THE SEAFLOOR MARINE DEBRIS ON THE NORTH AND THE CENTRAL PART OF THE MOROCCAN ATLANTIC WATERS FROM TANGIER (35°N) TO SIDI IFNI (29°N): COMPOSITION, ABUNDANCE, SPATIAL DISTRIBUTION, SOURCES AND MOVEMENT

H. Rhinane[1], R. Houssa[2], S. Loulad[1]*

[1] Faculty of Science, University Hassan II Casablanca, Morocco
[2] National Institute of Fisheries Reseach Casablanca, Morocco

KEY WORDS: marine ecosystem, Seafloor marine debris, trawling surveys, GIS, spatio-temporel pattern, hydrodynamic properties

ABSTRACT:

The accumulation of human debris in the marine ecosystem is one of the main hidden negative impacts of the economic and social development that humanity has witnessed after industrialization era which comes accompanied with the evolution of productions, the consumerism, as well as the emergence of the throw-away culture. In this paper, we studied the marine debris pollution on the seafloor of the North and Central Moroccan Atlantic waters from Tangier (35°N) to Sidi Ifni(29°N). The data were collected during two scientific trawling surveys conducted aboard the Charif Elidrissi Vessel in February-March 2015 and March 2018. The prospection operations allowed to collect a total of 329kg of Seafloor Marine Debris (SMD) with an average abundance ranging between 16.84 ± 20kg/km^2 to 30.15 ± 43kg/km^2. The plastic materials represented the higher percentage of collected items with more than 40% followed by textile debris which mainly composed of knotted fishing ropes used by the longliners in the area. The analysis of SMD composition and their Spatio-temporal pattern combined with the environmental and socio-economic parameters of the prospected area using GIS tools showed that the majority of collected items comes from fishing activities, and the rest comes from the coastal anthropogenic activities. Then the analysis of hydrodynamic properties of the area using AVISO data showed that the horizontal current in area that controls the exchange of water from the coastal area to the ocean interior plays a major role in scattering debris in this area far from their origins to the open ocean.

1. INTRODUCTION

The industrial revolution of the 18th century has led to many drastic changes in the relationship of the human being with his environment (Davood et al., 2015). It dramatically affects the ecology of the earth (Kazemi, Ghorbanpour, 2017), caused a series of direct and indirect impacts on several aspects of human beings life (Dancea, Merce, 2009) and consequently contributed to the deterioration of our environment (Choudhary et al., 2015) (overexploitation of energy, depletion of natural resources (Giljum et al., 2009), increase in harmful emissions resulting from massive industrial activities (Hunter, 2000), and many kinds of pollutions, climate change, and global warming (Ahuti, 2015)).

One of the prolific and indirect impacts of this era was the accumulation of anthropogenic litters on nature (Woodall et al., 2014), due to human, the evolution of the production and the consumerism (Flacher, 2005) as well as the emergence of the throw-away culture. According to (Barles, 2014), the waste has become over the years an index of the deviations of a consumer society.

The marine ecosystem has been recognized as one of the main receptors environment of almost of mismanaged human-made waste (McDermott, 2016). Due to years of littering, it becomes entirely filled with many external items of different sizes, shapes and types (Dan Wilhelmsson, 2013), generated from different anthropogenic origins either from land-based or sea-based activities (Jeftic et al., 2009), and reaching the marine environment by rivers, sewage, rainfall, stormwater, winds, land run-off (MSFD, 2016), natural disasters (UNEP/MAP, 2012, Thompson et al., 2004) or during maritime activities (as fishing or aquaculture) (A. Trouwborst, 2011).

The estimated annual input of litter entering the ocean exceeds 10MT according to the Ifremer, 15% of them floated on the sea surface, 15% on the water column and 70% sunk to the seabed (UNEP, 2015). The majority of these debris were composed of plastic (more than 50%) especially the single-use plastic (McDermott, 2016). According to (Jambeck et al., 2015), the annual input of land-based plastic debris per year is ranging between 4.8 and 12.7 million tons, 5 Trillion floated pieces floated on the sea surface according to (Eriksen et al., 2014) estimations (weighing 250,000 tons in total). At this annual rates of inputs, the amounts of plastic available to enter into the ocean may exceed 250 Mt by 2025 (Jambeck et al., 2015), and the accumulated quantity will outweigh the marine species by 2050 according to the Ellen McArthur Foundation predictions (https://www.ellenmacarthurfoundation.org).

