(RESEARCH ARTICLE)

Contribution to the assessment of marine litter in the North Moroccan Atlantic

Asia Ben haddouch *, Ayoub Baali, Abdelkrim Kalmouni, Amina Bouhallaoui and Samir Benbrahim

National Institute of Fisheries Research (INRH), Bd Sidi Abderrahmane, Ain Diab Casablanca, Morocco.

Abstract

Waste pollution has become a concern around the world. Pollution that affects both the terrestrial and marine environments. Regardless of the nature, type and origin, accumulation and mismanagement of waste pose a danger to the environment and human health, in particular the marine system. In the face of this ever-increasing phenomenon of pollution, studies have been carried out to assess the quantity of waste in order to characterize condensation sites and sources of pollution.

we present the results of the analysis and monitoring of the state of marine litter pollution, concerning the identification of quantities, the nature and the spatial distribution of macro-waste collected at all the fishing stations swept along the North Moroccan Atlantic space between Tangier (36°N) and Sidi Ifni (29°N). The data were collected by a bottom trawling campaign aboard the research vessel "Al Amir Moulay Abdallah" carried out from 21 to 31 May 2022 covering different stratums of depths (from 28 to 140 m) and following a sampling network of 60 stations distributed randomly in the study area.

In all the stations swept by the trawl during the prospecting, the majority of the waste is distributed only at half of the stations which focus mainly on the axis between Mehdia and El Jadida. At the 33 other stations, which are the majority in the coastal axis between El Jadida and Sidi Ifni, no waste was recorded during navigation. During this prospection, a total of 13,5 Kg is collected, and all waste recovered is classified into 18 categories, the majority is represented by plastic items (81%) of the waste collected. Other items such as wood, iron, textiles and rubber were poorly identified. These wastes could be the source of different sources, but based on the waste categorization, the main source is related to fishing activities.

Keywords: Marine litter; Categorization; North Moroccan Atlantic; Pollution

1. Introduction

Marine litter is recognized as a major current issue, defined as any persistent solid matter, manufactured or processed by humans and released, disposed of or abandoned in the marine and coastal environment [1]. These wastes are found in the oceans and on the coasts by various routes and from various sources that can be terrestrial or oceanic; they can also be transported long distances before being deposited [2]. 80% of marine litter comes from land-based sources, including tourism, industrial areas, discharges into rivers and wastewater effluents; the remaining 20% comes from marine activities, including commercial and recreational boating, aquaculture and fishing [3]. Many studies show that plastics are the most abundant marine litter [4], with an estimated 13 million tons of plastics being released into the ocean environment each year [1] (Lyons *et al.*, 2020). These numerous wastes that persist and accumulate over time pose environmental, social, economic and cultural problems [2]. In addition to having a direct impact on wildlife, through injury or death of seabirds, fish, mammals and turtles as a result of entanglement or ingestion [1], marine litter

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* Corresponding author: Asia Ben haddouch

negatively impacts the tourism economy. Fishing returns and shipping [4]. Water quality is also affected by the presence of wastes loaded with substances harmful to health.

The many wastes that persist and accumulate over time present environmental, social, economic and cultural problems [2]. They have a direct impact on wildlife through injury or death to seabirds, fish, mammals and turtles from entanglement or ingestion [1]. According to The Animal Fund (TAF), at least one million gulls and one hundred thousand marine mammals die each year from plastic pollution. The survivors of at least 100 species, including the Hawaiian Monk Seal and the Loggerhead Turtle, could be lost to plastic debris. The Ministry of Ecological Transition in France adds that abandoned or lost fishing nets continue to trap fish, turtles, birds and marine mammals for several years, a phenomenon called «ghost fishing».

In addition, marine litter has a negative impact on the tourism economy, fishing returns and poses a risk to marine navigation as it is likely to get caught in the propellers or rudders of vessels (Marek *et al.*, 2020). Water quality is also impacted by the presence of wastes loaded with harmful substances that can enter the food chain and could pose a health risk.

In order to evaluate the extent of this pollution and to determine its sources, several studies have been carried out worldwide. According to [5]; [6] and [7], the composition and density of wastes vary considerably from pole to equator as a function of wind, currents and marine hydrodynamics [8]. This is how all sites are affected by this type of pollution without borders.

On the seabed, the compilation of data from 16 studies covering the entire Mediterranean basin (see chapter 2.2.4) confirmed the importance of plastic at 62.7% +/- 5.47 of the total amount of waste [9]. This has also been confirmed by an analysis of regular monitoring data on the seabed in the Gulf of Lion [10].

 A study [11] analyzed sources of marine litter and estimated that 4.8 to 12.7 million tons of plastic were dumped into the ocean in 2010, with an average value of about 8.8 million tons. Analysis of the density of waste collected during trawling campaigns revealed that the most commonly recovered waste was plastic waste (found in 98% of trawls [12].

