MICROPLASTIC POLLUTION ON GRAN CANARIA ISLAND BEACHES

JORGE RAPP CABRERA

CURSO 2017/18

Directores:

Dra. Alicia Herrera Ulibarri

Dra. María M. Gómez Cabrera

Trabajo Fin de Título para la obtención del Grado en Ciencias del mar

TÍTULO

Microplastic pollution on Gran Canaria island beaches

DATOS PERSONALES

Nombre: Jorge

Apellidos: Rapp Cabrera

Titulación: Grado en Ciencias del Mar

DATOS DEL TRABAJO

Tutora: Alicia Herrera Ulibarri

Tutora: María M. Gómez Cabrera

Empresa: Instituto universitario **ECOAQUA,**

Universidad de Las Palmas de Gran Canaria

Departamento: Ecofisiología de Organismos Marinos (EOMAR)

Proyecto de Investigación: Microtrofic

Organismo Financiador: Universidad de Las Palmas de Gran Canaria

FIRMAS

Estudiante: Tutora: Tutora:

Fecha: ____.

Abstract

In recent decades, plastic pollution in the ocean has increased exponentially. With an estimation of more 270 thousand tons of plastics floating in the marine environment where they tend to migrate to the oceanic margins, accumulating in convective zones. The Canary Islands, located on the eastern margin of the Atlantic Ocean, are an obstacle to the Canary Current. There, it is of great interest to study the amount and type of plastic that migrates around the archipelago, as well as the proportion of plastic that washes up on the coast. This study of microplastic pollution on Canary Island beaches is a starting point for seasonal monitoring of plastic waste and future research that will aim to explain the consequences that this marine litter can have on marine ecosystems.

The majority of the items observed were fragments from bigger plastic objects, more of the 50% of the items sampled. The transparent resin pellets or nurdles, semispherical items used as raw material in the production of plastics, were found on most beaches and comprised 14% of the total microplastic pollution. This was unexpected because the Canary Islands do not have a plastics industry, so this marine debris was rafted to the islands via ocean circulation. In addition, microfibers were also found, averaging a maximum concentration of 2000 items/m^2. The distribution of microfibers was totally different from that of the larger microplastics and mesoplastics, suggesting a possible endogenous origin of the contamination, probably by wastewater discharges, ravines and beach users.

Key words

Marine debris, microfibers, microplastic, mesoplastics, beaches, Canary Islands

Contents

1. Introduction

Globally, more than 250 million tons of plastic wastes are produced every year, of which between of 2 and 5 % end up in the sea. This means a mean of 8 million tons of plastic waste is being discharged into the oceans (Jambeck et al., 2015) mostly by rivers (Lebreton et al., 2017).

A study based in an oceanographic model has estimated that there are around 5.25 trillion particles of plastic debris floating on sea surface (Eriksen et al., 2014). Furthermore, this study showed that polytyrene foam was the most frequent macroplastic and abandoned fishing buoys represented 58.3% of the macroplastic weight. This floating plastic represented 15% of the oceanic total. The rest was submerged below the sea surface (15%) or on the seabed (70%) (Jambeck et al., 2015). Other studies have shown that the fraction of floating waste tends to migrate to oceanic margins or accumulates in subtropical gyres (Cozar et al., 2014; Eriksen et al., 2014; Lebreton et al., 2017; Van Sebille, 2015). These studies have identified five large areas of accumulation.

However, not all the marine litter is macroplastic (>25 mm); there are two smaller fractions. One is an intermediate fraction (5-25 mm) termed mesoplastic (Lee et al., 2013); while the other, a fraction, termed microplastic (MP, Thompson et al., 2009), comprised of even smaller particles (< 5 mm, Arthur et al., 2009). In addition, inside the MPs one can distinguish two fractions, one between 1-5 mm (larger) and other below 1 mm (smaller) (Lee et al., 2013). Those that have been prefabricated with these dimensions are known as primary microplastics, and those have been generated from the fragmentation of larger plastic pieces are known as secondary microplastics (Barnes et al., 2009).

