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# Monitoring and characterization of macro-litter on the beaches of El Kala coastline of Algeria

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## ABSTRACT

The presence of marine litter on beaches is a real and significant problem, as it not only degrades the aesthetic value of landscapes but also affects the environment and exposes humans to nuisances and dangers, some of which can be very serious. To address this issue, a quantification and identification of macro-litter accumulated on the three main beaches of the El Kala coastline, North-East of Algeria (Grande Plage, El Mordjene, and Vieille Calle), was carried out over three seasons (autumn, winter, and spring). A total of 4283 items, corresponding to 161.21 kg of litter, were counted. The three beaches were classified as moderately clean according to the Clean Coast Index (CCI = 9.6), and the mean density was estimated at 0.48 ± 0.09 items/m². The order of abundance of marine litter along the coast of El Kala was as follows: plastic (52.72%) > other litter (14.45%) > metal (7.87%) > processed wood (6.07%) > glass/ceramic (5.51%) > textile (5.42%) > paper/cardboard (5.35%) > rubber (2.61%). More than half of these items (62.50%) were from land-based sources, mainly related to shoreline, tourism, and recreational activities. Our results suggest that specific management approaches should be applied to minimize the impact of macro-litter, with particular emphasis on plastic waste.

**Keywords:** macro-litter, clean coast index, monitoring, source, plastic, northeast Algeria.

## INTRODUCTION

Marine pollution is defined as the direct or indirect introduction of litter, substances, or energy, of human origin, which causes or is likely to cause harmful effects on living resources and marine ecosystems, with the consequence, a loss of biodiversity, risks for human health and obstacles to maritime activities (Goeury, 2014). Every year, nearly 2 billion tonnes of solid litter are produced worldwide (Statista, 2022), about 80% of which end up in the seas and oceans (Vanderzwaag and Powers, 2008; UNEP, 2009a; Andrady, 2011).

The Mediterranean Sea, a semi-enclosed basin, is one of the richest marine and coastal environments, but also one of the most vulnerable in the world due to its exposure to a wide range of anthropogenic pressures (Demeester, 2002). Bordered by 22 riparian countries, some of which treat it as a vast dumping ground, the Mediterranean has become a receptacle for various types of litter and pollutants (Vincent, 2020). The intense pressure from urbanization, maritime traffic (which accounts for 30% of global shipping), and tourism is estimated to generate approximately 500 tons of litter per day (Demeester, 2002). The responsibility for safeguarding the qualities of this marine environment lies not only with specialized international organizations and different states, but also with all citizens who must become aware of this problem, learn about it, and commit to participating in sanitation and environmental protection actions (Galgani and Loubersac, 2016).

In Algeria, the management of urban litter has long been a major public health and hygiene concern. Despite the development of new disposal techniques, such as sorting, recovery, recycling, and incineration, landfilling remains the most commonly used technique (Chaouch, 2007). While waste in the past was mostly composed of natural and biodegradable materials, this is no longer the case today with partially toxic litter that nature is no longer able to biodegrade, that is why this ancient practice of uncontrolled dumping has become one of the main causes of soil, water, and air pollution and therefore vital resources. Only controlled landfilling of urban waste can help prevent or minimize these environmental impacts.

The coastline of El Kala (El Tarf wilaya) faces significant economic pressures, particularly from tourism and fishing activities. Although the development of these activities has a positive impact on the local economy, they are also responsible for environmental degradation, the severity of which has only recently been recognized. Indeed, the coastline is not spared from the influx of litter brought by the sea, wind, river discharges, and human activities. Research has been conducted to study the distribution of marine litter along the Algerian east coast, particularly on the Annaba golf course (Chaouch et al., 2018; Djebar et al., 2024). However, the coastline of El Tarf has not yet been the subject of similar studies. To address existing gaps and propose effective marine litter management strategies, it is essential to develop a comprehensive understanding of the current state of this pollution. It is with this in mind that we studied the abundance, composition and source of solid litter (plastic, rubber, processed wood, glass/ceramic, metal, textile, paper/cardboard and other unidentified materials) cumbersome the main swimming beaches of the coastline of El Kala in the wilaya of El Tarf, North-East of Algeria.

## MATERIALS AND METHODS

### Description of the study area

The wilaya of El Tarf is located in the extreme northeast of Algeria and covers nearly 2912.64 km$^2$. It is bordered to the north by the Mediterranean Sea, to the south by the wilayas of Souk-Ahras and Guelma, to the west by the wilaya of Annaba, and to the east by Tunisia (Figure 1). The wilaya comprises 7 daïras that group 24 municipalities and has a total population of 481136 inhabitants, representing an average population density of 165 inhabitants per km$^2$. The coastline of the wilaya extends approximately 90 km in length (MICLAT, 2024). For this study, three beaches were selected and georeferenced using a GPS. The selection was based on several criteria, including the type of pollutants considered and the beaches' proximity to wastewater outfalls, river mouths and urban areas. The selected study sites were: Grande plage El Mordjene and Vieille Calle beaches.