In the African region, a growing number of studies have focused on the accumulation of waste on beaches and in offshore surface waters, but there is little information on waste in deeper waters [13] and [14]. Marine litter can have a negative impact on fishing activities, which employ more than 12 million Africans. At the level of the Moroccan marine ecosystem, [15] studied the abundance of macro wastes on the coastal wetland of Martil, in the northeast showing that the majority of marine litter is made up of plastic (57%) generally coming from terrestrial sources (tourism, runoff) and commercial fishing, Other studies on the distribution of seabed marine litter by trawling in the southern Atlantic Ocean of Morocco [14] and the Mediterranean [16] show that the main source of waste was from fishing activities.

The accumulation and transport of waste in the marine environment, particularly in the depths, could have several origins, including the poor management of land-based waste, especially in coastal cities. Despite the fact that management in Morocco has improved over the past few years, the quantity of waste produced continues to increase as a result of economic growth and urbanization, national production of similar household waste (DMA) has increased from 6.3 to 7.4 million tons per year between 2007 and 2015 (World Bank, 2017). Only 10% of these DMAs were recycled in 2017, well below the 20% target set for 2020 by the Moroccan Ministry of Environment. The lack of well-used landfills in coastal towns is a factor which facilitates the dispersal of waste which could be transported in coastal areas and subsequently in the oceans. The National Institute of Fisheries Research, involved in environmental monitoring and as a major player in marine scientific research, is carrying out a number of actions on the study of pollution of the marine environment, including waste and micro-pollution in the context of the multidisciplinary project.

As part of the INRH PG1 program "Environmental Monitoring of Marine Environments and Ecosystems", a waste survey at the level of the Moroccan North Atlantic between Tangier and Sidi Ifni was carried out with the aim of assessing the state of pollution in this area by marine macro-litter. All the analytical results obtained relate to the census of quantities, the nature and the spatial distribution of the macro-waste collected at all the fishing stations scanned along this area.

2. Material and methods

2.1. Prospecting area

Waste prospecting was carried out at various stations along the North Moroccan Atlantic area between Tangier and Sidi Ifni by a bottom trawling campaign aboard the research vessel «Al Amir Moulay Abdallah» from 21 to 31 May 2022.

This campaign is generally part of the regular research activities of the INRH, relating to the direct evaluation and monitoring of the stock of demersal resources of the Moroccan coasts, and in particular, as part of monitoring the status of cephalopod stocks, including octopus.

Among the objectives of this campaign, the collection of waste recovered by trawling along the prospecting to assess the state of waste pollution.

The survey area was covered by a stratified random sampling network (Figure 1). Sixty (60) fishing stations (trawl lines), ranging from 28 meters deep to 140 meters, were carried out.
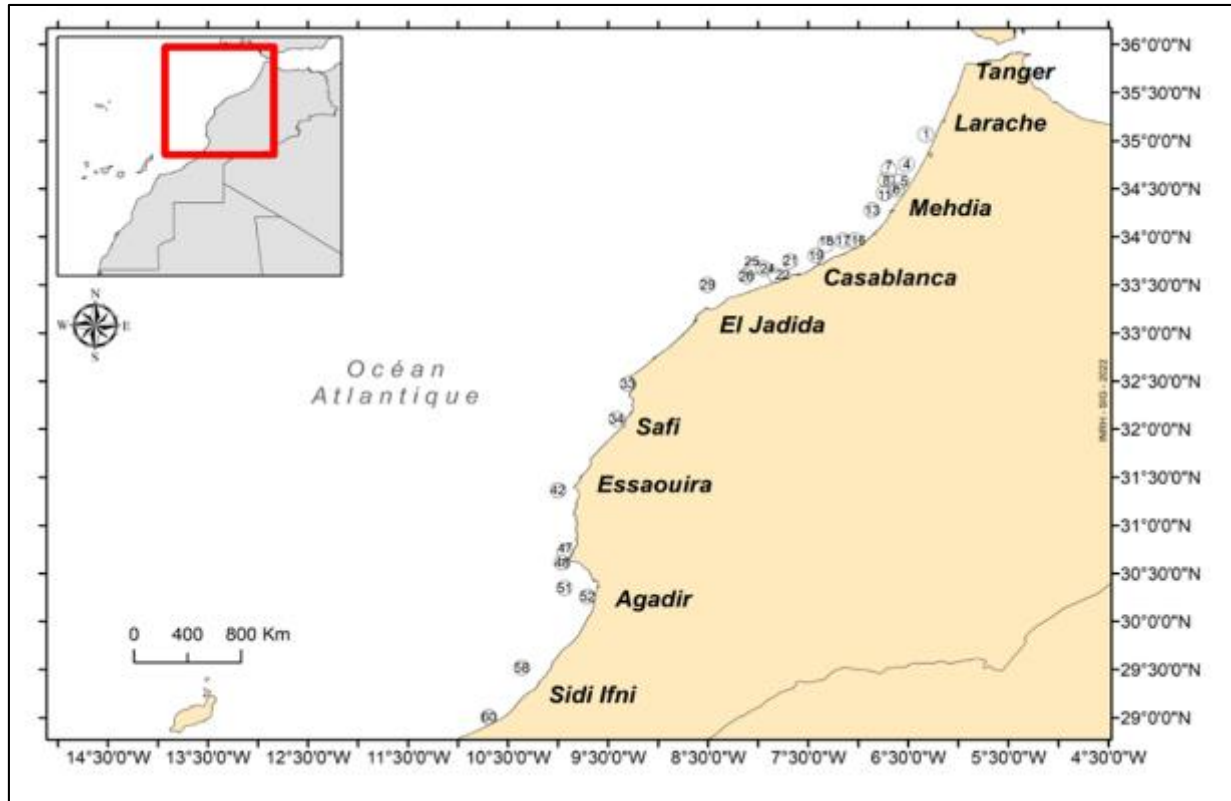

