# Quantitative analysis of microplastics in coastal sediment in beaches of Spain and Brazil

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**Key words**: Microplastics, Mediterranean Sea, Atlantic Ocean, Pollution.

**SUMMARY**

Microplastics are small particles of plastic nature, with a size smaller than 5 mm in diameter. These have a devastating potential in the environment. There are several factors that can influence the distribution of microplastics in the marine environment, such as wind conditions, turbulence generated by boat traffic, anthropic activities with a high degree of contamination and morphodynamic classification of the shore line. The objective of this work is to carry out a comparative study of the amount of microplastics found on different beaches of the east coast of Spain, bathed by the Mediterranean Sea and the southern coast of Brazil, bathed by the Atlantic Ocean. The methodology in both environments was based on the ESMARES Program methods, with three different steps: laboratory procedures, identification of microplastics and comparative analysis. It was observed that in Spain, the beach of Autocine had the highest amount of microplastics accounted for and the beach of Puzol had the lowest. In Brazil, the beach that obtained the highest number of microplastics was Brava and the one that obtained the lowest was Atalaia beach. This paper concluded that the factors that control the distribution of microplastics can be differentiated both locally and globally. In the first case, a predominance of anthropic factors is observed, influenced by morphodynamic characteristics and the coastal drift. In the second, the distribution of microplastics seems to be controlled, more, by the characteristics of the environment in which they are located.

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## 1. INTRODUCTION

Nowadays, plastic is one of the most widely used compounds in the world, and can be found in many products worn daily, such as toiletries, containers, plastic bags and others (KARAMI, 2017). It is esteem that Europe accounts for 18.5% of world production and Latin America for 4%. The Plastics Europe Organization estimated that there was an increase of 13 million tons between the year of 2016 and 2017, where the production of 335 million jumped to 348 million tons (PLASTICS EUROPE, 2018).

Besides the exponential production of plastic just around 26% of the world's plastic is currently recycled, while the remaining 74% is thrown into the environment. Of the total plastics not recycled 28% are untreated and often end up in rivers and lakes, 42% is sent to landfills or dumps where the loss of plastic is not accounted for, and often its final destination is the marine environment. The remaining 4% are found in water treatment plants or are taken directly to the oceans (ALIMI et al., 2018).

Although plastics have high durability, exposure to UV rays can cause the elastic properties of plastic to diminish. Thus, plastics exposed to UV rays are induced to oxidation and photochemical reaction, making them fragile and brittle (SONG et al., 2017). Mechanical abrasion is another process of plastic degradation by constant friction of wind, waves and / or sand. Mechanical abrasion is more common on beaches, being considered the most favorable environment for its fragmentation and erosion. (SONG et al., 2017). This fragmentation originates small plastic particles named microplastics.

Microplastics are small particles of a plastic nature, smaller than 5 mm in diameter (KANHAI et al., 2018) and have devastating potential in the environment due to their small size and high dispersion, reaching remote locations and possibly affecting several organisms independent of their trophic level in the ecosystem (OLIVATTO et al., 2018).

The effect of the presence of microplastics in the marine environment can be extremely detrimental due to their toxicity and bioaccumulation properties, being consumed by small fish, molluscs and other marine organisms, thus advancing trophic levels in the food chain (BELLAS et al., 2016).

There are several factors that can influence the distribution of microplastics in the marine environment, such as wind conditions, environmental characteristics, turbulence generated by vessel traffic, and highly polluted anthropogenic activities (OLIVATTO et al., 2018).

Chubarenko et al. (2018) studied the presence of microplastics in different environments of a beach in the Baltic Sea and concluded that local environment microplastics are brought towards the beaches with circulation processes rather than being taken to open water.

The study by Carvalho & Baptista (2016) revealed that microplastics found in Guanabara Bay, Rio de Janeiro, are from local environments such as rivers, however, the anthropogenic activities performed in the area, such as fishing and portuary activities can aggravate the situation and increase the amount of microplastics in the region.