Litterature showed that this phenomenon affects all the marine areas from the shoreline to the bottom (Gall, 2015, Thompson, 2017), no place or species are immune in the marine ecosystem. It was detected in sediment (Willis et al., 2017) in phytoplankton, in fish (Lusher et al., 2013), in seabird (Tanaka et al., 2013), in zooplankton (Cole et al., 2013), in amphipods (Thompson et al., 2004), etc).

Besides the widespread, this pollution caused a wide range of negative effects on marine wildlife (through entanglement, ingestion, transport of chemicals and alien invasions) (R Gregory, 2009, Gregory, 1999, Gall, 2015), on the economy (Newman

*Corresponding author

et al., 2015), and on the human safety and health (Smith et al., 2018).

Here we present the first assessment of seafloor marine debris in the north and the central part of the Moroccan Atlantic, from Tangier (35°N) to Sidi Ifni(29°N), using data collected during two scientific trawling surveys conducted on February-March 2015 and March 2018 with the Moroccan Institute of Fisheries Research using Charif El Idrissi vessel.

The aim of this study is to understand the problem of seafloor marine debris from the sources until the final area of accumulation. This result may contribute to creating a global overview of the distribution of marine debris all over the world seas and oceans in order to prevent or at least mitigate the impacts of this problem.

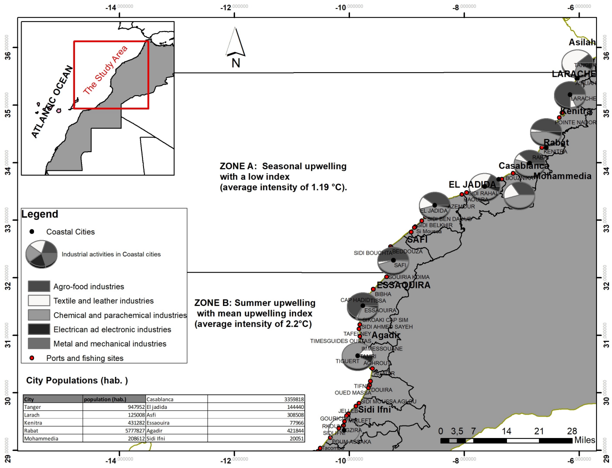
2. MATERIAL ANS METHODS

2.1 Study Area

The North and the Central part of the Moroccan Atlantic, from Tangier (35°N) to Sidi Ifni(29°N), it's a very regularized and less divided coast compared to the Mediterranean, marked by a succession of large concave and convex parts (Collignon, 1965). In addition, it characterized by the presence of large sand dunes covering the coast, a set of capes and cliffs (e.g cliffs between Safi and bedouzza (Weisrock, 1985), lagoons (e.g lagoon complex Sidi Moussa-Oualidia), estuaries, bays (e.g. Agadir Bay) and rocky flats. The continental shelf is very heterogeneous; narrow in some parts and very wide in the others (Collignon, 1965). The hydrographic network is very strong, composed of numerous rivers that flow directly in the Atlantic ocean (e.g. Sebou and Oum-er-Rbiâ, Loukkos, Bou Regreg, Tensift and Souss, Massa, Draa, etc) (Laouina, 2010).

Hidrodynamiqually, the Moroccan Atlantic Coast is part of the Canary Current Upwelling System, which extends from the Iberian Peninsula (43°N) to the south of Senegal (8°N), one of the world's four major Eastern Boundary Upwelling Ecosystems (Barton et al., 1998). The seasonal variability of the trade winds between winter and summer induces pronounced coastal SST anomalies and hence a strong seasonal variability of the upwelling in the area. This movement divided the Moroccan Atlantic into four homogeneous areas of different properties (Makaoui et al., 2005) two of them was in the North and the Central part of the Moroccan Atlantic; Zone A between 32.2 and 35.6°N has a strong seasonality with a low up-welling index (average intensity of 1.19°C), zone B (28 and 32°N) (INRH, 2014)(Figure 1).

In addition, This Area constitutes the nerve center of Morocco's economy, according to (Nakhli, 2010), especially Kenitra-Safi axis which concentrates 60% of the industrial units in the country (agro-processing industries, Chemical and petrochemical industries, electronics and mechanics, textiles as well as the heavy industrial activities such as the petrochemical, refining, and phosphates). In addition, it comprises several cities with commercial, industrial and tourist functions (Grand Casablanca, Kenitra, Safi-Jorf Lasfar, El Jadida, Agadir). Concerning the fishing sector, this zone was very rich in biological resources according to the (FAO, Organisation des Nations Unies pour l'alimentation et l'agriculture, 2003). The most important fishery resources exploited and the high demand in foreign markets were the pelagic fishery with a strong dominance of sardines (Sardina Pilchardus), the white hake (Merluccius Merluccius) and the Pink shrimp (Parapenaeus Longirostris) (INRH, 2014).