Figure 1 Distribution of trawl scanning stations in the North Atlantic (Tangier-Sidi Ifni) during the period 21 May to 1 June 2022 (INRH mapping service)

This coastal strip is characterized by a relief organization promoting the development of coastal lagoons and marshes of biological and ecological interest at the national and international level. It also facilitates a powerful movement of demographic concentration, which in a few decades has made the Atlantic coast the major axis around which are structured all the activities of modern Morocco and are concentrated the most important urban agglomerations. It concentrates most of the country's wealth creation activities, including large commercial ports.

In addition, the Moroccan Atlantic Ocean represents a receptacle of various watercourses coming from rivers such as Draa, Bouregreg, Oum Errabia and Sebou. These courses could be loaded with macro-waste and which can circulate and accumulate in marine waters and thus contribute to their pollution.

The Moroccan Atlantic coast is characterized by an active circulation whose resurgence of deep waters explained by the influence of the Upwelling phenomenon experienced by the Moroccan coasts due to the geographical situation of Morocco. A dynamic system that under the action of wind at the origin of the main currents such as the canary current (Figure 2) creates an upward vertical flow to the coast and brings on the continental shelf waters of subsurface origin. Namely, at the level of the Moroccan Atlantic, there are 4 upwelling zones: zone between Cap Cantin and Cap Ghir, zone between Cap Draa and Cap Juby, zone between Cap Boujdour and Dakhla and zone between Barbas and Cap Blanc [17].

2.2. Methodology

This survey was carried out using a stratified random sampling network consisting of 60 trawling stations with a standard duration of 30 minutes and a speed of about 3 knots.

The fishing gear used is a demersal bottom trawl. The trawl bag is 60 mm mesh and held open by a non-selective 20 mm mesh layer to study the benthic and semi-benthic populations as a whole.

Among the objectives of this campaign, the collection of waste recovered by trawling along the prospecting to assess the state of waste pollution

The research vessel was fitted with a two-sided GOC 73 bottom trawl with a vertical opening of 2 m, a horizontal opening of 15 m and a length of 40 m.

The duration of each trawl haul is 30 minutes with a trawl speed of about 3 knots. The positions of the trawling stations were chosen randomly for each depth stratum, the number of which may vary depending on the surface area of the strata and the type of bottom (trawlable or not).

The area swept by trawling at each station is estimated at 41670 m2 according to the following formula:

$$S= VxTxd$$

V: trawling speed (node)
T: trawl time (min)
D: Horizontal trawl opening in (m)
S= 30 x 92.6 x15
(3 node = 5.556 km/h = 92.6 m/min)

The density d of macro waste was calculated as follows [18]

d = n/S, where d is the density of waste per m2; n is the number of waste recorded; S is the area of each scanned station.

The waste samples collected from each station are returned in large plastic bags to the ecotoxicology laboratory and are identified, sorted and accounted for, and then super categorized according to the categorization grid.

3. Results

All recovered waste is classified into 18 categories according to the guidance document on the monitoring of marine litter in European seas, adopted by the EU MSFD Technical Sub-Group on Marine Litter, and UNEP/MAP MEDPOL IG.22/28"Monitoring Guidance Document on Ecological Objective 10: Marine Litter." The percentages of items in each category relative to all items collected are calculated (Table 1)

Table 1 List of waste collected at the Moroccan North Atlantic during the period 21 May to 01 June 2022

ID	STATAIONS	PLASTIC/POLYSTYRENE	Number	Weight	%
G3	ST 1		1	11.6	
G3	ST 5		1	5 g	
G3	ST 6		2	59g	
G3	ST 7		5	72,6	
G3	ST 8	Shopping bags (bag)	1	7,3 g	
G3	ST16		5	122.9	
G3	ST17		2	63,7g	34%
G3	ST18		2	83,7g	