In several investigations has been showen that the MP is ingested by many marine organisms from different trophic levels (Carbery et al., 2018). Ingestion may occur accidentally, for example by marine filter feeders, from small bivalves (Cauwenberghe and Janssen, 2014) to large whales (Besseling et al., 2015) or it may be purposefully by selective ingestion. This latter situation occurs in some species of planktivorous fishes. They ingest blue MPs because they confuse it with a species of blue copepod (Christian et al., 2017). Some marine turtles ingest plastic bags, confusing them with jellyfish, their natural food (Nelms et al., 2018).

Moreover, it has been shown that in some contaminated marine waters, MPs acquire chemical contaminants, among which are some persistent organic compounds (POC’s) (Van et al., 2012). This means that the MPs, in the marine environment, are associated with harmful chemical compounds that, by ingestion, are assimilated by the organisms who eat them (Rochman et al., 2013). Once in their bodies, the contaminants can impact their health (Rochman et al., 2014).

Therefore, it is of great interest, not only to the scientific community, but also to society, in general, to learn if these pollutants are being bioaccumulated along marine trophic webs. Are they biomagnified at the highest levels of the food web? Do they have a deleterious effect on these ecosystems (Carbery et al., 2018).

The Canary Islands, located in the oriental margin of the Atlantic Ocean and in the middle of the influence of Canary Current, have been shown to receive large amounts of plastic waste, registering maximum concentrations of around 300 g/m^2 on the northeastern coasts of eastern islands (Baztán et al., 2014; Herrera et al., 2018a). All the plastic material that reaches the Canary Islands, including microplastics, are a clear example of the type of floating waste that migrates along the eastern margin of the Atlantic Ocean.

However, not all plastic material that reaches the Canary Islands is of exogenous origin. There is evidence that there are certain types of microplastics that are being discharged into the sea and therefore could be endogenous contamination. It has been demonstrated in other regions of the world that microplastics are being spilled into the marine environment through wastewater discharges because the standard treatments applied to wastewater are not fully effective with the reception of MP, especially with the smaller fraction (< 1 mm) (Prata, 2018). There is evidence that the secondary treatment of wastewater retains 99% of the microplastics (Heinonen et al., 2017). Given this situation, if a wastewater discharge has a considerable daily flow, it could be considered that the remaining 1% could become a polluting vector of plastic of great importance for marine ecosystems.

For these reasons, the present investigation is proposed with the following objectives:

1. Determining the quantity and type of micro and mesoplastic that accumulate on the coasts of Gran Canaria.
2. Study the spatial variability of microplastic concentration.
3. Study the possible effect of wastewater discharges on microplastic contamination.

2. Material and methods

2.1. Study area

For the selection of study beaches, a number of general characteristics have been predetermined that the beaches must have:

1- Great capacity to retain marine litter according to its location and orientation.
2- Enough sand on the beach to promote sample collection.
3- Ted presence of sewage discharges nearby, according to the census of discharges published by the Canary Islands Government (GRAFCAN, 2017).
4- Easy access to the beach.

The objective of these requirements was to compare the accumulation of micro and mesoplastic on the different beaches and to determine the endogenous or exogenous origin of the pollution.

Taking into account the aforementioned requirements, 6 beaches were chosen. They were distributed evenly along the entire coastline of the island of Gran Canaria (Fig. 1):

- Bocabarranco Beach in Gáldar.
- Cicer Beach (located in Las Canteras) and La Laja Beach in Las Palmas de Gran Canaria.
- Cuervitos Beach (Vargas Beach) in Agüimes
- Del Águila Beach in San Bartolomé de Tirajana
- Veneguera Beach in Mogán.

Fig. 1 shows that most of these beaches are located along the north and east coasts of the island.

Previous studies by Baztán et al. (2014) and Herrera et al. (2018a) found that the predominantly northern (N) and northeastern (NE) directions of wind, waves and currents cause beaches on north and east coasts to accumulate more marine debris.

For this reason, most of the studied beaches located within the north-east range were chosen for this study. Leaving the beaches of Veneguera and Del Águila on the southern slope of the island to serve as controls (Fig. 1).

