruditapes decussatus*, respectively (Abidli et al., 2019). In comparison, the general Tunisian population is exposed to lower MP levels, with estimated intakes ranging between 22.73 to 43.73 items/person/year through the intake of the same mollusc species (Abidli et al., 2019).

Secondary MPs, including fibers, fragments, and films, are the most commonly detected MP types in Tunisia. These particles are formed when larger plastic debris breaks down due to mechanical forces and photochemical oxidation in the environment (Andrady, 2011). Fibers usually predominate, accounting for between 53.33 % and 91.3 % of MPs found in fish species (Abidli et al., 2019, 2021; Ben Hassine et al., 2024), though fragments may also be dominant in some cases (Belgacem et al., 2025; Zitouni et al., 2020). The abundance of fibers is attributed to their one-dimensional structure, which makes them prone to fragmentation (Koongolla et al., 2020). Fibers are also linked to various sources, including wastewater discharge, textile industries, shellfish farming, and the degradation of fishing gear (e.g., nets and ropes), with fishing gear losses alone contributing approximately 3968 tons of fiber pollution per month (Abidli et al., 2017, 2018, 2021; Ben Hassine et al., 2024; Belgacem et al., 2025). These fibers are easily ingested by fish and can cause tangling and internal blockages in their digestive systems (Ben Hassine et al., 2024). Conversely, fragments are typically denser than fibers, causing them to sink and accumulate in bottom sediments rather than remaining suspended in the water column (Belgacem et al., 2025; Claessens et al., 2011). However, their presence in surface waters and ingestion by aquatic organisms indicates that the degradation of larger plastics remains a significant source. Films are less prevalent, likely due to their rapid degradation, high dispersion, and detection challenges caused by their thin, transparent, and fragile nature.

Numerous colors of MPs have been observed in fish species in Tunisia, which indicates that particles may stem from a range of origins. The predominant colors are mostly black and blue (bidli et al., 2019, 2021; Ben Hassine et al., 2024). Colored MPs may be mistakenly ingested by predators due to their resemblance to natural prey. For instance, species like the common anchovy (*Engraulis encrasicolus)* and sardines, which share habitats and feeding patterns, show a preference for darker-colored prey (such as black and blue) during feeding (Jemaa et al., 2015; Renzi et al., 2019). This visual preference may explain the higher ingestion rates of darker-colored MPs observed in these species.

Small-sized MPs (0.33–3 mm) are the most abundant (bidli et al., 2019, 2021; Ben Hassine et al., 2024). Size is a key factor of MP bioavailability, as small MPs are easily ingested by marine organisms, especially those at lower trophic levels (Abidli et al., 2019; Zitouni et al., 2020; Lusher et al., 2013). MPs as small as 0.33–0.5 mm pose added risks due to their ability to adsorb harmful hydrophobic organic pollutants (Wang et al., 2019). The abundance of small MPs near shorelines suggests ongoing fragmentation, likely due to land-based sources, marine activity, and environmental factors like wind and biofouling. Size preferences have been observed between species such as mollusks and fish, reflecting differences in feeding behavior and particle selectivity (Abidli et al., 2021). Small-sized MPs have also been linked to induced oxidative stress (Zitouni et al., 2020). Other studies have found variations in the size distribution between organs (Belgacem et al., 2025; Zitouni et al., 2020). For instance, in gills, the primary size class is $\geq$ 3 μm (20), as compared to $<$ 1.2–0.45 μm and $<$3–1.2 μm in digestive glands or muscles (Belgacem et al., 2025; Zitouni et al., 2020). Larger MPs are often trapped on gills, while smaller ones are ingested and translocated into tissues like the digestive gland and eventually fish muscle (Belgacem et al., 2025; Karami et al., 2017). Marine-derived fish meals could transfer MPs directly to farmed fish tissues and indirectly to humans, posing serious threats to aquaculture and food safety (Hanachi et al., 2019; Hantoro et al., 2019).