G3	ST21		3	52,5 g	
G3	ST24		2	103 g	
G3	ST25		1	88 g	
G3	ST33		2	47 g	
G3	ST51		1	17,6 g	
G3	ST52		1	31,9 g	
G8	ST07	Bottles	1	19,6g	18.2%
G8	ST08		2	70.9g	
G8	ST16		2	203,9 g	
G8	ST26		1	277 g	
G8	ST33		1	53,5g	
G8	ST47		1	900 g	
G8	ST48		4	2620.4g	
G8	ST51		1	52,2 g	
G14	ST52	Can+Rope+Cement	2	1565 g	
G14	ST58		1	1192 g	
G10	ST16	Food container (clear package)	1	16,1 g	2.3%
G10	ST21		1	42,1 g	
G18	ST11	Crates and containers/baskets	1	268 g	12.9%
G18	ST18		1	225 g	
G18	ST21	(Crate Fragments)	2	65,2	
G18	ST22		1	83,5 g	
G18	ST24	Crates and containers/baskets	1	53,5 g	
G18	ST33	(Crate Fragments)	1	319 g	
G18	ST34		3	291 g	
G18	ST42		1	16 g	
G48	ST06	Synthetic rope	2	45,4g	10.5%
G48	ST07		2	44,9g	
G48	ST16		1	15,3 g	
G48	ST26		1	10g	
G48	ST47		1	14 g	
G48	ST48		2	90 g	
G51	ST06	Fishing nets	1	45,4	1.1%
G61	ST07	Waxed and Wax Fragment	1	756g	4.7%
G61	ST29		1	196 g	
G61	ST33		1	500 g	
G61	ST52		1	336 g	
ID	**STATIONS**	**RUBBER**	**Number**	**weight**	**%**

G125	ST07	Balloons	1	79g	1.17%
G127	ST52	Rubber boots	1	998 g	1.17%
ID	STATIONS	TISSUE/TEXTILE	Number	Weight	%
G137	ST13	Clothing	1	530 g	3.5%
G137	ST19		2	401 g	
G145	ST 60	Sock	1	165,8 g	1.17%
ID	**STATIONS**	**PAPER/CARDBOARD**	**Number**	**Weight**	**%**
G150	ST 29	Box milk	1	55 g	2.3%
G150	ST 48		1	45,9 g	
ID	**STATIONS**	**TREATED WOOD**	**Number**	**Weight**	**%**
G173	ST 33	Shaft Branch	1	36,5 g	1.17%
ID		METAL	Number	Weight	%
G176	ST4	Canned goods	1	22.7	1.17%
G194	ST 24	Cable	1	24,3 g	%
G197	ST18	(Gillette razor)	1	7 g	1.17%
ID	**STATIONS**	**SANITARY WASTE**	**Number**	**Weight**	**%**
G96	ST17	Sanitary napkins	1	14 g	1.17%

Among the 17 categories of waste found, shopping bags (G3) represent the highest percentage, with 34% (29 items) of the total items recorded in the entire surveyed area, followed by bottles of different sizes (G8 and G14) which represent 18.2% (16 items) of which those of G14 are used as an artificial support for the deposit of eggs (cans are filled with cement and ropes) (see photos). The G18 wheat packing cases with 12.9% (11 items) are the third largest category, followed by synthetic ropes (G48) and waxed fragments (G61) with 10.5% (9 items) and 4.7% (4 items) respectively (Figure 2).
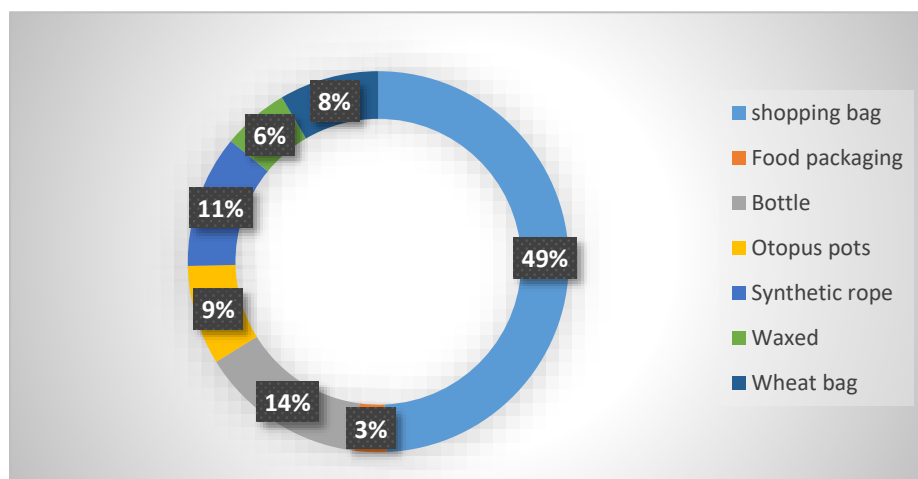

Figure 2 Categories of plastic macro-waste found in the North Atlantic

Other categories mentioned in the table such as clothing/cloths (G137), cans (G176), rubber boots (G127), sanitary towel (G96) and cardboard box (G148) Among the 85 items found, they are poorly represented and vary between 1.17% and 2.3%. The most important elements differ from station to station (Figure 3).