City	population (hab.)	Casablanca	3359818
Tanger	947952	El jadida	144440
Larach	125008	Asfi	308508
Kenitra	431282	Essaouira	77966
Rabat	5777827	Agadir	421844
Mohammedia	208612	Sidi Ifni	20051

Figure 1. The location of the studied Area between Tangier (35°N) to Sidi Ifni (29°N).

2.2 Surveys Methodology

Marine litter was collected during two trawling surveys organized by Moroccan Institute of Fisheries Research from Tangier to Sidi Ifni at two different periods, the first in February-March 2015 with 117 surveyed stations and the second in March 2018 with 101 hauls on board of Charif El Idrissi Vessel. The chosen sampling network was the same during both surveys from Larach to Sidi Ifni. By contrast, the area from Tangier and Larache was prospect only during the first survey and cancelled in the second due to some pre changes of the prospection plan by the Moroccan institute of fishery research.

Many data were recorded at each sampling event as the geographical position of the center (decimal degree), the surface temperature (°C), the depth (m), the seabed nature (sandy / muddy), the wind direction, and the quantity of all categories of SMD (kg) after dried, sorted, classified them depending on the material that they are made of.

2.3 Analysis Methodology

After the turn of the trawl, a multidimensional analysis was performed to study the SMD distribution in the study area. First, the abundance of debris was calculated in kg/km^2. Second, the analysis of distribution was done using two spatial tools Moran index I for the autocorrelation analysis (Zhang, Lin, 2007, Getis, 2008)and Kernel Density Estimation KDE for the hotspot mapping (B.W. Silverman, 1986). Third, the analysis of influence was realized using Generalized additive model (GAM) (M. CLARK, 2014) to understand the influence of the depth and the distance to the coast on the SMD recorded abundances. And finally, the Analysis of movement using the hydrodynamic data to determine the movement process of debris and their deposition (Figure 2).

3. RESULT

The total amount of SMD collected during the prospection surveys was 320kg in total; 143kg in 2015 and 186kg in 2018. The average calculated abundance differed from one period to the other. It reached 16.84 $\pm$ 20 kg/km^2 in the first survey and increased to the double in the second one (30.15 $\pm$ 43kg/km^2).

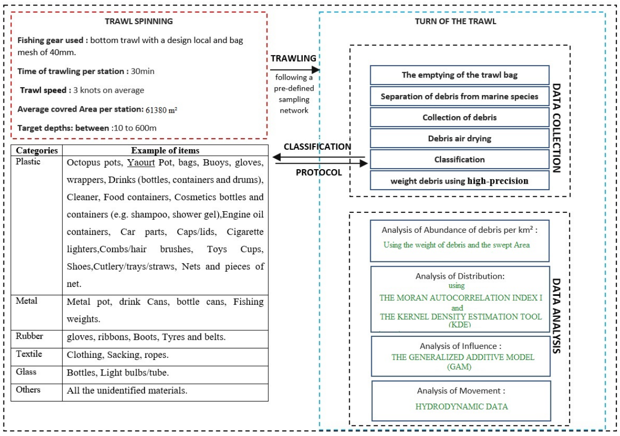


Figure 2. The methodoloy used to analyze the distribution of seafloor marine debris in Moroccan waters.

The debris collected was mainly composed of plastic bags, octopus pots, glass and plastic bottles, rubber gloves, knotted fishing ropes, and some unidentified materials (Figure 3). The highest relative common frequencies between both surveys were observed close to the common highly urbanized regions in the prospected area (e.g. Casablanca, Agadir, Kenitra).

Figure 3. Examples of marine debris items collected during the prospection surveys in the prospected area.

3.1 Analysis of composition and abundances

Based on the material type classification protocol, six broad categories of litters were extracted (Plastic, textile, metal, rubber, glass, and the last category that regroups all the unidentified materials). Two classes represent the most dominant categories of debris. First, the plastics items (mainly composed of a great number of octopus pots with 1kg of plastic in each one, bags, bottle, etc.). Second, the textile materials (composed of knotted fiber fishing ropes), generally used by the long lines). The remainder of collected items were recorded with low quantities as the glass debris composed of glass bottles, the metal debris composed of cans, the rubber litters composed of car tires, gloves, and finally, a category regrouped all the unidentified collected litters (Figure 4).