The Grande plage (36°53′52. N, 8°27′08. E), is an urban beach located to the east of downtown El Kala. It receives untreated urban waste from the central and western districts of the city. El Mordjene Beach (36°53’50. N, 8°25’40. E), is an urban beach located west of the city center of El Kala, near the new port. It receives urban litter from the central and eastern districts of El Kala without prior treatment. Vieille Calle beach (36°54’58. N, 8°20 23. E), is a remote and natural beach located on the western side of the El Kala coastline. It is assumed to be relatively free from significant pollution sources, due to its location, which is distant from major discharge points (Dahel et al., 2024).

These stations meet the criteria defined by Vlachogianni et al. (2017, 2019, and 2022). They have a low to moderate slope (approximately 1.5° to 4.5°), a minimum length of 100 meters, clear access to the sea (i.e., not blocked by breakwaters or jetties), and are accessible to survey teams throughout the year. The sites are also not subject to cleaning activities, except during the summer season, which was excluded from the study period.

### Protocol

This study was conducted in accordance with the recommendations outlined by Galgani et al. (2013), based on the OSPAR methodology (2010). Sampling focused on macro-litter present on beaches with a size greater than 2.5 cm (items > 2.5 cm). The study followed a seasonal chronology, covering autumn, winter, and spring, corresponding to October 2023, January 2024, and April 2024, respectively. The summer season, extending from June 1 to August 31, was excluded from the study following the instructions of Vlachogianni et al. (2017, 2019 and 2022), as beaches are subject to daily cleaning by public services during this period, notably as part of the "Ports and Dams Blue" operation, which begins each year in early June.

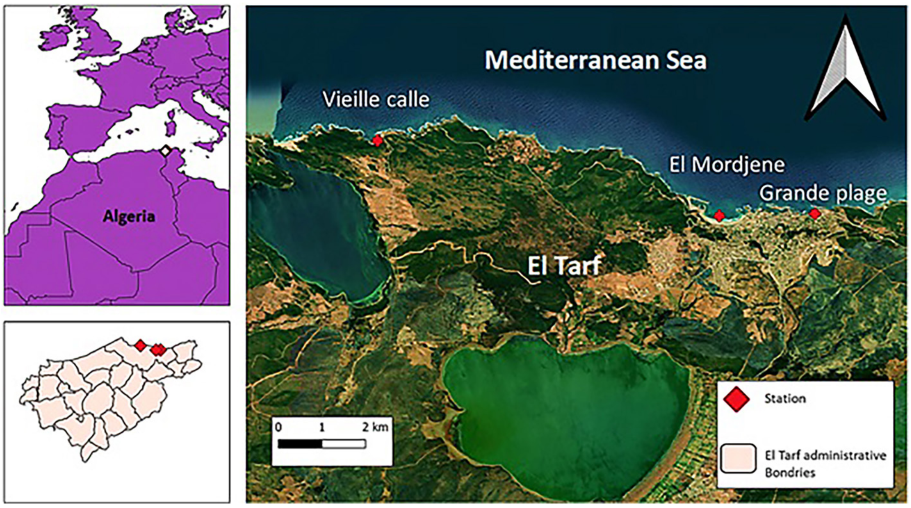


**Figure 1.** Location of the study area

The protocol includes a collection methodology, a sorting nomenclature, a count and weighing of litter, depending on their nature (plastic, rubber, processed wood, glass/ceramic, metal, textile, paper/cardboard and other materials) and this from a sampling unit that corresponds to a transect 100 meters long on a width of 10 m towards the back of the beach with a shoreline withdrawal of 0.5 m.

The density of collected macro-litter (CM) was determined according to Lippiatt et al. (2013):

$$CM = n / (w \times l) \quad (1)$$

where: *n* – number of litter items recorded,
*w* – width of the sampling unit and
*l* – length of the sampling unit.

The cleanliness of the beach was assessed using the clean coast index (CCI) developed by Alkalay et al. (2007), where:

$$CCI = CM \times K \quad (2)$$

where: *CM* representing the density of items per square meter and *K* being a constant equal to 20.

The degree of beach cleanliness was established according to the classification proposed by Alkalay et al. (2007). A CCI value between 0 and 2 characterizes a very clean beach with no visible litter present. Values between 2 and 5 indicate a clean beach where no litter is visible over a large area. A score between 5 and 10 corresponds to a moderately clean beach where a few pieces of litter can be detected. Values between 10 and 20 reflect a dirty beach with a significant accumulation of debris observed along the shoreline. Finally, a CCI value of 20 or more characterizes an extremely dirty beach, where most of the surface is covered with litter.

For each litter item found, we assigned a specific source, following the approach described by Vlachogianni et al. (2017 and 2019): (a) Shoreline, including poor waste management practices, tourism and recreational activities; (b) Fisheries and aquaculture; (c) Sanitary and sewage-related; (d) Fly-tipping; (e) Shipping; (f) Medical related; (g) Agriculture and (f) Non-sourced.