Figure 3 Example of marine litters collected in the North Atlantic during the period 21 May to 1 June 2022

3.1. Abundance of marine litter

Of the 60 stations swept by the trawl, only 27 showed a presence of waste of different kinds, these stations focus mainly on the axis between Mehdia and El Jadida. At the 33 other stations, the majority of which are on the coastal axis between El Jadida and Sidi Ifni, no waste was recorded during navigation. (Figure 4).
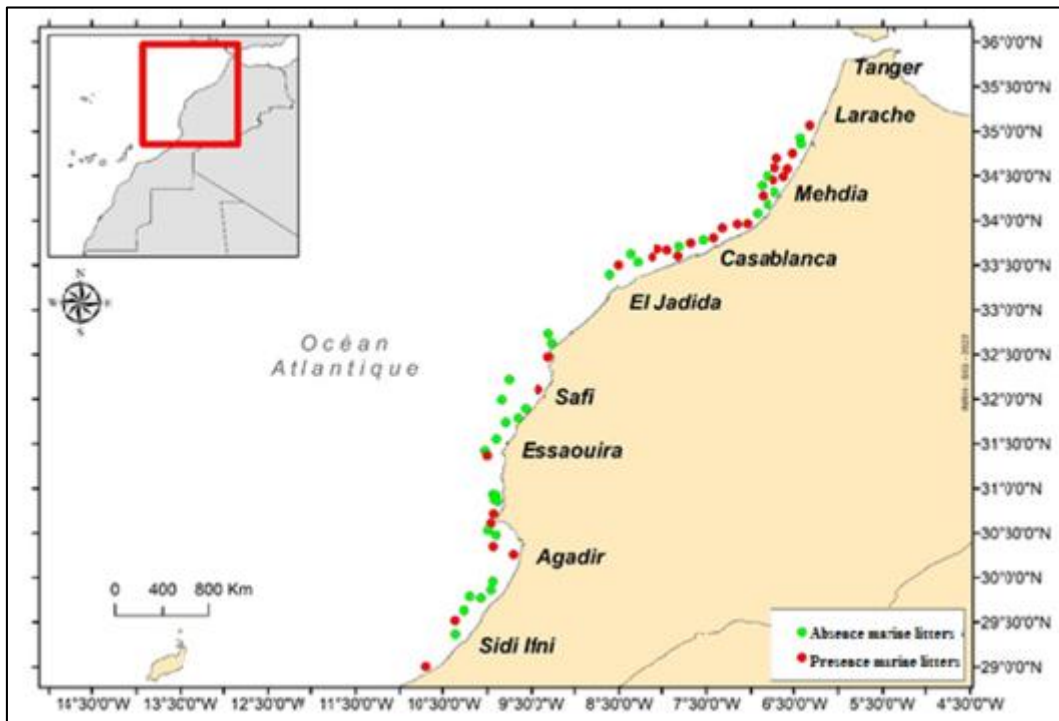

Figure 4 Location of marine litter in the North Atlantic between Tangier and Sidi Ifni during the period 21 May to 01 June 2022 (INRH mapping service)

The average abundance of marine litter collected from waste treatment plants expressed in items/m2 was calculated to be 76.5 ± 59.9 items/km2. The highest density of 240 items/km2 was recorded at station 7 in Mehdia (Rabat region) (Figures 1 and 2). The lowest values of 24 items/km2 are recorded in Essaouira and Agadir and at some stations in the Larache region.