Both the digestive tract and gills are key sites for MP absorption in aquatic organisms. The digestive tract typically exhibits a higher MP load than the gills, both in terms of particle size and concentration (Belgacem et al., 2025; Ben Hassine et al., 2024). MPs often resemble plankton, leading to their accumulation in the digestive systems of species such as sardines, making the digestive tract a critical site for assessing MP toxicity (Ben Hassine et al., 2024). In contrast, gills capture MPs passively during respiration, resulting in brief, non-selective exposure, which makes them useful for monitoring real-time environmental contamination (Ben Hassine et al., 2024). However, MP entrapment in gill filaments can cause physical damage, reduce respiratory efficiency, induce prolonged hypoxia, and potentially lead to mortality (Barboza et al., 2020; Ben Hassine et al., 2024).

The type of species found in Tunisia also influences MP accumulation due to species-specific detoxification mechanisms. Oysters are considered ideal for environmental monitoring because of their sessile nature and capacity to accumulate pollutants, while mussels are widely used in marine biomonitoring and laboratory studies to assess the fate and effects of MPs (Browne et al., 2008; Xie et al., 2016). Abidli et al. (Abidli et al., 2019) identified *Ruditapes decussatus* and *Bolinus brandaris* as suitable organisms for MP monitoring due to the high contamination levels observed in these species. Additionally, *Sarpa salpa* and *Liza aurata* have been proposed as potential bioindicators of marine plastic ingestion (Abidli et al., 2021). On the other hand, marine flora such as *Posidonia oceanica* seagrass can detect and trap plasticizers and degraded MPs, thereby contributing to the reduction of marine plastic pollution (Hassen et al., 2024).

In terms of polymer types, PP and PE are the most prevalent in surface waters, owing to their durability, widespread use, and low density (Abidli et al., 2019, 2021). However, processes such as biofouling and phytoplankton aggregation can increase the density of these particles, facilitating their vertical transport and explaining the presence of low-density polymers in deeper waters and sediments (Belgacem et al., 2025). The occasional prevalence of PET, a denser polymer, may be attributed to its extensive local usage and its suspension in the water column through turbulence or biofouling (Belgacem et al., 2025). In addition, various plastic additives, such as lubricants and stabilizers, have been detected in fish samples. These compounds pose increased health risks, particularly to species with longer intestinal retention times, and potentially to humans through dietary exposure (Abidli et al., 2021; Zitouni et al., 2020).

Variability among studies stems from differences in analytical methods, pollution levels at sampling sites, the species examined, and the absence of standardized protocols and units for microplastic quantification. Further research is essential to better understand human exposure and the associated health risks—particularly in Tunisia, where fish are widely consumed, often without gutting. In addition, improving waste management practices and securing increased funding for ongoing research are critical steps toward mitigating microplastic pollution and safeguarding public health.

The findings of this review should be interpreted in light of several limitations. First, the existing body of literature in the Arab region is limited in scope and geographically uneven, with several countries lacking any published data. Second, substantial methodological heterogeneity exists across studies, including differences in sampling strategies, digestion protocols, analytical techniques, particle size detection limits, and reporting units, which limits direct comparability and may partially explain variability in reported contamination levels. Most studies focused on microplastics, while nanoplastics remain largely uninvestigated due to analytical constraints. In addition, few studies conducted dietary intake assessments or human health risk evaluations. As a narrative review, this study did not perform a quantitative meta-analysis, and publication bias cannot be excluded. Furthermore, the lack of quality assessment limits the reliability and interpretability of the findings. These limitations highlight the need for harmonized methodologies, standardized reporting frameworks, and more comprehensive exposure and risk assessment studies in the region.

4. Conclusion

This review highlights the widespread MP contamination across the Arab region. MPs were detected in commonly consumed food commodities such as seafood, meat, and packaged products (bottled water and table salt), exposing humans to significant health risks. Despite these alarming findings, research on MPs in the Arab region remains limited. Moreover, the available studies employ diverse sampling, identification, and reporting methodologies, making cross-study comparisons challenging and hindering the accurate assessment of regional MP prevalence. There is a critical need for further research in this area, supported by standardized protocols and guidelines to facilitate consistent data collection and reporting. Such efforts are essential to inform evidence-based legislation and enhance food safety across the region.