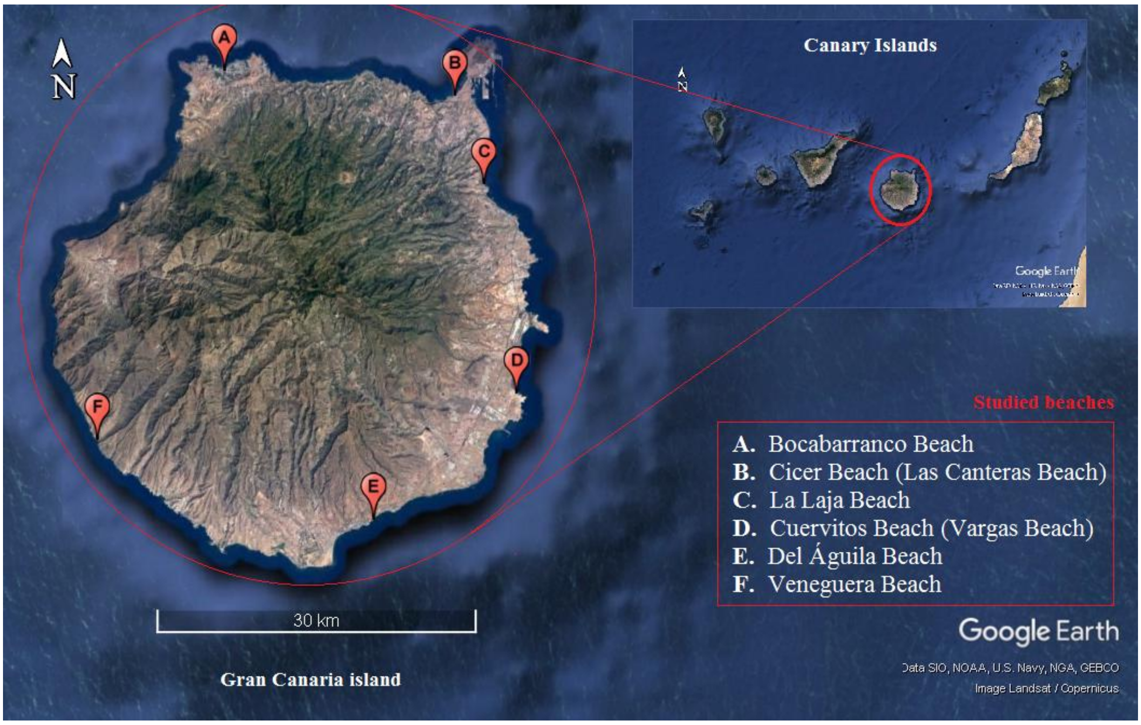

Fig. 1. Location of beaches obtained from Google Earth.

To determine the relation between MP accumulation and the sewage outflows, the wastewater discharges near the sampled beaches were located and characterized from the Canary Government data published in the GRAFCAN website (http://visor.grafcan.es/visorweb/). For this study, the outflows located closer than 5 km from the beaches were examined. A total of 35 wastewater discharges was studied.

As shown in figs. 2 to 8, each wastewater discharge was identified by a number and described in a colour according to its administrative status: red, if the wastewater discharge was not authorized, yellow, if it was in process, and green, if it was authorized. The point of emission of the discharges is represented by a circle, as shown in the GRAFCAN website, while the lines are merely descriptive arrows to indicate the identity of each wastewater discharge.

In addition, in the Annex (Table 6) is shown the difference in the flow rate of wastewater discharges. These data are relevant for the subsequent analyses of the influence of sewage discharges in the MP accumulation. Here, we consider Cicer Beach (Fig. 3), Cuervitos Beach (Fig. 5) and Veneguera Beach (Fig. 8) as control beaches when faced with the influence of wastewater discharges. These beaches have a low number of wastewater discharges compared to the rest.