## Statistical analysis

All statistical analyses were performed using R software (version 4.3). Temporal patterns in waste abundance were assessed using one-way ANOVAs, after applying a $log_{10}(x+1)$ transformation to normalize the data and stabilize variance. The assumption of homogeneity of variances was verified using Levene's test, confirming the suitability of ANOVA for these comparisons. Spatial variation in the abundance of waste items across the three sampled beaches (Grande Plage, El Mordjene, and Vieille Calle) was evaluated using a Chi-square test of independence, which assessed the association between waste type (eight anthropogenic categories) and sampling location, based on item counts per category. To analyze seasonal variations in the composition of waste, a Friedman test was used. This non-parametric test was suitable for comparing repeated measures of the same eight waste categories (plastic, rubber, processed wood, glass/ceramic, metal, textile, paper/cardboard, and other materials) across the three seasons (autumn, winter, and spring), given the limited sample size (n = 8) and non-parametric nature of the data. In addition, a Kruskal–Wallis test was conducted to compare the total abundance of waste items across the three beaches. When significant differences were detected, post-hoc pairwise comparisons were performed to identify specific contrasts between sites.

## RESULTS

### Abundance and composition of macro-litter

This study, conducted between October 2023 and April 2024, focused on three beaches: Grande Plage Beach, El Mordjene Beach, and Vieille Calle Beach. During the autumn, winter, and spring seasons, a total area of 3.000 m² was surveyed across these three sites. A total of 161.21 kg of litter was collected (59.49 kg in the Grande Plage, 49.98 kg in the El Mordjene, and 51.74 kg in the Vieille Calle), corresponding to 4283 items counted (1707, 1399, and 1177 items respectively). Across all three beaches, the majority of the waste, both in terms of weight and item count, was composed of plastic (Figure 2).

In order to comply with the guidelines proposed by Vlachogianni et al. (2017), we calculated seasonal values for abundance, density, and CCI using the number of waste items collected. Autumn sampling represented 35.26% of the total sample, winter a rate of 33.25%, and spring a rate of 31.50% (Figure 3). The dominance of plastic was observed over the three seasons, with 55.63% in autumn, 53% in spring and 49.37% in winter (Figure 4).

The average seasonal densities of marine macro-litter from the 3 beaches, indicated in Table 1 and Figure 5A, were estimated in Items/ m² at 0.50 ± 0.10 (Autumn), 0.47 ± 0.15 (Winter) and 0.45 ± 0.03 (Spring) with degrees of cleanliness, based on CCI, estimated at 10, 9.40 and 9 respectively.

As for the seasonal densities by beach (Table 1), they ranged from 0.31 to 0.62 items/m². The assessment of cleanliness levels using the clean coast index (CCI) indicated that El Mordjene and Vieille Calle beaches were moderately clean throughout the three seasons, with CCI values ranging between 5 and 10. In contrast, Grande Plage was classified as dirty, as it recorded CCI values between 10 and 20 during autumn and winter. However, in spring, it was considered moderately clean (Table 2).

The chi-square test revealed a highly significant association between waste composition and sampling location ($\chi^2 = 313.96$, df = 14, $p < 0.001$), indicating that the distribution of waste types varied significantly across the sites. Plastic was the most abundant category at all three locations, with its dominance particularly pronounced at Grande Plage. Additionally, El Mordjene exhibited relatively high proportions of processed wood and textile waste, while Vieille Calle showed a noticeably high presence of the "Other" category, possibly indicating unique or localized waste sources (Figure 2A; Table 1).

In contrast, the Friedman test revealed no significant differences in waste composition across seasons ($\chi^2 = 0.75$, df = 2, $p = 0.687$), suggesting that the relative proportions of waste types remained consistent throughout autumn, winter, and spring (Figures 3 and 4).