Declarations

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors"

Funding

This research did not receive any funding.

CRediT authorship contribution statement

Hussein F. Hassan: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Data curation, Conceptualization. **Roa Echtay:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Hanin El Hajj:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Sonel Lahdo:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Tala Jaafar:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Aya Fakhr El Dine:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Elias Akoury:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Maya Bassil:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Layal Karam:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Mohamed Abdelfatah:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Christelle Bou-Mitri:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation.

Ioannis Zuburtikudis: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Nisreen Alwan:** Writing – review & editing, Writing – original draft, Validation, Project administration, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

Not applicable

Data availability

All data generated or analysed during this study are included in this published article.

References

Abbasi, A., Sadeghi, P., & Taghizadeh Rahmat Abadi, Z. (2023). Characterization of microplastics in the digestive tract of commercial fish species from the Oman Sea. *Marine Pollution Bulletin, 197*, Article 115769. https://doi.org/10.1016/j.marpolbul.2023.115769

Abd-Elkader, A., Hamed, E. S. A. E., Mahdy, A., & Shabaka, S. (2023). Microplastics in marine invertebrates from the red sea coast of Egypt: Abundance, composition, and risks. *Marine Pollution Bulletin, 197*, Article 115760. https://doi.org/10.1016/j.marpolbul.2023.115760

Abidli, S., Akkari, N., Lahbib, Y., & Trigui El Menif, N. (2021). First evaluation of microplastics in two commercial fish species from the lagoons of bizerte and ghar el melh (northern tunisia). *Regional Studies in Marine Science, 41*, Article 101581. https://doi.org/10.1016/j.rsma.2020.101581

Abidli, S., Lahbib, Y., Rodríguez-González, P., Garcia Alonso, J., & El Menif, N. (2015). Butyltin compounds in sediment and biota from the lagoon of bizerte (northern tunisia): Potential risk for consumers? *Human Ecology Risk Assessment, 22*. https://doi.org/10.1080/10807039.2015.1064761

Abidli, S., Lahbib, Y., & Trigui El Menif, N. (2019). Microplastics in commercial molluscs from the lagoon of Bizerte (Northern Tunisia). *Marine Pollution Bulletin, 142*, 243–252. https://doi.org/10.1016/j.marpolbul.2019.03.048

Abidli, S., Toumi, H., Lahbib, Y., & Trigui El Menif, N. (2017). The first evaluation of mi croplastics in sediments from the complex Lagoon-Channel of Bizerte (northern Tunisia). *Water, Air, and Soil Pollution, 228*, 262. https://doi.org/10.1007/s11270-0173439-9

Abidli, S., Antunes, J. C., Ferreira, J. L., Lahbib, Y., Sobral, P., & Trigui El Menif, N. (2018). Microplastics in sediments from the littoral zone of the north tunisian coast (mediterranean sea). *Estuarine Coastal Shelf Science, 205*, 1–9. https://doi.org/10.1016/j.ecss.2018.03.006

Ahmad, M., Ahmad, J., Usama, Muhammad, Al-Swadi, Hamed Ahmed, Mousa, M. A., Rafique, M. I., Al-Wabel, M. I., & Abdullah. (2025). Microplastic contamination in commercial food and drink products and associated risk of potential human intake in Riyadh, Saudi Arabia. *Environmental Monitoring and Assessment, 197*(3). https://doi.org/10.1007/s10661-025-13680-9

Al Hammadi, M. A., Knuteson, S., Kanan, S., & Samara, F. (2022). Microplastic pollution in oyster bed ecosystems: An assessment of the northern shores of the United Arab Emirates. *Environmental Advances, 8*, Article 100214. https://doi.org/10.1016/j.envadv.2022.100214