Understanding the effects of microplastics on nature helps preserve marine and coastal environments.

## 2. OBJECTIVE

Compare the amount of microplastics found in different beaches of the southeastern coast of Spain along the province of Valencia, bathed by the Mediterranean Sea and in the beaches of northern Santa Catarina on the south coast of Brazil, bathed by the Atlantic Ocean.

## 3. METHODS

The methodology used was conceived based in the program "ESMAREs: Marine Strategies of Spain". The proposed methodology of this project has three main steps: sample collection, laboratory treatment with visual analysis of the samples and finally the comparison between the quantities of microplastics found, using statistical analysis, data population, morphodynamic characteristics of the beaches shore line and the coastal drift.

The beaches of the study were characterized according to their morphodynamics in dissipative, reflective and intermediate, according to the Wright & Short (1983) classification. According to Tomazelli & Villwock (1992), there is a lateral transfer of sediments, promoted by the activity of waves that affect the coast, which for many years is recognized as one of the most important factors responsible for the configuration of sediments and beaches, called coastal drift. This may also help explain the deposition of microplastics in the environments and the morphodynamics that the beaches present.

### 3.1 Characterization of the Study Zone

#### 3.1.1. Spanish Beaches

The beaches of the Spanish coast studied were: Puzol, Puebla Farnals, Malvarrosa, Pinedo and Autocine (Figure 1). They are located in the western basin, southeast of the Spanish coast, between latitudes 39 ° 20 'N and 39 ° 40' N and are influenced by the Mediterranean Sea.

Figure 1. Sample points in the Spanish beaches


The size of the population in the Mediterranean area is varied, depending on the activities performed around the beaches (Table 1).

Table 1. Population data from the Spanish beaches

| Beaches | Population Size |
|---|---|
| Puzol | 19.455 |
| Puebla Farnals | 7.840 |
| Malvarrosa | 791.413 |
| Pinedo | 1.745 |
| Autocine | 771 |
| Valência | 791.413 |

Font: INE (2018) and ICV (2017)

The beaches of Malvarrosa and Pinedo are based in the county of Valencia. This two beaches along with Autocine are closest to the port of Valencia and best known and frequently used by tourists. Both activities are factors that influence the variability in the population affecting the amount of pollutants found at the site.

Puebla Farnals and Puzol beaches are less well known to tourists and are predominantly frequented by locals. Puebla Farnal beach is also influenced by the presence of a marina.

The port of Valencia was built in the late 18th century and has undergone changes and expansions over the centuries. Studies show that the construction of the port changed the morphodynamic appearance of the beaches located near it, the northern region suffered a sediment accumulation advancing the shore line around 1 km (Pardo-Pascual & Sanjaune, 2018). The Malvarrosa beach is located north of the port and is subject to the high sediment retention indicating a possible change in its morphodynamics and a dissipative beach classification.

The beaches located south of the port, such as Pinedo and Autocine, suffered a high erosion that may have caused a greater slope in the beach profile, suggesting that the beaches of Pinedo and Autocine are classified as reflective. According to Muñoz-Perez et al. (2012) Puzol beach has a steep beach profile with only 150 meters long and can also be classified as reflective.