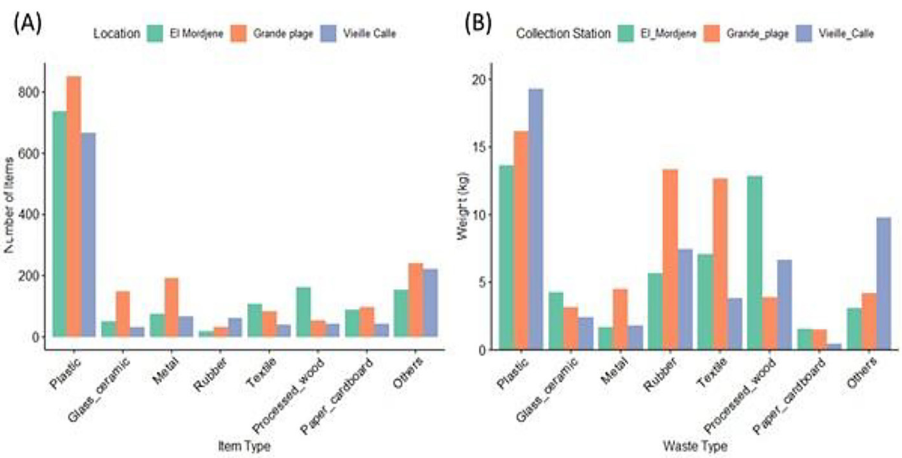


**Figure 2.** Abundance of marine litter types on the three beaches in number (A) and weight (B)

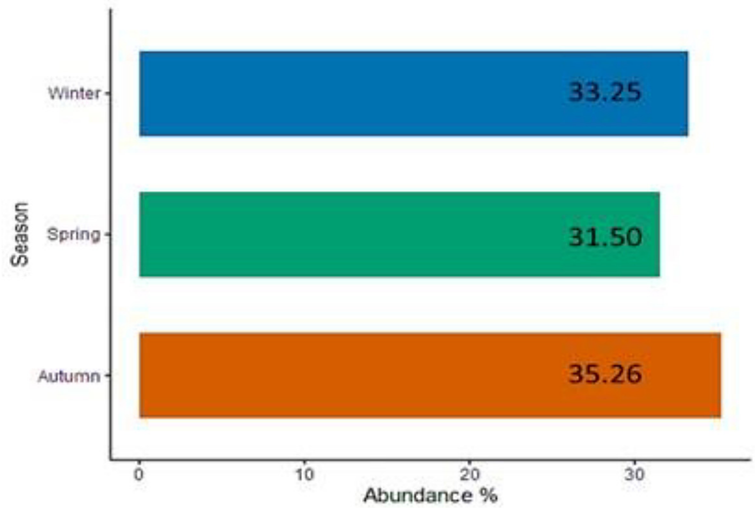


**Figure 3.** Abundance of beach litter over three sampling seasons

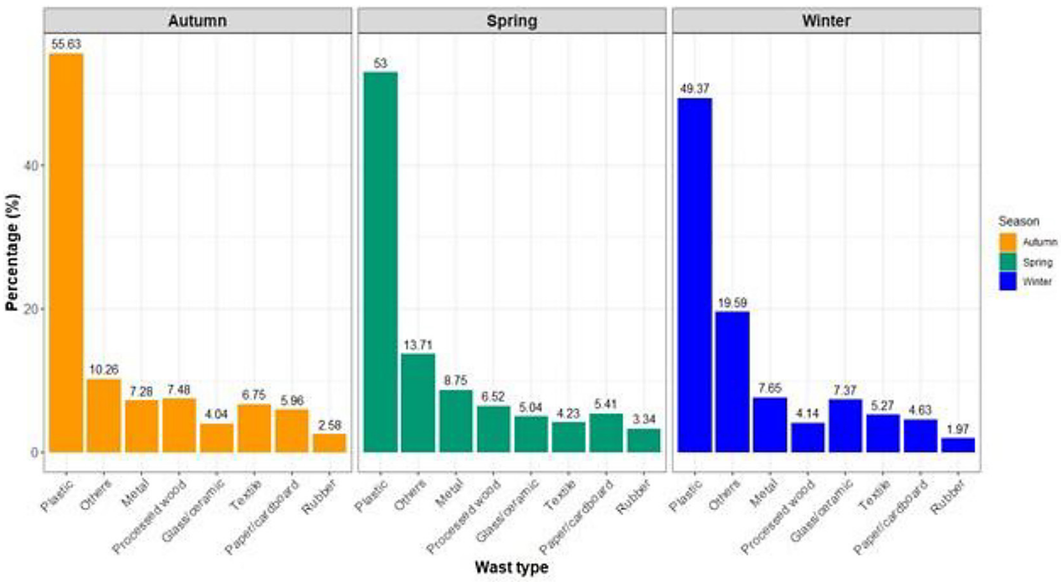


**Figure 4.** Marine litter collected during the different seasons

The environmental assessment of the three sampled beaches revealed notable differences in macro-litter density. The results of the statistical analysis (Chi-square test: $\chi^2 = 84.12$, df = 2, $p < 0.001$) confirm a highly significant variation in waste composition between sites. The Grande Plage was identified as the most polluted site, with a mean density of 0.57 ± 0.08 items/m² and a clean coast index (CCI) of 11.40, placing it in the Dirty category. In contrast, El Mordjene, with a mean density of 0.47 ± 0.04 items/m² and a CCI of 9.40, was classified as moderately clean. The Vieille Calle beach had the lowest waste density, at 0.39 ± 0.07 items/m², with a CCI of 7.80, ranking it as the cleanest of the three sites according to the CCI classification. These results are illustrated in Figure 5 and Table 2.

The Kruskal-Wallis test confirmed that these differences in mean waste density across the three beaches are statistically significant ($\chi^2 = 7.91$, df = 2, $p = 0.019$). Post-hoc pairwise comparisons indicated that Grande Plage differed significantly from both El Mordjene and Vieille Calle, reinforcing its classification as the most impacted site. These findings, also illustrated by the error bars of the graph, highlight the spatial heterogeneity in litter distribution, likely driven by variations in human activity, coastal dynamics, and local waste management practices. They underscore the importance of implementing site-specific strategies

**Table 1.** Seasonal litter abundance at the three investigated beaches

| Beaches | | Autumn | Winter | Spring |
|---|---|---|---|---|
| Grande plage | Density CM (Items/m²) | 0.61 | 0.62 | 0.48 |
| | Clean coast index (CCI) | 12.24 | 12.30 | 9.60 |
| | Degree of cleanliness | Dirty | Dirty | Moderately clean |
| El Mordjene | Density CM (Items/m²) | 0.49 | 0.50 | 0.42 |
| | Clean coast index (CCI) | 9.72 | 9.94 | 8.32 |
| | Degree of cleanliness | Moderately clean | Moderately clean | Moderately clean |
| Vieille Calle | Density CM (Items/m²) | 0.41 | 0.31 | 0.45 |
| | Clean coast index (CCI) | 8.24 | 6.24 | 9.06 |
| | Degree of cleanliness | Moderately clean | Moderately clean | Moderately clean |
| Mean Density per season (Items/m²) | | 0.50 ± 0.10 S.D. | 0.47± 0.15 S.D. | 0.45 ± 0.03 S.D. |
| Clean coast index (CCI) | | 10 | 9.40 | 9 |
| Degree of cleanliness | | Moderately clean | Moderately clean | Moderately clean |