Al-Salem, S., Uddin, S., & Al-Yamani, F. (2020a). An assessment of microplastics threat to the marine environment: A short review in context of the Arabian/Persian Gulf. *Marine Environmental Research, 159*, Article 104961. https://doi.org/10.1016/j.marenvres.2020.104961

Al-Salem, S. M., Uddin, S., & Lyons, B. (2020b). Evidence of microplastics in gut content of major consumed marine fish species in the State of Kuwait (of the Arabian/Persian Gulf). *Marine Pollution Bulletin, 154*, Article 111052. https://doi.org/10.1016/j.marpolbul.2020.111052

Almaiman, L., Aljomah, A., Bineid, M., Aljeldah, F. M., Aldawsari, F., Liebmann, B., Lomako, I., Sexlinger, K., & Alarfaj, R. (2021). The occurrence and dietary intake related to the presence of microplastics in drinking water in Saudi Arabia. *Environmental Monitoring and Assessment, 193*(7). https://doi.org/10.1007/s10661-021-09132-9

Ameur, W. B., Trabelsi, S., El Megdiche, Y., Hassine, S. B., Barhoumi, B., Hammami, B., Eljarrat, E., Barceló, D., & Driss, M. R. (2013). Concentration of polychlorinated biphenyls and organochlorine pesticides in mullet (Mugil cephalus) and sea bass (Dicentrarchus labrax) from Bizerte Lagoon (Northern Tunisia). *Chemosphere, 90*(9), 2372–2380. https://doi.org/10.1016/j.chemosphere.2012.10.028

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

Baalkhuyura, F. M., Bin Dohaish, E.-J. A., Elhalwagy, M. E. A., Alikunhi, N. M., AlSuwailem, A. M., Røstad, A., Coker, D. J., Berumen, M. L., & Duarte, C. M. (2018). Microplastic in the gastrointestinal tract of fishes along the Saudi arabian Red Sea coast. *Marine Pollution Bulletin, 131*, 407–415. https://doi.org/10.1016/j.marpolbul.2018.04.040

Bajt, O. (2021). From plastics to microplastics and organisms. *FEBS Open Bio, 11*(4), 954–966. https://doi.org/10.1002/2211-5463.13120

Barboza, L. G. A., Lopes, C., Oliveira, P., Bessa, F., Otero, V., Henriques, B., Raimundo, J., Caetano, M., Vale, C., & Guilhermino, L. (2020). Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *The Science of the Total Environment, 717*, Article 134625. https://doi.org/10.1016/j.scitotenv.2019.134625

Barboza, L. G. A., Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety, and human health. *Marine Pollution Bulletin, 133*, 336–348. https://doi.org/10.1016/j.marpolbul.2018.05.047

Ben Hassine, I., Abidli, S., Lahbib, Y., & Trigui El Menif, N. (2024). First characterization and spatial distribution of microplastics in Sardina pilchardus fish gathered along the northern Tunisian coast. *Ecohydrology Hydrobiology*. https://doi.org/10.1016/j.ecohyd.2024.06.004

Belgacem, R., Zitouni, N., Khazri, A., Abidi, O., Ghayth Alzwawy, A., Béjaoui, M., Bouleefah, F., Banni, M., & Mahmoudi, E. (2025). Distribution of environmental microplastics in different tissues of indigenous freshwater bivalves (Unio spp.): A case study from the Sejenane River in Northern Tunisia. *Environmental Toxicology and Chemistry, 1*(20). https://doi.org/10.1093/etojnl/vgae023

Blackburn, K., & Green, D. (2022). The potential effects of microplastics on human health: What is known and what is unknown. *Ambio, 51*(3), 518–530. https://doi.org/10.1007/s13280-021-01589-9

Bouzekry, A., Mghili, B., Bouadil, O., Mancuso, M., Ben-Haddad, M., Bottari, T., & Aksissou, M. (2023). First report of microplastic ingestion in edible fish along Moroccan Mediterranean coasts. *Sustainability, 15*(23), Article 16313. https://doi.org/10.3390/su152316313