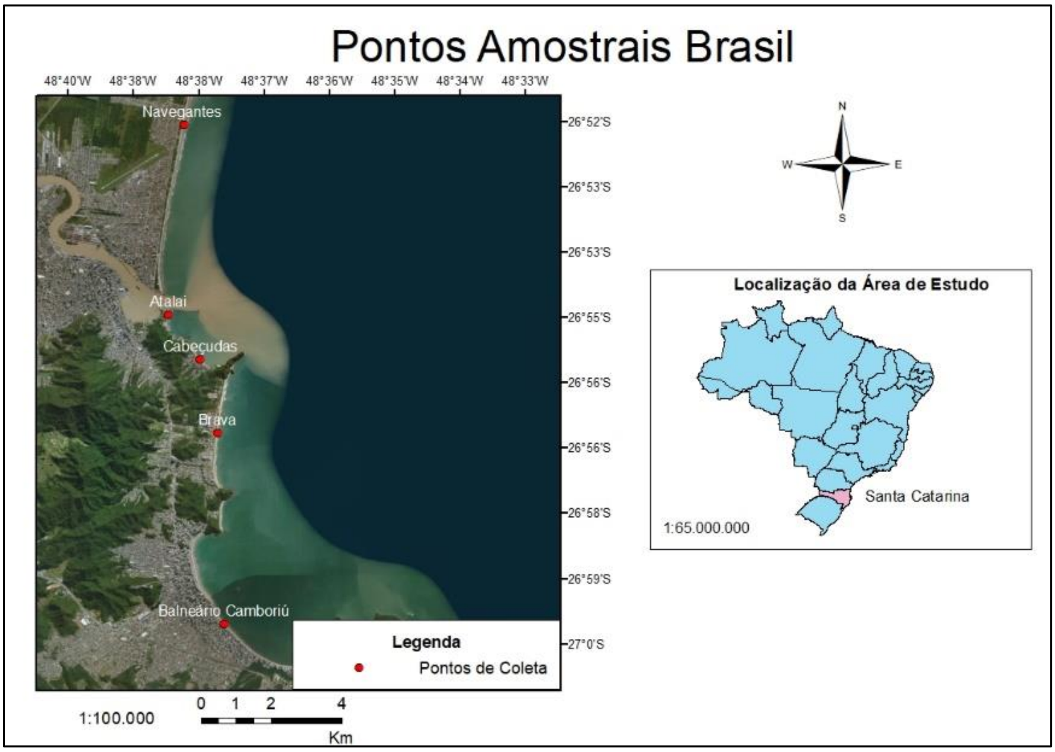
The Puebla Farnal beach was classified as intermediate beach since in the region there was a predominance of beaches with this characteristic, as can be observed in the work of Díez et al. (2017).

Using oceanographic buoy data, we were able to determine the direction of the waves and the currents in the different zones studied. Thus concluding that Spanish beaches suffer a north-south coastal drift. This can be verified by analyzing the time series for 2016 and 2019 (Ministerio de Formento 2019 and Ministry of Development 2019)

#### 3.1.2. Brazilian Beaches

The Brazilian beaches studied were: Balneário Camboriú, Brava, Atalaia, Navegantes and Cabeçudas, which are influenced by the Atlantic Ocean (Figure 2), located on the north central coast of the state of Santa Catarina, in southern Brazil, between latitudes 27 ° 00 'S and 26 ° 50' S.

Figure 2. Sample points of Brazilian beaches



The study area is located in the state of Santa Catarina, in the counties of Balneário Camboriú, Itajaí and Navegantes. The IBGE made a population estimative for 2018, which shows an important variation in population size (Table 2). This population variability is due the different activities provided for the population.

Table 2. Population data of Brazilian beaches, survey 2010

| Beaches | Population Size |
|---|---|
| Balneário Camboriú | 138.732 |
| Navegantes | 79.285 |
| Brava | 4.294 |
| Cabeçudas/Atalaia | 1.129 |

Font: IBGE (2010)

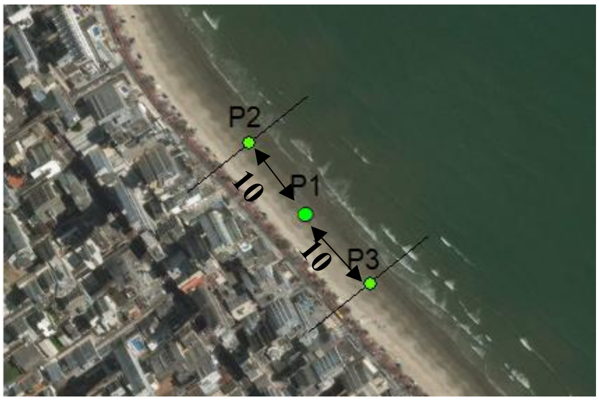
Atalaia and Cabeçudas belong to the same county (Itajaí), but there is a greater concentration of the population in Cabeçudas. It is important to emphasize that just like the Spanish beaches some Brazilian beaches suffer a bigger impact by tourists.