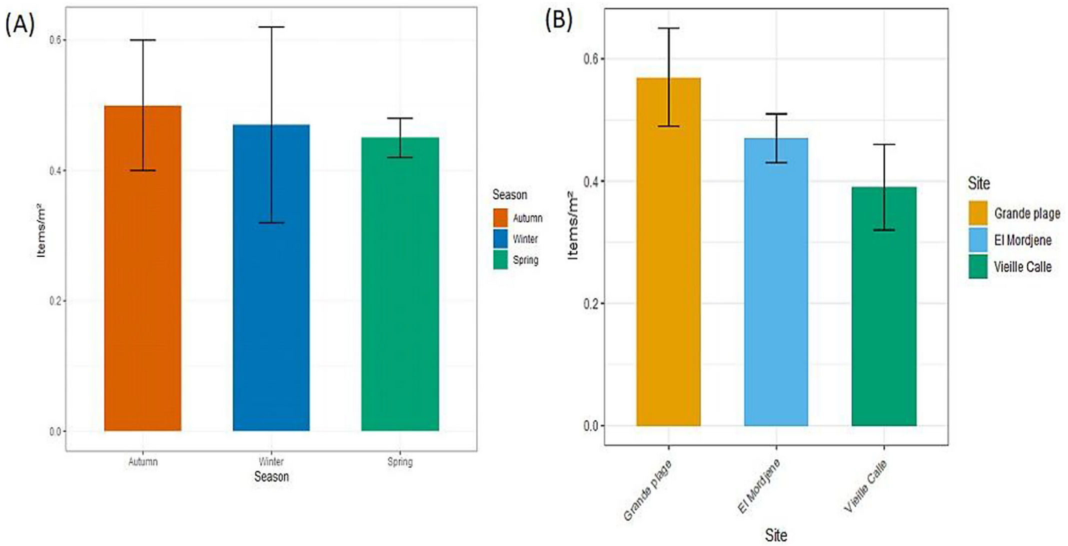


**Figure 5.** Comparative assessment of marine litter densities across seasons (A) and beaches (B)

**Table 2.** Density and degree of cleanliness of the study area

| Parameter | Grande plage | El Mordjene | Vieille Calle | El Kala coast (North-Eastern Algeria) |
|---|---|---|---|---|
| Number of items per 100 m | 1 707 | 1 399 | 1 177 | 4 283 |
| Mean density CM (Items/m²) | 0.57 ± 0.08 S.D. | 0.47 ± 0.04 S.D. | 0.39 ± 0.07 S.D. | 0.48 ± 0.09 S.D. |
| CCI | 11.40 | 9.40 | 7.80 | 9.60 |
| Degree of cleanliness | Dirty | Moderately clean | Moderately clean | Moderately clean |

to effectively address the varying levels of pollution across coastal areas.

Figure 6 illustrates the distribution rates of macro-litter collected across the three beaches during the three study seasons. The order of waste abundance was as follows: plastic (52.72%), others (14.45%), metal (7.87%), processed wood (6.07%), glass/ceramic (5.51%), textile (5.42%), paper/cardboard (5.35%) and rubber (2.61%).

## Sources of macro-litter

Our investigation identified 39 types of macro-litter (items > 2.5 cm), grouped into 8

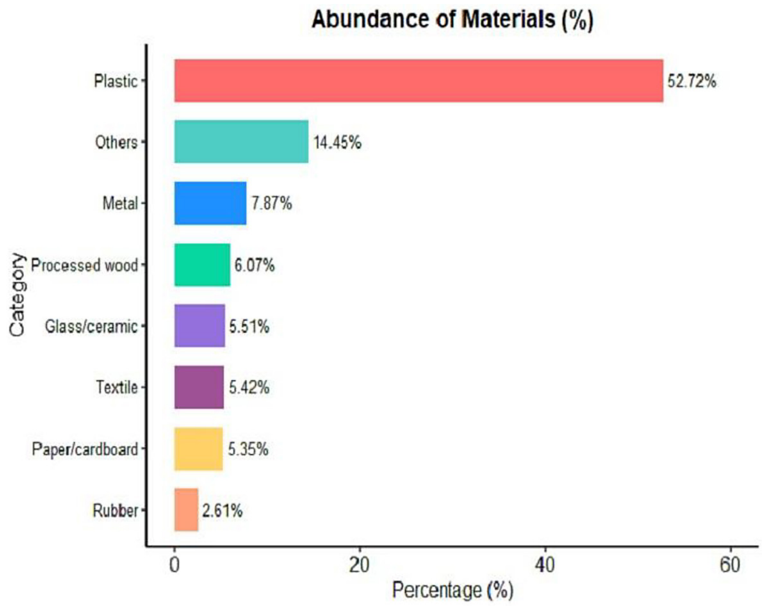


**Figure 6.** Abundance of macro-litter across the three study beaches

categories and classified according to their probable sources (Table 3 and Figure 7).