Browne, M. A., Dissanayake, A., Galloway, T. S., Lowe, D. M., & Thompson, R. C. (2008). Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L). *Environmental Science & Technology, 42*(13), 5026–5031. https://doi.org/10.1021/es800249a

Cai, H., Xu, E. G., Du, F., Li, R., Liu, J., & Shi, H. (2021). Analysis of environmental nanoplastics: Progress and challenges. *Chemical Engineering Journal (Lausanne, Switzerland : 1996), 410*, Article 128208. https://doi.org/10.1016/j.cej.2020.128208

Carney Almroth, B. M., Åström, L., Roslund, S., Petersson, H., Johansson, M., & Persson, N. (2018). Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. *Environmental Science Pollution Research, 25*(2), 1191–1199. https://doi.org/10.1007/s11356-017-0528-7

Chatterjee, S., & Sharma, S. (2019). Microplastics in our oceans and Marine health. *Field Actions Science Reports*. https://journals.openedition.org/factsreports/5257.

Cincinelli, A., Scopetani, C., Chelazzi, D., Martellini, T., Pogojeva, M., & Slobodnik, J. (2021). Microplastics in the Black Sea sediments. *The Science of the Total Environment, 760*, Article 143898. https://doi.org/10.1016/j.scitotenv.2020.143898

Claessens, M., De Meester, S., Van Landuyt, L., De Clerck, K., & Janssen, C.R. (2011). Occurrence and distribution of microplastics in marine sediments along the Belgian.

Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin, 62*(12), 2588–2597. https://doi.org/10.1016/j.marpolbul.2011.09.025

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human consumption of microplastics. *Environmental Science & Technology, 53*(12), 7068–7074. https://doi.org/10.1021/acs.est.9b01517

De Sales-Ribeiro, C., Brito-Casillas, Y., Fernandez, A., & Caballero, M. J. (2020). An end to the controversy over the microscopic detection and effects of pristine microplastics in fish organs. *Scientific Reports, 10*(1), Article 12434. https://doi.org/10.1038/s41598-020-69062-3

Djekoun, M., Gaaied, S., Romdhani, I., Rida, A. M., Missaoui, Y., Boubekeur, M. S., Trea, F., Lakbar, C., Ouali, K., & Banni, M. (2024). Abundance and distribution of environmental microplastic in edible fish and mussels from the south Mediterranean coasts. *Marine Pollution Bulletin, 206*, Article 116705. https://doi.org/10.1016/j.marpolbul.2024.116705

Dokl, M., Copot, A., Krajnc, D., Fan, Y. V., Vujanović, A., Aviso, K. B., Tan, R. R., Kravanja, Z., & Čuček, L. (2024). Global projections of plastic use, end-of-life fate and potential changes in consumption, reduction, recycling and replacement with bioplastics to 2050. *Sustainable Production and Consumption, 51*, 498–518. https://doi.org/10.1016/j.spc.2024.08.005

Gallo, F., Fossi, C., Weber, R., Santillo, D., Sousa, J., Ingram, I., Nadal, A., & Romano, D. (2018). Marine litter, plastics, and microplastics and their toxic chemical components: The need for urgent preventive measures. *Environmental Sciences Europe, 30*(1), 13. https://doi.org/10.1186/s12302-018-0139-z

Habib, R. Z., Kindi, R. A., Salem, F. A., Kittaneh, W. F., Poulose, V., Iftikhar, S. H., Mourad, A. I., & Thiemann, T. (2022a). Microplastic contamination of chicken meat and fish through plastic cutting boards. *International Journal of Environmental Research and Public Health, 19*(20), Article 13442. https://doi.org/10.3390/ijerph192013442

Habib, R. Z., Poulose, V., Alsaidi, R., Kendi, R. A., Iftikhar, S. H., Mourad, A. I., Kittaneh, W. F., & Thiemann, T. (2022b). Plastic cutting boards as a source of microplastics in meat. *Food Additives Contaminants Part A, 39*(3), 609–619. https://doi.org/10.1080/19440049.2021.2017002