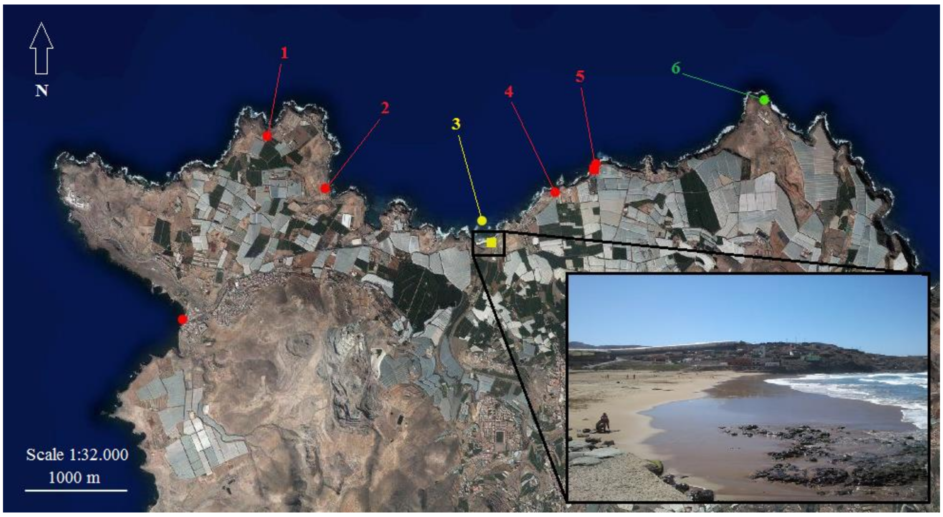

Fig. 2. Wastewater discharges closer than 5 km from the Bocabarranc Beach.

Fig. 3. Wastewater discharges closer than 5 km from the Cicer Beach (in Las Canteras Beach).

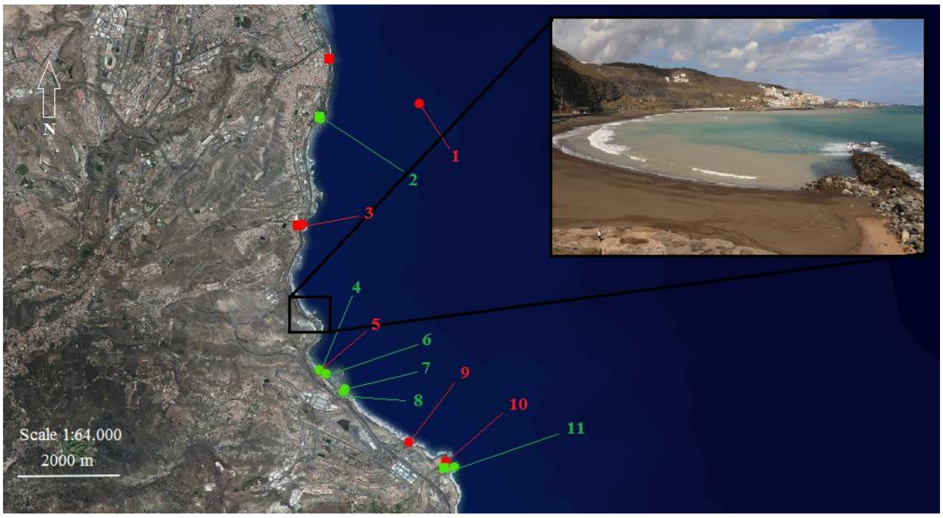

Fig. 4. Wastewater discharges closer than 5 km from the La Laja Beach.

Fig. 5. Wastewater discharges closer than 5 km from the Cuervitos Beach (in Vargas Beach).

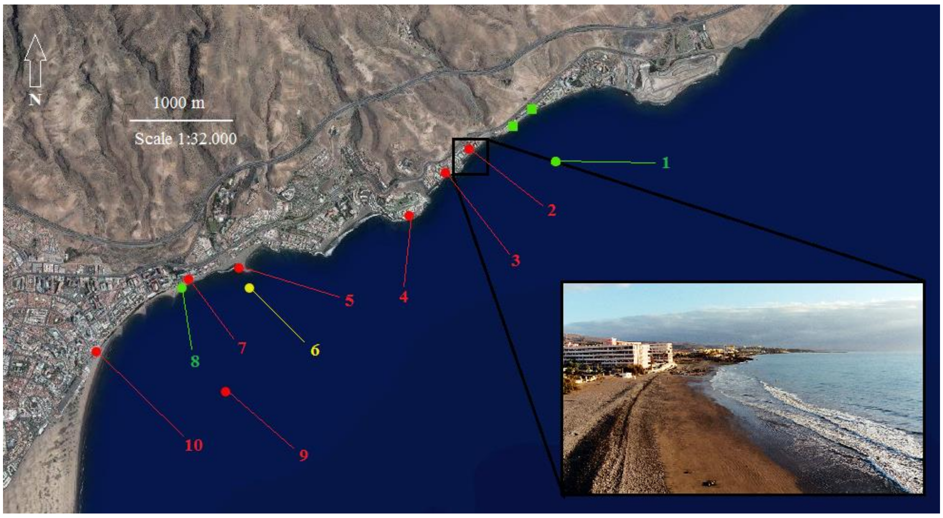

Fig. 6. Wastewater discharges closer than 5 km from the Del Águila Beach.