The analysis of collected macro-litter revealed that Shoreline, including poor waste management practices, tourism, and recreational activities, contributed with 48.72% of waste on beaches; Fisheries and aquaculture with 15.38 %; Sanitary and sewage-related, Shipping, Medical related, and Agriculture with 2.56% each; Fly-tipping with 7.69% as for non-sourced with 17.95% (Figure 7A). More than half of these items (62.50%) were from land sources, 25% from marine sources, and the remaining 12.50% from mixed sources (Figure 7 B).

## DISCUSSION

The monitoring of the abundance of macro-litter (items > 2.5 cm) on the coast of El Kala in the El Tarf wilaya, conducted on three beaches, Grande plage, El Mordjene, and Vieille Calle between October 2023 and April 2024, during the season's autumn, winter and spring, allowed to establish a diagnosis of the state of pollution of the coastline, highlighting the appearance of certain types of waste.

On an area of 3000 $m^2$ divided between the three beaches, 161.21 kg of litter were collected, corresponding to 4283 items counted. The mean waste density (CM) was 0.48 ± 0.09 SD Items/$m^2$ with a CCI of 9.60. Under the guidelines of Vlachogianni et al. (2017), we compared our results solely based on the number of wastes, thus our results approximate those found by Buoninsegni et al. (2022) in Italy, However, they are low compared to those observed by Ebere et al. (2019) in Nigeria, Oztekin et al. (2019) and Ertaş et al. (2022) in Turkey, Mokos et al. (2020) in Croatia, Ben Dhiab et al. (2022) and Ben Slimane et al. (2025) in Tunisia (Table 4). On the other hand, Nachite et al. (2018) found results lower than ours, they estimated the density and cleanliness index at CM = 0.05 Items/$m^2$ and CCI = 1.1 respectively, indicating very clean beaches along the Moroccan Mediterranean coast (Table 4).

In Algeria, most studies on marine litter have focused exclusively on plastic debris (Tata et al., 2020; Taïbi et al., 2021; Grini et al., 2022; Ghezali et al., 2023; Bentaallah et al.,2024). Only the study by Djebar et al. (2024), conducted on the different macro-litter on the coast of Annaba (Northeast Algeria), allowed us to compare our results. Djebar et al. (2024) reported a litter density of 0.30 Items/$m^2$ and a CCI of 6. These values are close to those obtained in the present study, classifying the beaches of eastern Algeria as moderately clean (Table 4).

The seasonal density of macro-litter showed a peak in Autumn with 0.50 Items/$m^2$, compared to 0.47 Items/$m^2$ in Winter and 0.45 Items/$m^2$ in Spring. These results could be explained, on the one hand, by the reduction, or even the absence of cleaning operations carried out by the local

**Table 3.** Various macro-litter collected and their probable sources

| Category | Type | Source |
|---|---|---|
| Plastic | Shopping bags | Shoreline |
| | Bottles | Shoreline |
| | Caps | Shoreline |
| | Food containers | Shoreline |
| | Hard plastic objects (tube, lid, etc.) | Agriculture |
| | Fishing net | Fisheries |
| | Fishing line | Fisheries |
| | Other fishing-related items (floaters, etc.) | Fisheries |
| | Rope/strapping band | Fisheries |
| | Polystyrene | Non-sourced |
| | Cigarette butts | Shoreline |
| | Lighters | Shoreline |
| | Straws | Shoreline |
| | Cotton bud sticks | Sanitary and sewage related |
| | Syringes | Medical related |
| | Foam sponge | Non-sourced |
| | Plastic fragments | Non-sourced |
| Glass/ceramic | Bottles | Shoreline |
| | Glass fragments | Non-sourced |
| | Ceramic fragments | Non-sourced |
| Metal | Cans | Shoreline |
| | Tin cans | Shoreline |
| | Aluminum food containers | Shoreline |
| | Medium-sized containers (paint, chemical products, etc.) | Shipping |
| Rubber | Tires | Fly-tipping |
| | Gloves | Non-sourced |
| | Shoe soles | Shoreline |
| | Sandals and flip-flops | Shoreline |
| Textile | Clothing | Shoreline |
| | Large pieces (carpets, mattresses, etc.) | Fly-tipping |
| | Natural ropes | Fisheries |
| Processed wood | Planks | Fly-tipping |
| | lockers | Fisheries |
| | Toothpicks | Shoreline |
| Paper/cardboard | Cigarette packs | Shoreline |
| | Food containers | Shoreline |
| | Cardboard | Shoreline |
| Others | Food products | Shoreline |
| | Unidentified products | Non-sourced |

municipality after the summer season, and on the other hand, by the significant stranding and accumulation of debris transported by marine currents and wind. Indeed, the Mediterranean currents circulating in Algerian waters flow from west to east (UNEP/WHO, 1999), suggesting that the waste could come from the coasts located to the north and west of the coastline. Furthermore, the winds coming from the northeast sector (N60°), with summer speeds ranging between 6 and 10 knots (LEM, 2007), may also contribute to the accumulation of this debris. In addition, the increase in litter density recorded on the 2 urban beaches, Grande plage and El Mordjene (0.57 and 0.47