The analysis of the abundances of these classes has shown some significant differences between the two prospection surveys. In 2015, The anthropogenic debris was found in 40 tows out of 117 executed, the densities recorded in a single 30-minute tow were ranging between 0 to 513 kg/km^2, mostly consisting of plastic materials with an average density of 6.78 ± 32kg/km^2, while the highest value (328 kg/km^2) was recorded in a sample located at the North of Agadir where 22 plastic pots of Octopus Vulgaris have been collected. Then the textile materials were ranked the second most common category with 5.87 ± 45kg/km^2, followed by metal debris with 2.12 ± 20kg/km^2, rubber debris with 0.12 ± 1.35kg/km^2, glass debris with 0.05 ± 0.42kg/km^2. Finally, the unidentified materials represented an average density of 1.91 ± 15.11kg/km^2.

For the second prospecting survey (March 2018), the litters were recorded in 71 tows from 101, the calculated densities per station were ranging between 0 to 803.5 kg/km^2. The plastic debris, as the first survey and the majority of studies around the world (e.g. (Galil et al., 1995, Galgani et al., 1996, Ramirez-Llodra et al., 2011) represented the most dominant category accounting for 16.07 ± 69.35 kg/km^2 followed by textile debris with 12.72 ± 89.91 kg/km^2, rubber debris with 0.74 ± 4.66 kg/km^2, glass debris with 0.19 ± 0.8 kg/km^2, metal debris with 0.03 ± 0.29 kg/km^2 and finally the unidentified materials with 0.38 ± 3.38 kg/km^2.

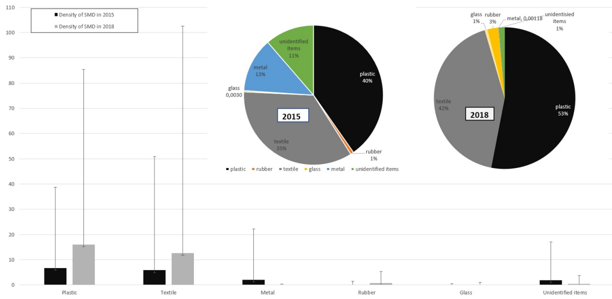


Figure 4. The average abundance of each category of debris collected in the prospected area in (kg/km^2).

3.2 Analysis of Spatial variability of SMD

The SMD was distributed in a discontinuous manner throughout the study area (Figure 5). In general, the highest densities of man-made debris were recorded in low and medium distances to the coastline, and at different depths especially between 0 to 100 meters. The variation in recorded densities between surveys allowed to subdivide the area on three parts of common characteristics. The first unit between Larache and Casablanca showed some relatively high density values recorded at the majority of prospection stations closer to the coast, especially near to Casablanca, Kenitra and at the mouth of Sebou in both prospection periods, and along Larache and Kenitra axis in the second survey. The second unit between Casablanca and south of Essaouira, indicated significant differences in distribution between both prospection surveys because it was surveyed during very difficult weather conditions with tides exceeding 4m in some days in both surveys which may influence the trawling operations and make the prospection difficult to impossible in some cases. In 2015, the SMD was found in distance so far from the coastal line and at higher depths, representing densities relatively low to moderate ranging generally between 0 to 18kg/km^2, except one station prospected near to Safi where the density exceeds 513kg/km^2. While in 2018 survey, the quantities of SMD collected were higher than the first survey, they are distributed in distances ranging between 2 to 33NM far from the coast and at depths ranging between 28 to 300m, but the average density per station was approximately the same to that recorded in the first survey (between 0 to 18kg/km^2) except for 3 prospected stations where the recorded density exceeds 50kg/km^2. The last unit between the South of Essaouira and Sidi had significantly higher densities of SMD than the second zone. they were distributed between 4 to 40NM far from the coast at different depths. Their abundance reached 256kg/km^2 as a maximum score in the first prospection survey and 803kg/km^2 in the second, recorded both on the periphery of Agadir.

The Measurement of spatial autocorrelation using the global Moran I index (Esri environment, ArcGIS) applied on the location of the stations and the weight of collected debris values (kg), showed that the overall distribution pattern mode of SMD was the same in both surveys for all categories. The pattern of plastic items was well-structured with a less than 1% probability of random dispersion. By contrast, the other categories models reflected a tendency to a random dispersion in the space (Table 1).

Servey	**Input Field** The density of different categories of SMD	**Z-score**	**Interpretation**
February -March 2015	**Plastic**	1,50	Probability of less than 10% of this cluster than model could be the result of random distr-. of ibution.
	Textile **Metal** **Rubber** **Glass** **Other**	-0,30 -0,12 -0,45 -0,57 -0,77	Model does not seem to be very different than random.
March 2018	**Plastic**	1,50	Probability of less than 10% of this cluster model could be the result of random distr-. of ibution.
	Textile **Metal** **Rubber** **Glass** **Other**	-0,35 -0,68 -0,7 -0,127 -0,5	Model does not seem to be very different than random.