Hamed, M., Martyniuk, C. J., Lee, J., Shi, H., & Sayed, A. E. H. (2023). Distribution, abundance, and composition of microplastics in market fishes from the Red and Mediterranean seas in Egypt. *Journal of Sea Research, 194*, Article 102407. https://doi.org/10.1016/j.seares.2023.102407

Hamed, M., Mazi, W., Alatawi, I. S., Omer, N., Jame, R., Abdelaziz, M. A., & Khaled, M. A. (2024). Characterization, surface deformation analysis, and sources of small plastic fragments collected in diverse environments of Egypt. *Marine Pollution Bulletin, 209*, Article 117222. https://doi.org/10.1016/j.marpolbul.2024.117222

Hanachi, P., Karbalaei, S., Walker, T. R., Cole, M., & Hosseini, S. V. (2019). Abundance and properties of microplastics found in commercial fish meal and cultured common carp (Cyprinus carpio). *Environmental Science and Pollution Research International, 26*(23), 23777–23787. https://doi.org/10.1007/s11356-019-05637-6

Hantoro, I., Löhr, A. J., Van Belleghem, F. G. A. J., Widianarko, B., & Ragas, A. M. J (2019). Microplastics in coastal areas and seafood: Implications for food safety. *Food Additives Contaminants. Part A, 36*(5), 674–711. https://doi.org/10.1080/19440049.2019.1585581

Hartmann, N. B., Hüffer, T., Thompson, R. C., Hassellöv, M., Verschoor, A., Daugaard, A. E., Rist, S., Karlsson, T., Brennholt, N., Cole, M., Herrling, M. P., Hess, M. C., Ivleva, N. P., Lusher, A. L., & Wagner, M. (2019). Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. *Environmental Science & Technology, 53*(3), 1039–1047. https://doi.org/10.1021/acs.est.8b05297

Hassen, B., Sghaier, D. B., Matmati, E., Mraouna, R., & El Bour, M. (2024). Detection and quantification of microplastics in Posidonia oceanica banquettes in the Gulf of Gabes, Tunisia. *Environmental Science and Pollution Research International, 31*(46), 57196–57203. https://doi.org/10.1007/s11356-023-30798-w

Jemaa, S., Bacha, M., Khalaf, G., Dessailly, D., Rabhi, K., & Amara, R. (2015). What can otolith shape analysis tell us about population structure of the european sardine, sardina pilchardus, from atlantic and mediterranean waters? *Journal of Sea Research, 96*, 11–17. https://doi.org/10.1016/j.seares.2014.11.002

Kannan, K., & Vimalkumar, K. (2021). A review of Human exposure to microplastics and insights into microplastics as obesogens. *Frontiers in Endocrinology, 12*, Article 724989. https://doi.org/10.3389/fendo.2021.724989

Karami, A., Golieskardi, A., Bin Ho, Y., Larat, V., & Salamatinia, B. (2017b). Microplastics in eviscerated flesh and excised organs of dried fish. *Scientific Reports*, 1e9. https://doi.org/10.1038/s41598-017-05828-6

Koongolla, J. B., Lin, L., Pan, Y. F., Yang, C. P., Sun, D. R., Liu, S., Xu, X. R., Maharana, D., Huang, J. S., & Li, H. X. (2020). Occurrence of microplastics in gastrointestinal tracts and gills of fish from Beibu Gulf, South China Sea. *Environmental Pollution (Barking, Essex : 1987), 258*, Article 113734. https://doi.org/10.1016/j.envpol.2019.113734

Kor, K., Jannat, B., Ershadifar, H., & Ghazilou, A. (2023). Microplastic occurrence in finfish and shellfish from the mangroves of the northern Gulf of Oman. *Marine Pollution Bulletin, 189*, Article 114788. https://doi.org/10.1016/j.marpolbul.2023.114788

Li, W., Zu, B., Yang, Q., Guo, J., & Li, J. (2023). Sources, distribution, and environmental effects of microplastics: A systematic review. *RSC Advances, 13*(23), 15566–15574. https://doi.org/10.1039/d3ra02169f