In terms of weight, the largest masses of waste estimated at 2.930 kg and 2.68 kg are found respectively at stations 48 and 52 in the Agadir region. Densities vary between 0.19 kg/km2 and 64.4 kg/km2 and the average density is estimated at 11.19 ± 17.7 kg/km2. The lowest quantities are recorded at stations 1, 4 and 5 between Larache and Mehdia (Figure 5)
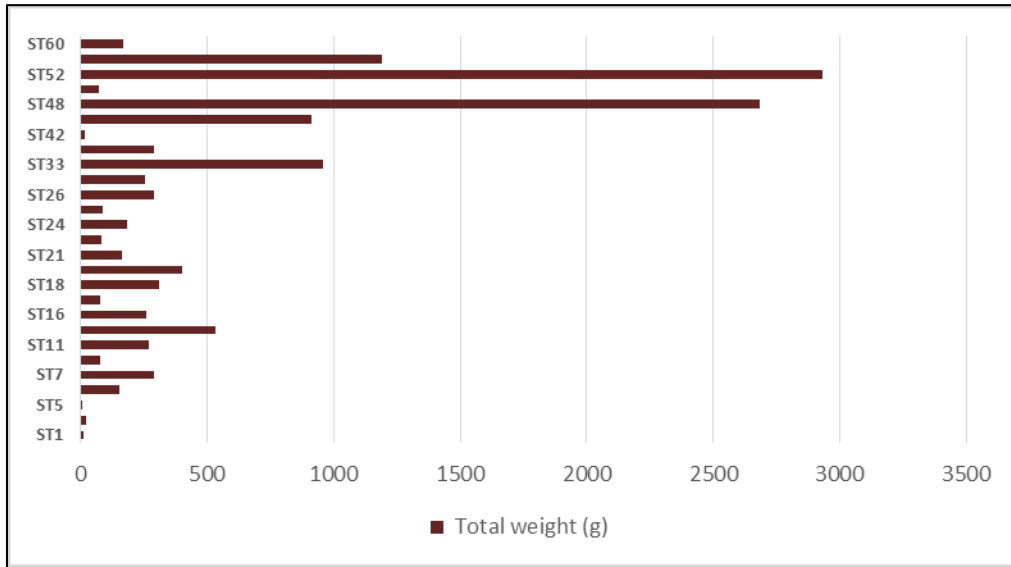

Figure 5 Distribution and quantification of waste in the Moroccan North Atlantic

All items recorded at the waste sites are estimated to be 85 items ranging from 1 item to 10 items with a total weight of 13,545 kg. The majority of these items are classified as waste from fishing gear and single-use plastic (Figure 6)
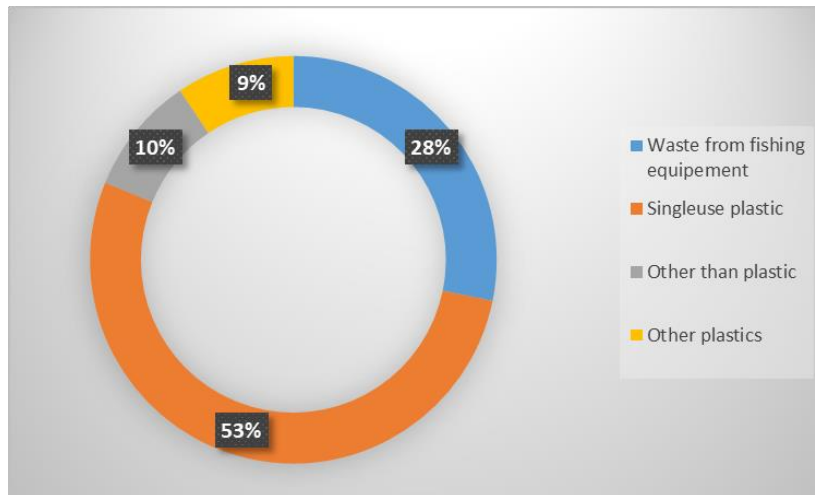

Figure 6 Source of waste collected in the North Atlantic

3.2. Composition of marine litter

Registered marine litter was classified into 7 groups of material types (Figure 7)

The vast majority of waste (81%) is made from plastic, a category of waste dominant on the coastal zone between Tangier and Sidi Ifni. The second largest groups of waste items are rubber and fabric/textile with 9% each, while metal, paper/cardboard, wood and sanitary waste account for only 0.42%, 0.79%, 0.28% and 0.11% of total waste, respectively.
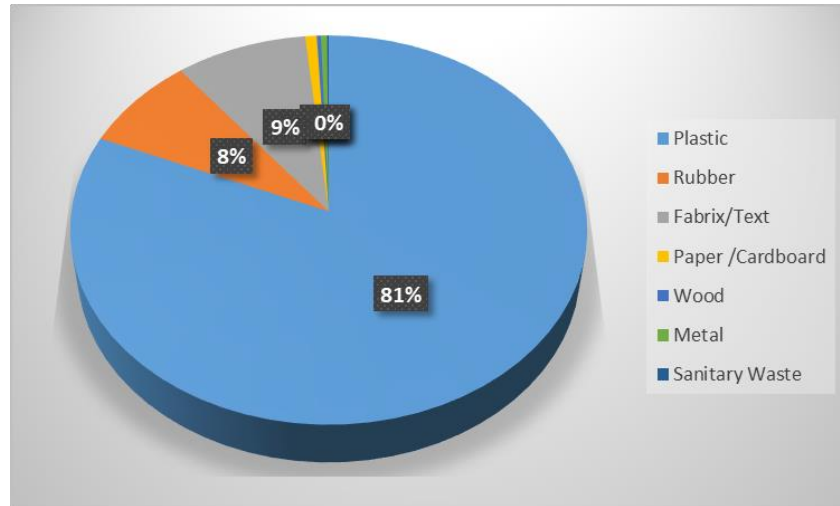
Figure 7 Percentage (%) of total waste by category type at North Atlantic