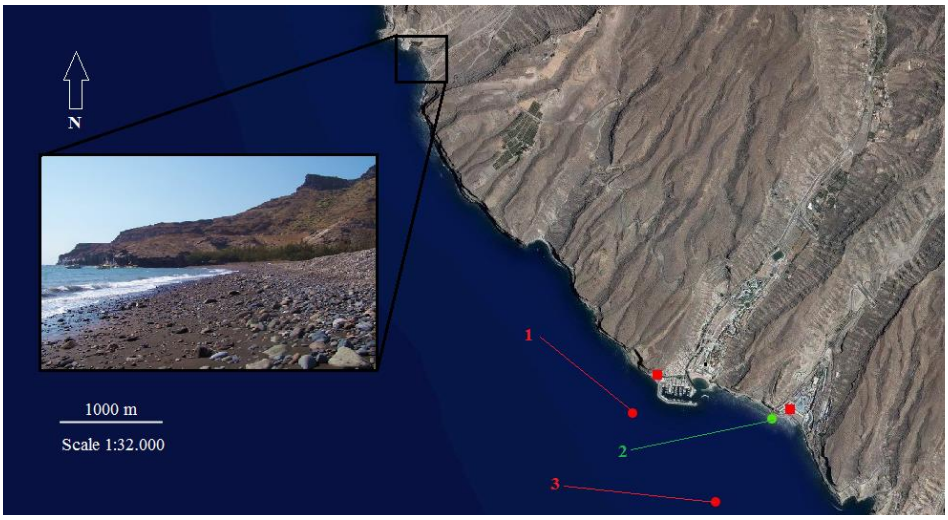

Fig. 7. Wastewater discharges closer than 5 km from the Veneguera Beach.

2.2. Characteristics of the beaches.

Table 1. describes the main general characteristics of each beach. It gives location, orientation, anthropological pressure and sediment distribution:

Table 1. General characteristics of the beaches studied.

	Bocabarranco	**Cicer**	**La Laja**	**Cuervitos**	**Del Águila**	**Veneguera**
Location:	NW	NNE	NE	E	SE	SW
Latitude	28° 9'29.20"N	28° 7'57.03"N	28° 3'24.41"N	27°52'47.49"N	27°46'32.33"N	27°50'48.51"N
Longitude	15°39'55.49"W	15°26'38.23"W	15°25'4.26"W	15°23'25.22"W	15°31'43.68"W	15°47'28.84"W
Direction	NNW	NW	NE	NE	SSE	SW
Anthropogenic presure:	Medium	High	Medium	Low	High	Low
Users	No	Yes	No	No	Yes	No
Urban	Yes	Yes	Yes	No	Yes	No
Wastewater discharges	Yes	Yes	Yes	Yes	Yes	Yes
Cleaning	No	Yes	No	No	Yes	No
Mouth of a ravine	Yes	Yes	No	No	No	Yes
Total longitude	240 m	2949 m	1270 m	100 m	430 m	340 m
Intertidal width in sampling area	30 m	20 m	25 m	20 m	20 m	10 m
Sediments:	Sand and boulders	Sand	Sand	Sand	Sand and boulders	Sand and boulders

The anthropogenic pressure on the beaches has been described qualitatively (low, medium or high) according to the following qualities: number of users, presence of emissaries within a radius of 5 km and location (within or outside an urban centre).

Therefore, as shown in Table 1, Cuervitos and Veneguera have low levels of anthropogenic pressure, while Cicer and Del Águila have high levels. Bocabarranco and La Laja showed an average value.

2.3. Characteristics of the wastewater discharges.

For each wastewater discharge, the characteristics described below have been analysed on the basis of the technical specifications provided by the GRAFCAN viewer from the Canary Islands Government:

- Flow rate in $m^3/hour$.
- Nature of the effluent.
- Effluent treatment
- Continuity of the wastewater discharge.
- Distance to the sampling area.