Lourenço, P. M., Serra-Gonçalves, C., Ferreira, J. L., Catry, T., & Granadeiro, J. P. (2017). Plastic and other microfibers in sediments, macroinvertebrates, and shorebirds from three intertidal wetlands of southern Europe and West Africa. *Enviromental. Pollution, 231*, 123–133. https://doi.org/10.1016/j.envpol.2017.07.103

Lusher, A. L., McHugh, M., & Thompson, R. C. (2013). Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. *Marine Pollution Bulletin, 67*(1–2), 94–99. https://doi.org/10.1016/j.marpolbul.2012.11.028

Maaghloud, H., Houssa, R., Bellali, F., El Bouqdaoui, K., Ouansafi, S., Loulad, S., & Fahde, A. (2021). Microplastic ingestion by Atlantic horse mackerel (Trachurus trachurus) in the North and central Moroccan Atlantic coast between Larache (35°30′N) and Boujdour (26°30′N). *Enviromental. Pollution, 288*, Article 117781. https://doi.org/10.1016/j.envpol.2021.117781

Malak, H. J. (2021). *Detecting microplastics in bottled water*. American University of Beirut). AUB ScholarWorks. Master's thesis https://scholarworks.aub.edu.lb/handle/10938/23136.

Nakat, Z., Dgheim, N., Ballout, J., & Bou-Mitri, C. (2023). Occurrence and exposure to microplastics in salt for human consumption, present on the Lebanese market. *Food Control, 145*, Article 109414. https://doi.org/10.1016/j.foodcont.2022.109414

Osman, A. I., Hosny, M., Eltaweil, A. S., Omar, S., Elgarahy, A. M., Farghali, M., Yap, P., Wu, Y., Nagandran, S., Batumalaie, K., Gopinath, S. C. B., John, O. D., Sekar, M., Saikia, T., Karunanithi, P., Hatta, M. H. M., & Akinyede, K. A. (2023). Microplastic sources, formation, toxicity, and remediation: a review. *Environmental Chemistry Letters*, 1–41. https://doi.org/10.1007/s10311-023-01593-3

Ouheddou, M., Abelouah, M. R., Ben-Haddad, M., Hajji, S., Laaraj, Nour Eddine, Akhouchal, Ihya, Barra, I., Rangel-Buitrago, N., Agnaou, Mustapha, & Alla, A. A (2024). Microplastics in Morocco's most consumed fisheries: Chemical characterization, ecological traits, and implications for human health. *Marine Pollution Bulletin, 210*, Article 117334. https://doi.org/10.1016/j.marpolbul.2024.117334

Plastics Europe. (2022, October). *Plastics - the facts 2022*. Plastics Europe. https://plasticseurope.org/wp-content/uploads/2022/10/PE-PLASTICS-THE-FACTS_V7-Tue_19-10-1.pdf.

Ramos, S., Espincho, F., Rodrigues, S. M., Pereira, R., Silva, D., Rivoira, L., Perdigão, R., & Almeida, C. M. R. (2025). An integrated approach to assessing the potential of plastic fishing gear to release microplastics. *Water, 17*(10), 1439. https://doi.org/10.3390/w17101439

Rashid, E., Hussain, S. M., Ali, S., Munir, M., Ghafoor, A., Yilmaz, E., … Naeem, E. (2025). Impacts of microplastic accumulation in aquatic environment: Physiological, eco-toxicological, immunological, and neurotoxic effects. *Aquatic Toxicology, 279*, Article 107232. https://doi.org/10.1016/j.aquatox.2024.107232

Renzi, M., Specchiulli, A., Blašković, A., Manzo, C., Mancinelli, G., & Cilenti, L. (2019). Marine litter in stomach content of small pelagic fishes from the Adriatic Sea: Sardines (Sardina pilchardus) and anchovies (Engraulis encrasicolus). *Environmental Science and Pollution Research International, 26*(3), 2771–2781.

Saad, D., & Alamin, H. (2023). The first evidence of microplastic presence in the River Nile in Khartoum, Sudan: Using Nile Tilapia fish as a bio-indicator. *Heliyon*, 10(1), e23393. https://doi.org/10.1016/j.heliyon.2023.e23393.