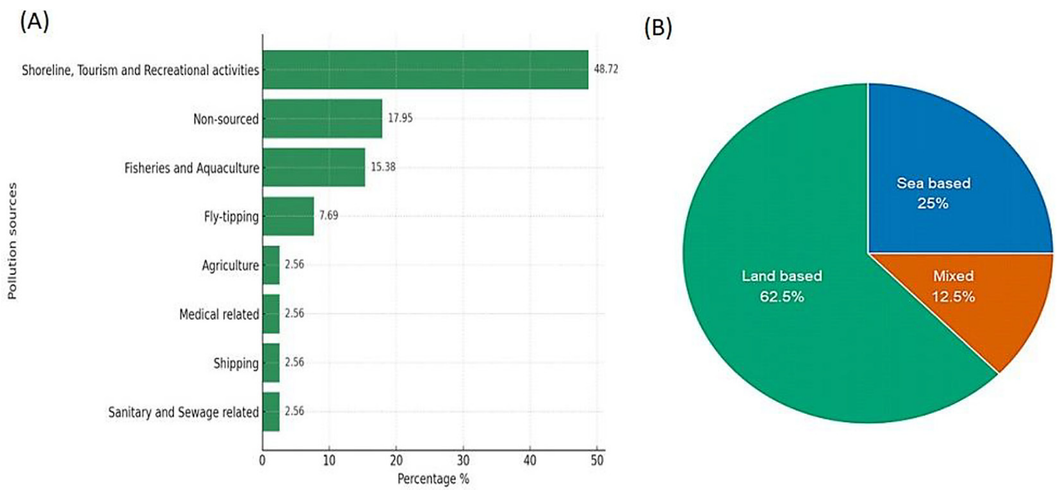


**Figure 7.** Source of macro-litter (A); Origin of macro-litter collected on the three beaches (B)

**Table 4.** Comparison of mean macro-litter density and clean coast index (CCI) values reported by various authors in different regions

| Locality | Authors | Period | Mean density (Items/m²) | CCI | Degree of cleanliness |
|---|---|---|---|---|---|
| Central Croatian Adriatic Sea | Mokos et al. (2020) | Sum./18- Spr./ 19 | 2.55 | 48.40 | Extremely dirty |
| Boccasette beach in Adriatic Sea (Rovigo, Italy) | Buoninsegni et al. (2022) | Nov./19 – Oct./20 | 0.35 | 7 | Moderately clean |
| Southern Black Sea (Turkey) | Oztekin et al. (2019) | Spr./15- Win./16 | 1.51 | 30.20 | Extremely dirty |
| Çakalburnu Lagoon (Turkey) | Ertaş et al. (2022) | Nov./20- Aug./21 | 0.64 | 12.71 | Dirty |
| Southeastern Nigeria | Ebere et al. (2019) | Spr.- Sum./19 | 3.49 | 70 | Extremely dirty |
| Moroccan Mediterranean Coast | Nachite et al. (2018) | Aut./15- Spr./16 | 0.05 | 1.10 | Very Clean |
| North-Eastern Tunisia | Ben Slimane et al. (2025) | Apr.-Dec./23 | 1.01 | 20.20 | Extremely dirty |
| Monastir Coast (East Tunisia) | Ben Dhiab et al. (2022) | Aut. -Sum./21 | 3.09 | 61.80 | Extremely dirty |
| Annaba Coast (East Algeria) | Djebar et al.(2024) | Win./24 | 0 .30 | 6 | Moderately clean |
| El Kala coast (East Algeria): | Present study | Aut./23- Spr./ 24 | 0.48 | 9.60 | Moderately clean |

Items/m$^{2,}$ respectively, compared to Vieille Calle (0.39 Items/m $^{2}$) is explained by their locations at the center of the city. These two beaches receive significant quantities of debris, due to their location near residential areas. The influx of vacationers during the winter and spring seasons may also contribute to this pollution.

By classifying the waste in order of abundance, plastic, an artificial polymer, accounts for 52.72% of the total. It mainly consisted of cups, bottles, plastic bags, caps, food packaging, polystyrene, cotton buds, cigarette butts and fishing equipment. Plastic pollution has a severe global impact, harming ecosystems, flora, and fauna, while also posing potential risks to human health (Derraik, 2002; UNEP, 2009 b). Algeria is not spared by this scourge, where plastic represents a major share of marine litter, estimated at 87% according to the report of the National Waste Agency (AND), resulting from the monitoring and tracking campaign for marine litter carried out in 2020. A significant portion of this waste escapes from Algerian coastal areas to disperse in the Mediterranean Sea (Jambeck et al., 2015).