From this analysis, the data obtained are summarised in Table 6 of the Annex.

2.4. Sampling process.

In the present work, the methodology proposed in the protocol, included that in Herrera et al. (2018b) were applied, following the guidelines proposed by (Besley et al., 2017) for the beach sampling protocol:

A 50x50 cm quadrant is placed in the sand, leaving the high tide line with the plastic debris in the middle of the quadrant, as shown in Fig. 8 (right).

Fig. 8. On the left is a photograph of the sample bag. On the right corresponding to a sample collected on the beach of Bocabarranco on 2/2/2018, it showed the placement of the quadrant on the high tide line.

Then, a photo is taken and the sample is collected:

- **For the larger fraction (1-25 mm)** the surface layer (about 1 cm) of the sediment was removed with a metal bucket. The sample obtained was placed in a mesh bag with an opening of 1 mm. The mesh was rinsed so that the sand was removed, and all organic and inorganic material greater than 1 mm was retained.

- **For the smaller fraction (0.01-1 mm)**, a sub-sample of 50-100 mL of sediment was collected with a metal spoon and stored in a sealed container for further processing.

Three replicates were collected per beach and as much information as possible is recorded about the state of the beach and the meteorological and oceanographic conditions observed.

Samples were collected between 1 and 5 February 2018, days coinciding with the equatorial lowlands. Therefore, the seasonality of the samples would correspond to winter.

Larger fraction (1-25 mm)

1- Place the sample into a 500 mL beaker. If the sample contains organic material add 100 mL of 96% ethanol in order to separate plastics from organic debris by density. The organic material (algae and plant debris) remains on the surface, while the inorganic material sinks (plastic debris and sediment).
2- If sediment is present, add 100 mL with of NaCl saturated solution (358.9 g/L). The plastic material remains on the surface while the sediment sinks.

The plastic material is removed and deposited in a petri dish.

Note: In step 1, together with the organic material, the plastic material with a density less than 0.8 g/cm3, such as EPS (Polystyrene (expanded foam)) and XPS (Polystyrene (extruded foam)) foam, remains floating, in this case remove the material with a tweezers and deposit it on the Petri dish before disposing of the ethanol with the organic material.

Smaller fraction (0.01-1 mm)

1- Deposit 50 mL of the sample in a 500 mL beaker, add 200 mL of a NaCl saturated solution (358.9 g/L).
2- Stir for 20 minutes at 600 rpm and leave to decant for 24 hours.
3- Once the sedimentary material is completely decanted at the bottom of the beaker, the saturated water is extracted by siphoning.
4- Finally, the water removed is filtered with a polycarbonate filter of 10 μm of pore.

2.5. Quantification and classification of plastic waste.

Once the samples had dried, they were differentiated by type and colour and then quantified. Among the most common types of plastics in the oceans, we can distinguish 5 major groups: fragments, fibres, foams, films and micro-pellets (Rezania et al., 2018).

Larger fraction (1-25 mm)

For the fraction (1-25 mm), as shown in the Fig. 9, two fractions were classified by size, the **larger microplastic (1-5 mm)** and the fraction of **mesoplastic (5-25 mm)**. The data were standardized, the concentration of plastics per square metre (number of items/m^2) and per liter of sand (number of items/L) was obtained for each fraction, and the total percentage of colours and types was determined.

Fig. 9. Photograph of the sample 1-25 mm collected at Cuervitos beach on 1/2/2018. On the left, the larger microplastic (1-5 mm), and on the right the fraction of mesoplastic (5-25 mm).

Smaller fraction (0.01-1 mm)

The quantification and classification by colours and types was carried out under a binocular microscope (Leica DMS1000 with integrated CMOS camera). The data were normalized by concentration of plastics per litre of sand (nº of items/L) and per square metre (nº of items/m^2) and the total percentage of colours per beach was determined.

Fig. 10. Photograph of red microfiber corresponding to a sample collected at La Laja Beach on February 1, 2018.