Saeed, T., Jandal, N., Al-Mutairi, A., & Taqi, H. (2020). Microplastics in Kuwait marine environment: Results of first survey. *Marine Pollution Bulletin, 152*, Article 110880. https://doi.org/10.1016/j.marpolbul.2020.110880

Santini, S., De Beni, E., Martellini, T., Sarti, C., Randazzo, D., Ciraolo, R., Scopetani, C., & Cincinelli, A. (2022). Occurrence of natural and synthetic micro-fibers in the Mediterranean Sea: a review. *Toxics, 10*(7), 391. https://doi.org/10.3390/toxics10070391

Shabaka, S. H., Marey, R. S., Ghobashy, M., Abushady, A. M., Ismail, G. A., & Khairy, H. M. (2020). Thermal analysis and enhanced visual technique for assessment of microplastics in fish from an urban harbor, mediterranean coast of egypt. *Marine Pollution Bulletin, 159*, Article 111465. https://doi.org/10.1016/j.marpolbul.2020.111465

Sharma, S., & Chatterjee, S. (2017). Microplastic pollution, a threat to marine ecosystem and human health: a short review. *Environ. Sci. Pollution Res., 24*(27), 21530–21547. https://doi.org/10.1007/s11356-017-9910-8

Shobier, A. H., Shabaka, S. H., El-Sayed, A. A. M., Shreadah, M. A., & Abdel Ghani, S. A. (2024). Assessment of persistent and emerging pollutants levels in marine bivalves in the gulf of suez, egypt. *Marine Pollution Bulletin, 208*, Article 117000. https://doi.org/10.1016/j.marpolbul.2024.117000

Tang, L., Feng, J., Li, C., Liang, J., Zhang, S., & Yang, Z. (2023). Global occurrence, drivers, and environmental risks of microplastics in marine environments. *Journal of Environmental Management, 329*, Article 116961. https://doi.org/10.1016/j.jenvman.2022.116961

Teuten, E. L., Saquing, J. M., Knappe, D. R., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of Royal Society of London Series B Biology Science, 364*(1526), 2027–2045. https://doi.org/10.1098/rstb.2008.0284

Wang, J., Liu, X., Li, Y., Powell, T., Wang, X., Wang, G., & Zhang, P. (2019). Microplastics as contaminants in the soil environment: a mini-review. *The Science of the total environment, 691*, 848–857. https://doi.org/10.1016/j.scitotenv.2019.07.209

Wright, S. L., Rowe, D., Thompson, R. C., & Galloway, T. S. (2013). Microplastic ingestion decreases energy reserves in marine worms. *Current Biology, 23*(23), R1031–R1033. https://doi.org/10.1016/j.cub.2013.10.068

Xie, J., Zhao, Y., Wu, H., Teng, J., Yang, D., Chen, L., Zhang, Y., Li, F., Ji, C., Cong, M., & Zhao, J. (2016). An integrative biomarker approach to assess the environmental stress in the north coast of shandong peninsula using native oysters, crassostrea gigas. *Marine Pollution Bulletin, 112*. https://doi.org/10.1016/j.marpolbul.2016.07.049

Yoshida, T., Takanishi, T., Nakai, S., Yorimoto, A., & Morimoto, T. (2002). The critical level of water deficit causing a decrease in human exercise performance: A practical field study. *European Journal of Applied Physiology, 87*(6), 529–534. https://doi.org/10.1007/s00421-002-0651-z

Zitouni, N., Bousserrhine, N., Belbekhouche, S., Missawi, O., Alphonse, V., Boughatass, I., & Banni, M. (2020). First report on the presence of small microplastics ($\leq$ 3 μm) in tissue of the commercial fish Serranus scriba (Linnaeus. 1758) from Tunisian coasts and associated cellular alterations. *Environmental Pollution, 263*, Article 114576. https://doi.org/10.1016/j.envpol.2020.114576