Table 1. The application of the index of spatial autocorrelation (Moran I) to all categories of SMD collected in the surveyed area in February-March 2015 and March 2018 surveys. The calculated Z-score indicates the statistical significance given the number of features in the dataset.

The KDE estimation technique showed a remarkable spatial variability of distribution between the prospection surveys (Figure 6). Generally, two common hot spot areas were recorded, the first between North of Kenitra to Casablanca and the second from the south of Safi to the South of Agadir. While the middle of the prospected area (between Casablanca and Essaouira) showed different distribution aspects between 2015 and 2018 surveys.

3.3 Analysis of influence

The analysis of relations between the bathymetry / the distance to the coast and the abundance of debris showed that no linear and direct relationships exist between these two parameters and the SMD abundance variations.

Using the GAM model, we found that in a total of 117 stations prospected in 2015, plastic debris was widely distributed in a distances from the coastal line exceeding from 3 to 15NM and at depths extended from 10 to 230m, whereas textile debris was found from 3 to 15NM especially in the depths strata between 10 to 150 m, rubbers were found at distance low than 13NM

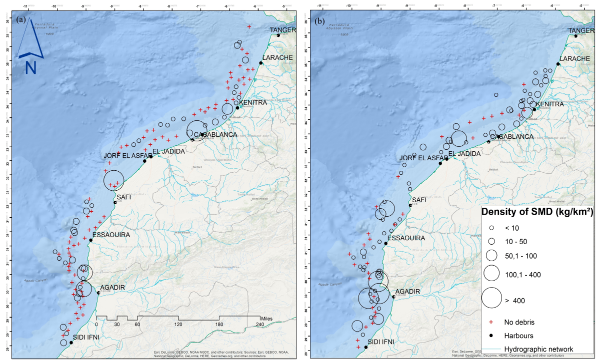


Figure 5. The spatial distribution of SMD between Tangier and Sidi Ifni during the both prospection surveys on board of the charif Al Idrissi vessel.(a) in 2015,(b) in 2018.

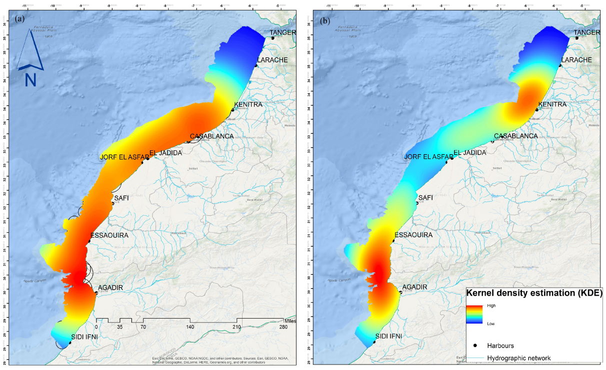


Figure 6. The prediction map of debris distribution using kernel density tool (KDE).

between 100 to 350m of depth, metals were recorded between 5 to 12NM at depths ranging between 40 to 180m depth, glass debris were generally found at distances low than 7NM between 10 to 100m depths and finally the unidentified collected materials were dispersed in a distances to the coastline less than 10NM and at depths doesn't exceed 150m (Figure 7).

However, in 2018 the majority of debris were found usually at a low and medium distance from the coastline at 4 different depths ranging from 25 to 732 meters. The plastic debris was distributed in distance exceeding 15NM and at depths extended from 25 to 150m and from 500 to 700m. The textile debris was collected in 4-17NM from the coastline and at two strata depth ranging between 20-220m and 340-700m. For the rubber debris, they were concentrated in distances ranging between 5 to 14 and 20 to 38NM and at depths ranging between 315 to 610 m, the metal debris was concentrated between 310 to 610, depth and between 17 to 30 m far fromd the coast. The glass debris showed the same overall accumulation pattern as the metal materials. The unidentified items were recorded between 40 to 80NM and at depth up to 250m Figure 8).