2.6. Statistical analysis

The data were processed using the Excel and RStudio statistical programs. At each fraction, an *ANOVA Test* was performed to determine if there were significant differences in concentrations between the beaches, and if so, a *Tukey's Test* was performed to determine which beaches had differences between them. Previously, the statistical conditions that the data met to verify the *ANOVA* were checked; the homocedasticity from the *Levene Test* and the normality of the residues from the *Shapiro-Wilk Test*. If one of these conditions was not met, the necessary changes were made. If all the changes were checked and the conditions were not met, a parametric test (*Kruskal-Wallis Test*) was applied to determine whether there were significant differences in concentrations between the beaches.

In addition, to determine an assumed relationship in the distribution of concentrations between the three fractions, linear correlations were found.

The data obtained for the 35 wastewater discharges was analysed (table 6, annex). A descriptive analysis was carried out in order to find statistical relationships between the concentrations obtained on each beach and the wastewater discharge adjacent to them, taking into account the following explanatory variables:

- The nature of the effluent.
- The distance of the wastewater discharges to the study area.
- The wastewater discharges flow.

A number of "simplifications" were made beforehand, taking into account the following exclusion criteria:

- Only continuous wastewater discharges were taken into account.
- Wastewater discharge with a lack of information according to their flow were discarded.

Subsequently, an analysis of main components was carried out to analyse the differences between the beaches as a function of the explanatory variables mentioned above, independently of the concentrations of plastics.

3. Results

3.1. Spatial variability in micro and mesoplastics accumulation.

The smaller fraction of microplastics (0.01-1 mm) (only micro-fibres) found in La Laja showed a maximum concentration of 2640 items/m^2. The maximum values for the larger fraction of microplastics (1-5 mm) and the mesoplastics (5-25 mm) were found in Cuervitos, reached 1544 items/m^2 and 256 items/m^2, respectively. On the other hand, Veneguera obtained the minimum values in micro-fibres with a concentration of 160 items/m^2 and La Laja in larger microplastics with 32 items/m^2, both beaches obtained the minimum of mesoplastics with 0 items on the samples.

Table 2 shows the mean values (± standard deviation) obtained at each sampling location. As is shown, the concentrations of micro and mesoplastics were very different between the study zones. In general, the replicates showed large differences in concentration, as can be observed in the high values of the standard deviations.

Table 2. Mean concentrations and standard deviation in items/m^2 for each fraction in each beach.

	Microplastics 0.01-1 mm		**Microplastics 1-5 mm**		**Mesoplastics 5-25 mm**	
Beaches	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*
Bocabarranco	933	395	423	97	33	8
Cicer	1413	533	564	766	16	17
Laja	2000	604	428	638	44	46
Cuervitos	613	244	975	533	148	95
Del Águila	667	370	133	84	5	2
Veneguera	213	46	65	8	7	6

One of the main objectives was to know the distribution of the concentrations around the Gran Canarias's coast and if there were significant differences between them. As mentioned above in the section on material and methods, to answer this question, a statistical analysis was performed for each fraction.