Brazilian beaches had been classified according to the work of Wright and Short (1983) in previous studies (Menezes, 1999; Abreu & Heidrich, 2012). According to Menezes (1999) the beaches of Balneário Camboriú and Navegantes can be classified as dissipative beaches and Brava beach as intermediate. Atalaia beach can be classified as dissipative and Cabeçudas beach as reflective according to Abreu & Heidrich (2012).

### 3.2 Sample Collection

At each beach, three different samples were collected during the winter period. The first point (P1) was intentionally chosen, approximately in the center of the beach, and the other 2 points (P2 and P3) were collected 10 meters from the original first point (Figure 3).

Figure 31. Distance and Spacing of sample points




Samples were collected using a 50 X 50 cm quadrant with 5 cm depth. According to Carson et al. (2011), 50% of microplastics are located in the first five centimeters of the sediment column.

After using the quadrant, the samples were homogenized and divided into four equal parts (quadrant) and only one quadrant was collected. Approximately 1 kg of sample was collected from the beaches for each point and separated into plastic bags.

### 3.3 Laboratory Treatment and Analysis

After sample collection, pre-treatment and subsequent laboratory filtration were performed to separate the microplastics present in the sediment. The following pre-treatment laboratory procedures were performed:

- Homogenization and weighing of samples approximately 400 grams;
- Drying in oven at 60 degrees for 24 hours;
- Sieving in 4 and 1 mm meshes for 3 to 5 minutes;

The microplastic between 4 and 1 mm was identified and the remaining sediment smaller than 1 mm suffered the following procedures to enable the microplastics recognition:

- Removal of organic matter using 30% (v / v) hydrogen peroxide for 24 hours.
- Treatment with saturated sodium chloride, approximately 150 ml, homogenized for 5 minutes and decanted for another 5-10 minutes. The homogenization and decantation process should be repeated twice.
- Filtration using a 0.47μm glass fiber filter of the supernatant solution.

### 3.4 Sample Identification and Classification

For the identification of the microplastics, the glass fiber filters were observed with the aid of a microscope lens with 4 times magnification. Microplastics were identified and quantified according to shape using the method of Stolte et al. (2014). A record of 50 microscopic fields was performed.

### 3.5 Comparative Analysis

After the identification and classification of the samples, the results were statistically analyzed using the Rstudio software (RSTUDIO, 2019). The parametric statistical technique (ANOVA) was used.

## 4. RESULTS

After the identification and classification of microplastics no fragments between 4 and 1 mm were found in both Spanish and Brazilian beaches.

Tables 3 and 4 show the number of microplastics accounted for in Spain and Brazil respectively. Each column of the table represents the total amount founded in the 400 grams in the fraction smaller than 1 mm.

Table 3. Microplastic identified in Spanish beaches (Number of Particles in 400g )

| Beach: | Puzol | Puebla Farnals | Malvarrosa | Pinedo | Autocine |
|---|---|---|---|---|---|
| P1 | 372 | 479 | 346 | 1076 | 1394 |
| P2 | 339 | 327 | 217 | 711 | 1079 |
| P3 | 269 | 441 | 608 | 655 | 1064 |
| **Average:** | **339** | **441** | **346** | **711** | **1079** |
| **Total:** | **980** | **1247** | **1171** | **2442** | **3537** |