In most stations, plastic waste is dominant in terms of weight and density. At station 4 located in the region of Mehdia, only one metal item (sardine box) was collected. Similarly, at station 13 and station 60 respectively from the region of Casablanca and the region Sidi Ifni, the only type of waste found is the fabric. Sanitary waste was recorded in small quantities on the axis between Mehdia and Casablanca (Figure 8)
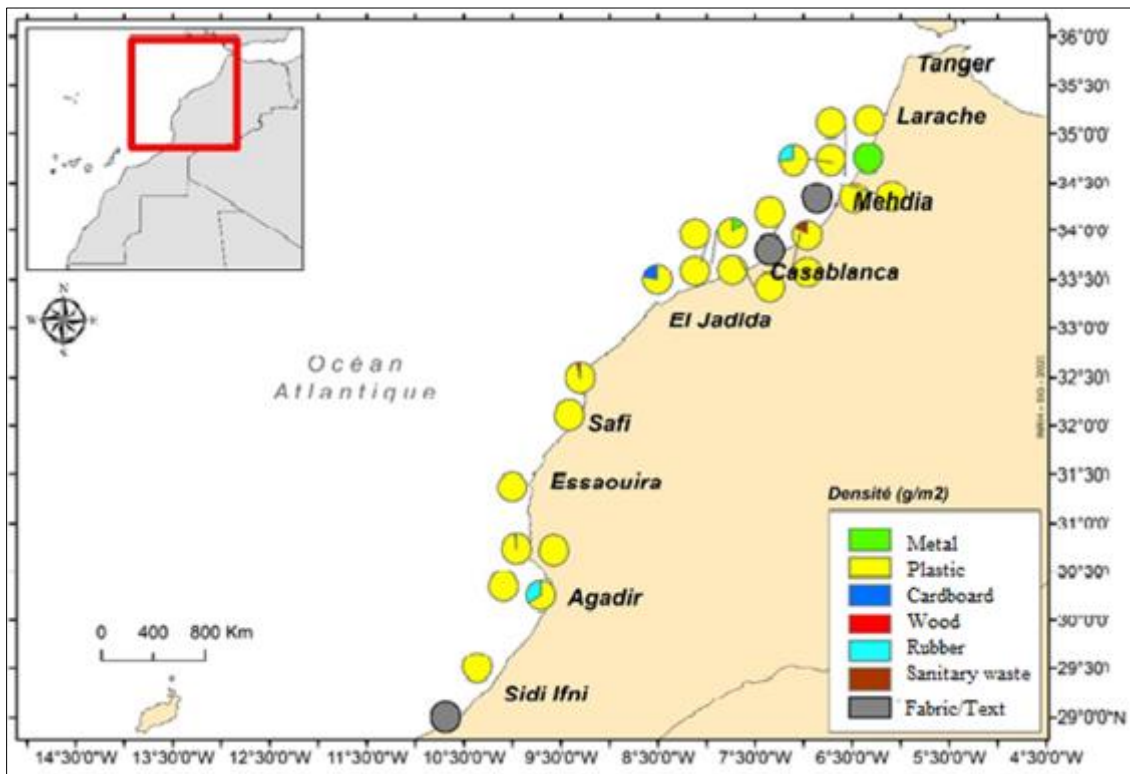

Figure 8 Distribution and composition of waste in the North Atlantic in terms of density

4. Discussion

In recent years and following the magnitude of the danger of marine pollution, in-depth studies on marine litter in Morocco have been carried out at both the Atlantic and Mediterranean seas.

In the North Moroccan Atlantic, the data on seabed waste from the northern part of Morocco's Exclusive Economic waters in the Atlantic Ocean (a single campaign) showed that about 81% of the total waste recovered was plastic, the

majority of which were plastic supply bags, plastic bottles, plastic waxes and fragments of waxes, as well as plastic pots used to capture octopus (*Octopus vulgaris*), or as artificial refuges for depositing female Octopus eggs. This result is similar to the one reported by Loulad et al who found in 2017 that plastics represent more than 50% in the South Moroccan Atlantic [14], and about 73% in the Mediterranean in 2019[16] during the scientific work that was published on the study of abundance, distribution and composition of marine litter on the seabed of the southern part of Morocco's exclusive economic waters in the Atlantic Ocean and the Moroccan Mediterranean.