4. DISCUSSION

The anthropic marine debris pollution affected the Atlantic Ocean as all the world oceans and sea but with different quantities; sizes and compositions. Research have highlighted five massive accumulation gyres of human trash in the world (garbage patches),

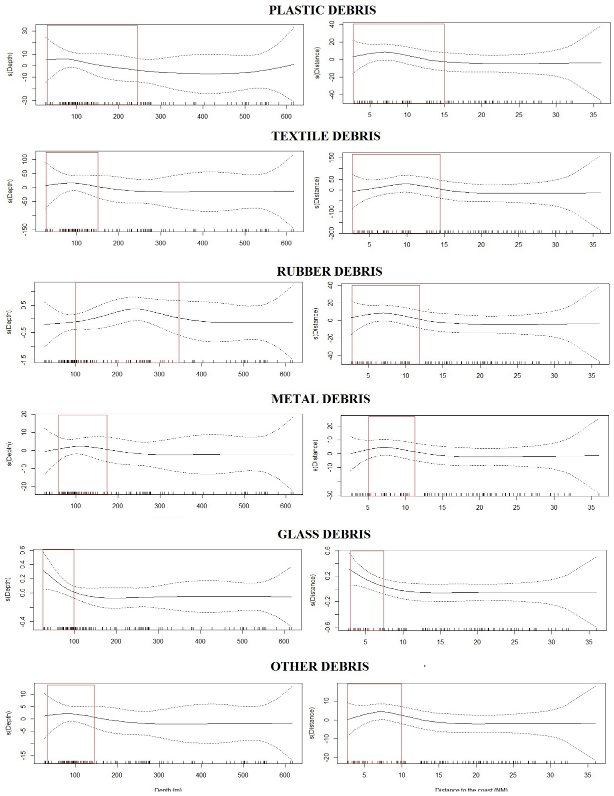


Figure 7. Analysis of relationships between the average density of different categories of collected SMD in 2015 and the depth / the distance to the coastline using the generalized additive model (GAM).

two of them exist in the Atlantic waters. The first was discovered for the first time by (Carpenter, Smith, 1972) in the North Atlantic, specifically in the Surgass Sea near to 30°N. It extended over an area of 3.625753 km^2 , where each km^2 contained 20,328 ± 2324 pieces of debris according to (Law et al., 2010) estimations. The Second gyre was recorded in the south of the Atlantic, covering an area of about 1.296.180 km^2, each km^2 represent a density of debris exceeding 26,898 items/km^2, 70,96 g/km^2 according to (Eriksen et al., 2013), the majority of them where a plastic materials debris (6 pieces in each km^2) (Ryan, 2013) coming from south of America (60%) and Africa (40%) (Lebreton et al., 2012). For the other zones of the Atlantic as some protected areas (e.g. (Barnes et al., 2018), beaches(e.g. (Becherucci et al., 2017)), surface waters (e.g. (Colton et al., 1974, Collins, Hermes, 2019)) and deep seas(e.g. (Loulad et al., 2017)), they represented a mean to low densities of debris that varied from an area to the other depending on many factors as the characteristics of the prospected zone (the proximity to large cities, human coastal activities, etc), the wind, the hydrographic, the hydrodynamic process (wave, ocean, current and tidal cycles) and regional-scale topography of the studied area (Jeftic et al., 2009, NOAA, 2014, Barnes et al., 2009).

The Seafloor of the North and the Central parts of the Moroccan Atlantic waters was one of Atlantic coast that the marine debris pollution has never been studied before. This study was the first focusing on this issue on an area that extended from Tangier (35°N) to Sidi Ifni (29°N). The sampling operations by trawl was organized by the Moroccan Institute of Fisheries Research on abroad of Charif al Idrissi vessel in Feb-March 2015 and

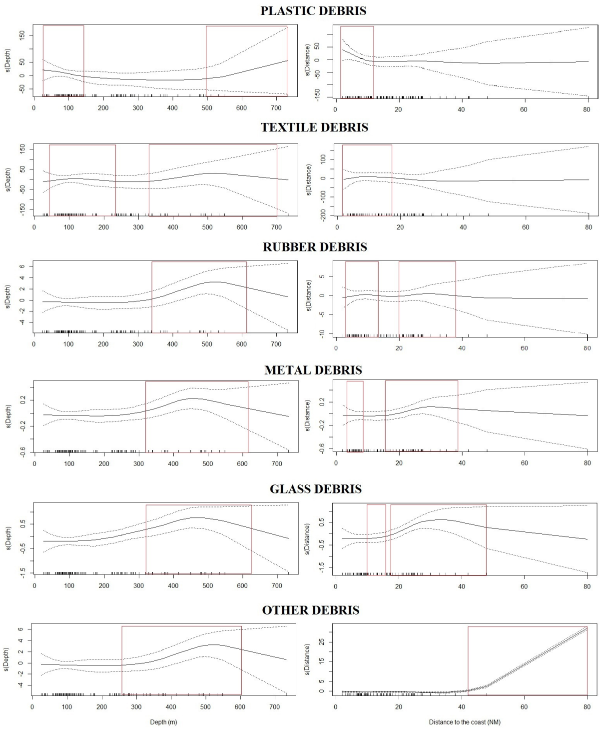


Figure 8. Analysis of Non-linear relationships between the average density of different categories collected in 2018 and the depth / the distance to the coastline using the Generalized Additive Model (GAM).