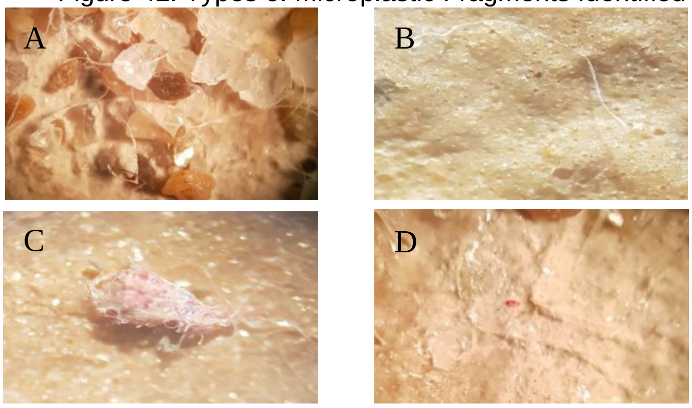
Table 4. Microplastic identified in Brazilian beaches (Number of Particles in 400g )

| Beach: | Balneário Camboriú | Brava | Navegantes | Atalaia | Cabeçudas |
|---|---|---|---|---|---|
| P1 | 45 | 66 | 58 | 21 | 41 |
| P2 | 62 | 62 | 26 | 23 | 58 |
| P3 | 52 | 102 | 41 | 16 | 61 |
| **Average:** | **52** | **66** | **41** | **21** | **58** |
| **Total:** | **159** | **230** | **125** | **60** | **160** |

Table 3 shows that Autocine beach had the highest number of microplastics accounted for and Puzol beach had the smallest amount. For the analyzes performed in Brazilian beaches (Table 4) Brava presented the highest total of microplastics and Atalaia the lowest.

The fragments were classified comparing their aspects with the types of microplastics found in the study by Stolte et al. (2014). The ones identified as microplastics can be seen in Figures 4A to 4D.

Figure 42. Types of Microplastic Fragments Identified




Legend: A) White Fibers B) White Fibers C) Conglomerate of Red and White Fibers D) Pink Fragment

In both countries the most commonly found form of microplastics was fibers. Only a few samples showed small fiber conglomerates (Figure 4C) and fragments of no apparent shape (Figure 4D).

### 4.3 Spanish Beaches Analysis

The data analyzed meet the normality requirements (Tables 5 and 6).

Table 5. Shapiro Teste Spanish Data

| (Shapiro Test) | |
|---|---|
| **Beaches** | **p-value** |
| Puzol | 0,54 |
| Puebla Farnals | 0,40 |
| Malvarrosa | 0,90 |
| Pinedo | 0,30 |
| Autocine | 0,09 |

Table 6. Bartlett Teste Spanish Data

**(Bartlett Test)**

| **Homogenity of Variances** | **p-value** |
|---|---|
| Microplastic quantity/ Beaches | 0,80 |

The ANOVA test presented p-value of 0.001. The Tukey test (Table 7) identifies significant differences between the beaches.

Table 7. Test Tukey Spanish Data

| **Beaches Comparasion** | **p-value** |
|---|---|
| Malvarrosa vs Autocine | 0,004 * |
| Pinedo vs Autocine | 0,518 |
| Puebla Farnals vs Autocine | 0,009 * |
| Puzol vs Autocine | 0,002 * |
| Pinedo vs Malvarrosa | 0,046 |
| Puebla Farnals vs Malvarrosa | 0,975 |
| Puzol vs Malvarrosa | 0,993 |
| Puebla Farnals vs Pinedo | 0,112 |
| Puzol vs Pinedo | 0,024 * |
| Puzol vs Puebla Farnals | 0,853 |

There was a significantly statistical different amount of microplastics between the beaches analyzed.