The average quantities of waste recorded along the North Atlantic Exploration Area range from 0 Kg to 2.93 kg, and the number densities reported in this study range from 24 items/km2 to 240 items/km2 and in terms of weight, they vary between 0.12 Kg/Km2 and 64.4 kg/km2 with an average density of 11.19± 17.7kg/km2, this value remains low compared to that recorded by Loulad et al in 2017 in the south Moroccan Atlantic (0 to 1768 kg/km2) [14], and by Rhinane et al in 2019 (16.84 ± 20kg/km2) [19] at the North and Central Moroccan Atlantic, but almost similar to those published in 2017 at the Moroccan Mediterranean for the period 2012 to 2015 (26 ± 68 Kg/km2 to 80± 133 Kg/km2). The largest concentration of waste was discovered in the Agadir region, is confirmed by Rhinane et al in 2019[19]. In comparison with other stations, this density could be a consequence of the large coastal urbanization, riverside influxes and increasing maritime traffic in this region.

In general, these levels of waste vary greatly and are subject to factors such as nearby urban activities, coastal and coastal uses, winds and currents.

On an aggregate basis, metal, wood, sanitary waste and paper/paperboard related items represented a small percentage ranging from 0.11% to 0.79% of all items collected at 27 stations, these values are similar to those found in the Moroccan Mediterranean, but remain low in comparison with those of a study conducted in the eastern Mediterranean explained by maximum values of 21.9% of metals and 22,4% of glass and ceramics [20]

Among of the collected waste, a significant share (53%) represents single-use plastic waste (food bag, can and bottles), followed by a 28% of waste related to fishing, including nets and ropes that predominate in commercial fishing areas. Across the world's oceans, it has been estimated that 640,000 tons of ghost nets are scattered, or 10% of marine litter (UNEP, 2009). The presence of this type of waste could be attributed to shipping and fishing activities as sources of pollution.

Sources of marine litter are traditionally categorized as land or marine sources, depending on where they enter the water. Other factors such as ocean currents, climate and tides, as well as proximity to urban centers to waste disposal sites, industrial and recreational areas, shipping lanes and commercial fishing grounds influence the type and amount of marine litter found in open ocean areas or collected along beaches and in the ocean, including underwater areas. In general, marine litter enters the ocean from both land-based and ocean-based point and non-point sources, and can travel long distances before being deposited on shorelines or on the ocean floor, on land, at sea or in bays. Accidental release of litter from coastal landfills and litter from water transport, recreational activities on beaches, illegal dumping in coastal and marine waters, are all practices that contribute to the problem of marine litter. Marine litter can be transported indirectly to the sea or the coast by rivers, sewers and storm water outlets, runoff, and flooding during storms, or can be brought by the winds. Land-based sources are tourism and recreational use of the coast, landfills and landfills, wild dumps, local businesses, industry, ports and unprotected waste disposal sites.

The plastic items found (81%) of which the majority are shopping bags, bottles and canisters are strongly linked to land-based sources and likely reach the ocean as a result of beach activities, brought by the winds and the circulation of water, especially since the Moroccan Atlantic area is characterized by the presence of the Upwelling phenomenon, thus facilitating the movement of this waste towards the bottom, or transported by the waterways, the rivers that flow into the Atlantic Ocean, such as Bouregrag, Oum Errabia and the Sabou River, and the rainwater and sewage that flows into the ocean. A recent study [11] analyzed sources of marine litter and estimated that between 4.8 and 12.7 million tons of plastic were released into the ocean in 2010, with an average value of about 8.8 million tons, with about 2% litter on the beaches. (US National Marine Litter Studies). Food and household waste, including sanitary waste (0.42), can be classified both in the category of coastal and recreational activities and in the category of crews/passengers on board all types of vessels and of boats+

Abbreviations

- COP: Conference of the Parties
- UE: Union European
- UNEP/MAP: United Nations Environment Program/Mediterranean Action Plan

- INRH: Institut Nationale de Recherche Halieutique
- MSFD: Marine Strategy Framework Directive (2008/56/EC)
- MED POL: Program for the Assessment and Control of Pollution in the Mediterranean Region
- NOAA: National Oceanic and Atmospheric Administration (US)

5. Conclusion

Following the prospection of the seabed waste of the northern part of Morocco's exclusive economic waters in the Atlantic Ocean, a large part of the articles found (81%) on most of the scanned stations were single-use, short-life plastic items such as food bags, bottles and cans used as Octopus pots and some fast-food containers. Other items, other than plastic, were identified (rubber, fabrics and metal), but with small percentages of the total registered waste. These wastes could be the source of different sources, but based on the waste categorization, the main source is related to fishing activities. In general, marine waste pollution is the result of poor waste management, whether at sea or on land. Among the root causes of the accumulation of waste at sea is the linear use of resources from their production to their final disposal, through their unique and short-term use. Therefore, management measures should focus on educating users (consumers and citizens) and, on the other hand, the full implementation of circular economy programs and/or policies aimed at significantly reducing the use of these products (for example, the prohibition or collection of a tax on single-use plastic products).

Compliance with ethical standards

Acknowledgments

Disclosure of conflict of interest

The authors declare that they have no competing interests

Statement of ethical approval

The present research work does not contain any studies performed on animal's/humans subjects by any of the authors'.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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