March 2018. The result showed an average density of SMD ranging between 16.84kg/km^2 to 30.15kg/km^2. This density considered as a low value compared to the other studies conducted on the seafloor of many areas that showed a huge range of SMD abundances varied between 0 to 100,000 item/km^2 (Galgani et al., 2015), and even low in the density recorded in the southern part of the same waters that range between 0 to 1768kg/km^2.

The SMD composition analysis showed, as the majority of marine debris studies around the world (e.g (Gerigny et al., 2019, Urban-Malinga et al., 2018)), that the plastic debris (mainly composed of plastic pots used for the octopus fisheries in the area) constitutes the most widespread category of litters in the study area. It exceeds 40% of the total collected items, followed by textiles litters which composed totally of fishing ropes (fibers). These two SMD categories represented 63% of the total captured amount in 2015 and 67% in 2018. Their distribution pattern showed a remarkable concentration in the periphery of Casablanca, Agadir and offshore of Safi El-Jadida, Essaouira, and Sidi Ifni in both periods. Whereas, the other kinds of debris (such glass, metal rubber, and others materials) were concentrated close to the coasts especially near to the stations prospected at distances close to the big urban agglomerations (e.g. Casablanca, Larache, Kenitra, el-Jadida, Agadir), and on the offshore of the prospected Area but with a less important amounts compared to the coastal zone.

4.1 The probable sources of debris

the distribution aspect of SMD allowed to divide them into two classes depending on their sources, first those related to activities generally carried out on land such as plastic bags, shampoo packaging, yogurt, boots, gloves, etc. and those resulting from

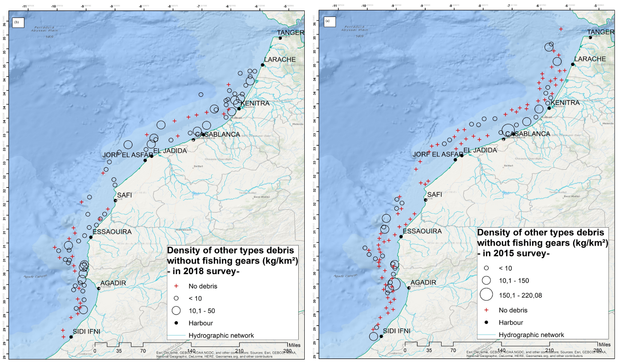


Figure 9. The spatial distribution of land-based debris in the Seafloor of the North and the Centrale part of the Moroccan Atlantic in both surveys: (a) :2015, (b): 2018.

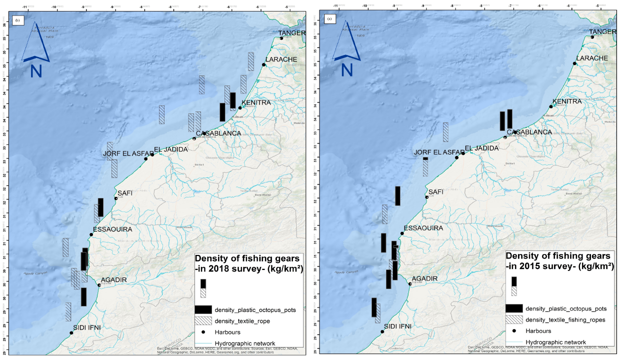


Figure 10. The spatial distribution of fishing related debris in the seafloor of the North and the Central part of the Moroccan Atlantic in both surveys: (a) :2015, (b): 2018.