Autocine and Pinedo are significantly different from the others which was expected, since both are closer to each other, have similar anthropogenic activities and are characterized as reflective beaches. The rise of tourists in the region impacts and increase the pollution, which may explain the high number of microplastics present. Also, the beaches are classified as reflective which can explain the high amounts of microplastics found, since these beaches are able to retain most of the contaminants found in them.

The direction of the coastal drift (north-south) can assist with the explanation, where microplastics may have a higher deposition tendency on the southernmost beaches, such as Pinedo and Autocine. The Port of Valencia is located in this area, but it was not possible to state that the port activity contributes to the contribution of microplastics.

Furthermore, the beaches of Malvarrosa, Puebla Farnals and Puzol are not significantly different from each other, and have much smaller amounts of microplastics than the beaches of Autocine and Pinedo. However, Malvarrosa presented a slightly higher concentration of microplastics than Puebla Farnals and Puzol, probably due to the contribution of microplastics received by the coastal drift.

### 4.4 Análise Praias do Brasil

After proving the normality requirements (Tables 8 and 9) it was proceeded exactly as in the Spanish beaches.

Table 8. Shapiro Teste Brazilian Data

**(Shapiro Test)**

| **Beach** | **p-value** |
|---|---|
| Balneário Camboriú | 0,90 |
| Brava | 0,22 |
| Navegantes | 0,80 |
| Atalaia | 0,47 |
| Cabeçudas | 0,22 |

Table 9. Bartlett Teste Brazilian Data

**(Bartlett Test)**

| **Homogenity of Variances** | **p-value** |
|---|---|
| Microplastic quantity/ Beaches | 0,44 |

In this case the ANOVA also presented a p-value of 0.001. The Tukey test (Table 10) shows the significant differences between the beaches.

Table 10. Teste Tukey Brazilian Data

| **Comparação de Praias** | **p-valor** |
|---|---|
| Balneário vs Atalaia | 0,007 * |
| Brava vs Atalaia | 0,001 * |
| Cabeçudas vs Atalaia | 0,007 * |
| Navegantes vs Atalaia | 0,054 |
| Brava vs Balneário | 0,504 |
| Cabeçudas vs Balneário | 1 |
| Navegantes vs Balneário | 0,682 |
| Cabeçudas vs Brava | 0,504 |
| Navegantes vs Brava | 0,082 |
| Navegantes vs Cabeçudas | 0,682 |

Atalaia was significantly equal to Navegantes, perhaps because both are mainly frequented by the local population and are dissipative beaches, where pollutants such as microplastic have a lower possibility of being accumulated. Atalaia also has a coastal drift that indicates a deposition of microplastics to the west, away from the collection point in the center of the beach, which may explain the smaller amount of microplastics observed for this location.

Brava, Cabeçudas and Balneário Camboriú presented higher amounts of microplastics. These beaches are also the ones that receive the largest number of tourists throughout the year for that reason it is common to find bars and small vendors through the beach. In the case of Cabeçudas, some bars use the beach as part of their establishment, placing plastic chairs and tables along the sand. All of these factors may contribute to the microplastics set on the region.

Although the three beaches (Brava, Cabeçudas and Balneário Camboriú) did not presented a significant statistical difference, the distribution of microplastics can be analyzed according to their morphodynamics classification and coastal drift, as well as the influence of the rivers present in the region.

Balneário Camboriú is classified as dissipative indicating that the beach may have a facility to disperse the microplastics and a tendency to accumulate on the edges of the shore line due to the coastal drift, point located away from the sample point.

Cabeçudas and Brava beaches are characterized as reflective and intermediate, respectively, which may indicate greater retention of microplastic at the central point.

In both cases, both in Brazilian and Spanish beaches, confirm the results previously obtained by authors such as Carvalho and Neto (2016) and Bosker et al. (2018), which is the origin of microplastics is from marine environment such as rivers and the ocean, anthropogenic activities performed in the area increase the amount of microplastics in the shore line.