The predominance of plastic litter has been regularly observed by Vlachogianni et al. (2017, 2018, 2019, and 2022) in the Mediterranean region. This trend is also confirmed by several studies carried out not only in this area, but also in various other coastal regions: 49.19% and 82.6% in Spain (García-Rivera et al., 2017; Asensio-Montesinos et al., 2019), 95.61% and 79.69% in Turkey (Oztekin et al., 2019; Terzi et al., 2020), 59% in Nigeria (Ebere et al., 2019), 94.88% in Croatia (Mokos et al., 2020), 71.4% in Qatar (Veerasingam et al., 2020), 96% in Italy (Buoninsegni et al., 2022), 91.4% in Greece (Kouvara et al., 2024) and 83.3% in Tunisia (Ben Slimane et al., 2025). In Algeria, a similar dominance was observed in Annaba, with proportions of 29% according to Chaouch et al. (2018) and 31% according to Djebar et al. (2024). A quantity of unclassified objects, described as "other" was found on the coast (14.45%), mainly consisting of food products and others not identified due to their advanced state of degradation. Metals, including cans, tin cans, aluminum food containers, scrap pieces, and other metal waste, represented the third most abundant type of waste, accounting for 7.87%. This percentage is close to that reported by Djebar et al. (2024) on the coasts of Annaba (7%), but lower than the value recorded by Chaouch et al. (2018), which reached 23%. Our rate is also comparable to those found by Veerasingam et al. (2020) in Qatar (9.3%) and by Ertaş et al. (2022) in Turkey (between 7.4% and 9.4%), while exceeding those reported by Asensio-Montesinos et al. (2019) in Spain (3.2%) and by Kouvara et al. (2024) in Greece (2.12%). The Processed wood accounted for 6.07% of the total waste during the study period, and was generally represented by pieces of construction beams, painted timbers, lockers, and toothpicks. This result is close to that reported by Djebar et al. (2024), who found 8%, and remains lower than the value reported by Chaouch et al. (2018) on the coasts of Annaba (15%). This percentage was also close to those of Ertaş et al. (2022) in Turkey (between 5.7% and 8.4%) and higher than those of Asensio-Montesinos et al. (2019) in Spain (0.5%), Kouvara et al. (2024) in Greece (0.88%), and Veerasingam et al. (2020) in Qatar (2%). Paper/cardboard, textile, and glass/ceramic each accounted for approximately 5% of the total litter collected. These portions are significantly lower than those reported by Djebar et al. (2024) who recorded values of 11%, 7% and 23% respectively. However, they are similar to the paper/cardboard and textile rates found by Chaouch et al. (2018), which were 6% and 5%, respectively, although the glass/ceramic category had reached a much higher rate of 22%. Our results are also comparable to those reported by Asensio-Montesinos et al. (2019) in Spain (5.6%, 2.3%, and 3.4%) and by Veerasingam et al. (2020) in Qatar (4.4%, 4.0%, and 5.1%). In contrast, these values exceed those recorded in Greece by Kouvara et al. (2024), who reported lower percentages of 2.59%, 0.56%, and 1.81%, respectively. Finally, rubber, represented by tires, shoe soles, and gloves, accounted for 2.61%. Similar or significantly lower rates were reported by Veerasingam et al. (2020) in Qatar (3.9%), Asensio-Montesinos et al. (2019) in Spain (0.6%), and Kouvara et al. (2024) in Greece (0.56%).

The observed disparities in litter rates between coastal regions can be attributed to several factors, including methodological differences applied during surveys. (Oztekin et al., 2019). Furthermore, population density is a determining factor, as more densely populated areas naturally generate more waste likely to end up on beaches. In our study, the two urban beaches, the large beach and El Mordjene beach, confirm this hypothesis, as they generated more waste. The proximity of beaches to direct sources of pollution, such as landfills, ports, or industrial areas, also impacts the amount of litter present, which is the case for our two urban beaches (Dahel et al., 2024). Finally, the physical characteristics of the coastline, including its orientation relative to prevailing winds and sea currents, play a crucial role in the transport, accumulation, and dispersion of marine litter. These natural factors influence the buoyancy and trajectory of waste, leading to either accumulation or limited deposition depending on the specific marine dynamics of each sector (Galgani et al., 2015; Oztekin et al., 2019). Therefore, the interaction of these various factors largely explains the variations observed in pollution levels.

According to the existing literature, around 80% of marine litter originates from land-based sources, while the remainder comes from maritime activities (Banque mondiale, 2022; Ifremer, Cedre, 2023). This observation corroborates our findings, as 62.5% of the recorded debris was of terrestrial origin, primarily resulting from shoreline, tourism, and recreational activities. In contrast, sea-based debris accounted for 25%, mainly originating from fisheries and aquaculture. Similar results have been reported by several authors, including Vlachogianni et al. (2018, 2019), Mokos et al. (2020), Gjyli et al. (2020). Identifying the sources of marine litter is a crucial step toward effectively addressing the issue. According to Jambeck et al. (2015), the management of marine litter must start with the management of land-based waste, which ends up at 80% in the oceans and seas.

## CONCLUSIONS

The results of this study show that the coastline of El Kala (Northeastern Algeria) is moderately affected by marine litter, with a clear predominance of plastics (52.72%). Seasonal variations revealed higher waste densities in autumn, while spatial differences indicated that urban beaches (Grande Plage and El Mordjene) were more polluted than less frequented sites (Vieille Calle). The composition of the debris, dominated by plastics but also including metals, processed wood, paper/cardboard, textiles and glass, indicates diverse sources, with a majority of items (62.5%) originating from land-based activities. Compared to other Mediterranean and African coasts, El Kala shows intermediate levels of pollution, highlighting the influence of population pressure, waste management practices and coastal configuration.

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