fishing activities (octopus pots, longline ropes) we find that we have two completely different distribution modes. First, the distribution of land based seafloor marine debris concentrated generally in near to the coast with less important quantities on the offshore in both surveys (Figure 8) showed that the coastal pressures exerted on the marine environment due to the strong coastal agglomeration as well as the concentration of the industrial and tourism activities on the coast were the main reasons of evacuation of this category of debris. According to the published local monographs, the studied area was booming economically and demographically especially in the last few years. On one hand, the coastline was delimited by the largest cities of the Moroccan territory (Casablanca, Rabat, Sale, Larache, Kenitra, Mohammedia, El Jadida, Safi, Agadir); with a population density that exceeds in some cities, 17.777 hab/km^2 according to a national census in 2014. On the other hand, it concentrates the majority of tourism activities especially in Casablanca and Agadir and heavy industrial, economic activities (e.g. refining and petrochemicals in Mohammedia, phosphates industries in Safi and Jorf Lasfar), especially in Kenitra-Safi axis which concentrates 60% of industrial units in Morocco according to (Nakhli, 2010). These coastal pressures led to the emergence of three main black lines along the Moroccan North and the central Atlantic coasts, which considered as the most vulnerable to the human pressures and the most supplying the Atlantic ocean with the human pollutants; the mouth of Sebou river which drains all domestic, industrial and agricultural debris from the cities of Fez, Meknes, Sidi Kacem, Sidi Slimane and Kenitra; the industrial axis Mohammedia-Casablanca-El Jadida-Safi, and the bay of Agadir which was under the pressure of the fishing and the tourism activities in the area (Nakhli, 2010). This finding correlates perfectly with the areas where the majority of SMD in this class has been collected.

Second, the distribution mode fishing-related debris (Figure 9) which in its turn was divided inTO two sub-distribution mode one of the plastic octopus pots and the other of the longline ropes. On one hand, the plastic octopus pots have been recorded near to Safi,in Essaouira, Agadir, Kenitra and Casablanca and in some stations on the offshore (2015 survey); knowing that these gears which consist approximatively of 900g to 1kg of plastic used for the capture of Octopus Vulgaris by artisanal boats (a technique used since 1990 in Morocco) in some areas in Moroccan waters, were totally banned for use in this area as mentioned in the Management Plan (MP) of cephalopods published in 2015 by INRH in the area due to their harmfulness to the environment and marine resources (Jeftic et al., 2009), and have been replaced by the "jig", but only at the level of Agadir, Safi, Essaouira and Sidi Ifni in the North Atlantic Zone (Northern Ougnit) as defined by the National Institute of fisheries resources. Thier existence might be a strong indicator of illegal and non-controlled fishing activities in the area, and this is unfortunately confirmed in a press release issued in 2014, where they were talking about 28,000 plastic pots collected in the periphery of Agadir coming from the illegal fishing activities in the area (http://aujourdhui.ma/actualite/peche-illicite-de-poulpe-28-000-pots-saisis-a-agadir-113599). On the other hand, the knotted fishing ropes used by the longliners were found at different distances and depths. This distribution aspect correlates perfectly with their zone of activity which not subjected to any specific delimitation. A longline fishing vessel started his activity from the nearshore to the offshore depending on the species targeted and the capacity of the vessel. Then, due to some external conditions as the weather and the vandalism this may abandon or lost in the water, if it is not thrown away voluntarily because it becomes unusable.

4.2 The mechanism of transportation debris

As mentioned above, some pieces of debris (either some plastic bags and packaging or artisanal octopus pots used by boats that can not technically exceed 20 MN far from the coast) were collected far from their origins on the offshore of the study area. The altimetry satellite observations (aviso data) showed that the North and the central part of the Atlantic is flushed by an horizontal currents that connect the coast to the open ocean and control the horizontal exchange from the coastal area to the ocean interior (Figure 10). This flow can transport SMD from the coastal area to the open ocean and contribute to its dispersion far from these origins; this fully explains the presence of certain pieces on the offshore of the study area.

5. CONCLUSION

The prospection on the North and the Central of Moroccan Atlantic coast allowed us to conclude that the activity of fishing as well as the land-based activities were the main responsible for the existence of the SMD in the area. These results showed that Morocco is no more far from this pollution and the country must move to stop and mitigate the widespread of this problem due to its harmful impacts on the economy, the environment, the human health and safety. The solutions consist on putting in place standardized methods to combat this phenomenon, adopt

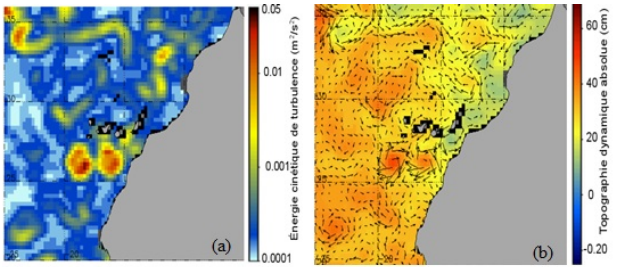


Figure 11. a: Eddy Kinetic Energy derived from AVISO data, b: Overlapping of sea surface height and derived geostrophic velocity fileld

laws to prevent the use and production of certain environmentally harmful materials, promote local infrastructure and solid waste management in the country, and raise awareness about the effects of the debris disposal in marine ecosystems.

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