### 4.3.3 Análise Espanha vs Brasil

Finally, a comparison between the beaches of Spain and Brazil, concluded that the both countries have significant statistical and high difference between the number of microplastic founded (Figure 5).

Figure 5. Comparison between Spanish and Brazilian Beaches

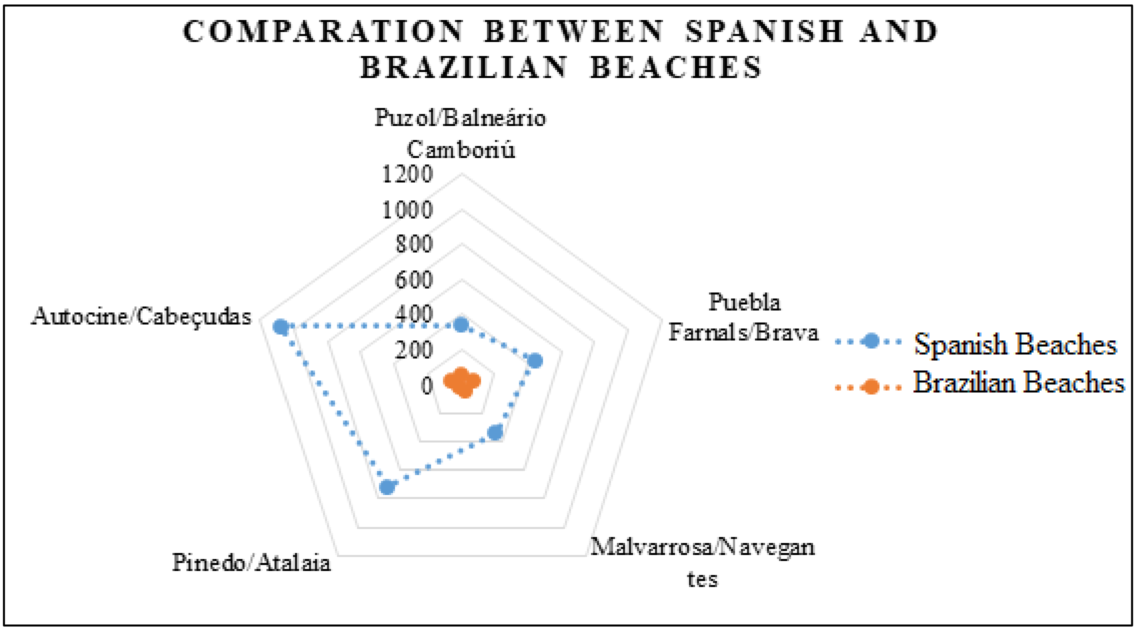


Figure 5 shows that all the studied beaches of Spain have much higher number of microplastics than the Brazilian beaches. When comparing Figure 6 and Figure 7, it can be observed that none of the 5 Brazilian beach, regardless of whether or not it has a characteristic similar to a Spanish beach, obtained similar amount of microplastics.

Figure 6. Quantity of microplastic in each Spain beach

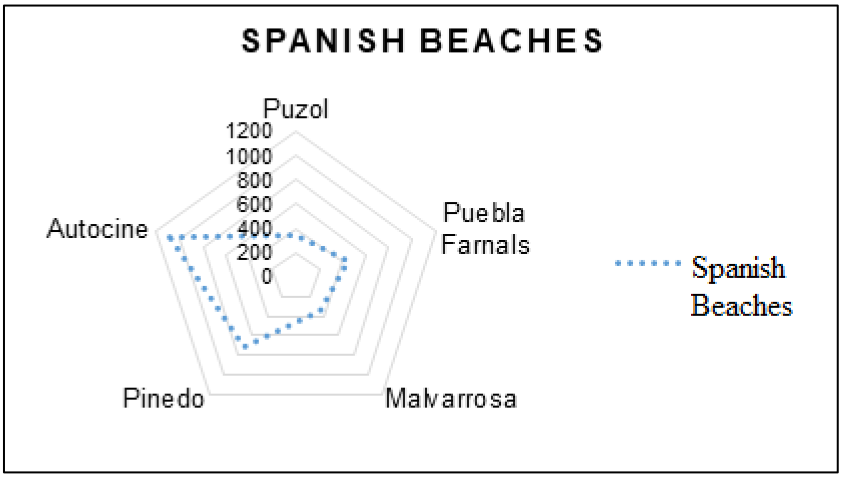
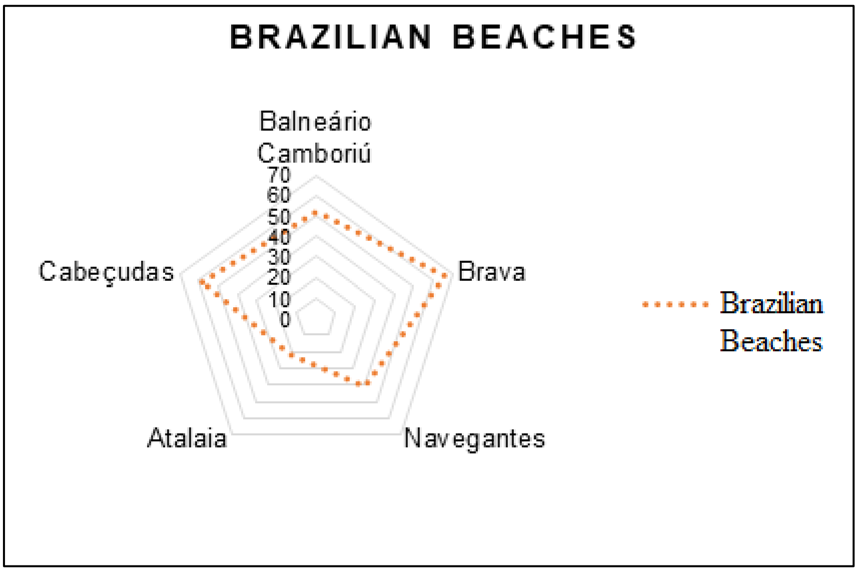



Figure 7. Quantity of microplastic in each Brazilian beach




Chubarenko et al. (2018), says that the microplastics found on sandy beaches are likely originated in the marine environment they are affected by, this could explain why there is such a difference between the countries studied.

The amount of microplastic in Spain is higher because the Mediterranean has a higher retention of pollutants than the Atlantic Ocean. Moreover, when observing the currents that influence the study areas, it is possible to verify that in the Brazilian beach region the South

Atlantic current flows in the opposite direction of the beaches, possibly displacing the microplastics away from the coast. In contrast, in Spanish beaches where the currents of the Mediterranean Sea do not allow such an intense flow of water exchange in the region possibly causing a greater retention in the amount of microplastics.

Finally, by comparing our study with the study of Vianello *et al.* (2013) done in the Lagoon of Venice the amount of microplastic found of 2175 to 672 particles in kg was inferior. However, comparing with another study in sediment from China the amount of microplastic found 435 to 250 in only 50 grams of dry sediment was superior to our study (QIU, Q. *et al.*, 2015).

## 5. CONCLUSION

In conclusion there is a difference between the amount of microplastics found in different beaches of the east coast of Spain and the south coast of Brazil. Beaches bordering the Mediterranean Sea had a higher number of microplastics.

A statistical difference was identified between the Autocine and Pinedo beaches compared to the Malvarrosa, Puebla Farnal and Puzol beaches, where the former had a higher amount of microplastics. In the case of Brazilian beaches, Brava, Cabeçudas and Balneário Camboriú beaches presented a higher amount of microplastic than Atalaia and Navegantes beaches.

Due the variability in the amount of microplastic founded in different papers in the existing literature, it's important the deepening of this study area.

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## BIOGRAPHICAL NOTES

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