3.1.1. Fraction of microplastic 0.01- 1 mm.

- **Distribution of concentrations:**

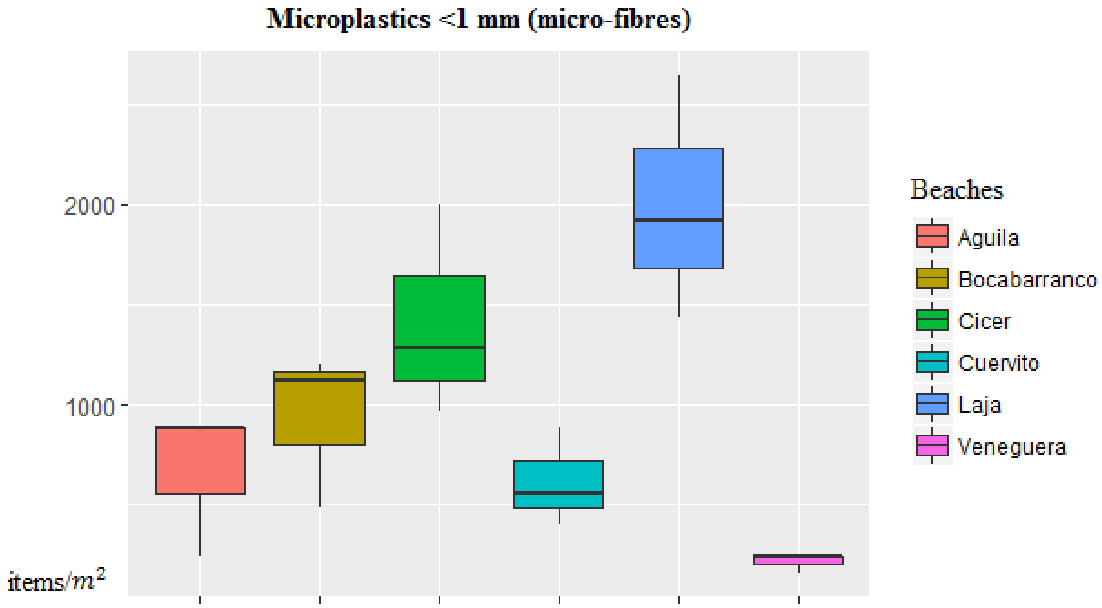

Fig. 11. Concentrations of micro-fibres for each beach (items/m²).

- **Concentrations statistical analysis:**

Analysis of Variance Model	p.value = **0.002** < α (0.05)

Statistical analysis showed that there are significant differences of concentrations between beaches. Then, a *Tukey multiple comparisons of means* was done to find which beaches had differences (p value < 0.05):

Table 3. Tukey multiple comparisons of means 95% family-wise confidence level.

Beaches	*p value*
La Laja – Del Águila	0.017
La Laja - Cuervitos	0.013
La Laja - Veneguera	0.001
Veneguera - Cicer	0.033

3.1.2. Fraction of microplastics 1-5 mm.

- Distribution of concentrations:

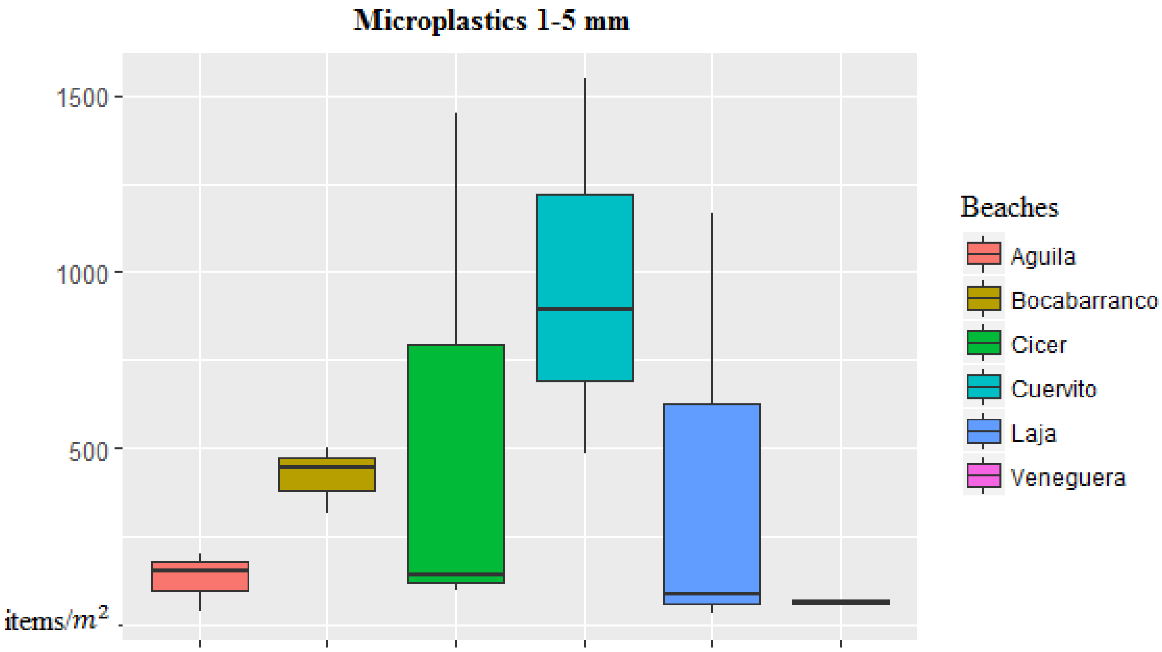

Fig. 12. Concentrations of microplastics 1-5 mm for each beach (items/m^2).

- **Concentrations statistical analysis:**

After applying the possible transformations, the data were not normal. Then, a non-parametric test for this data was done:

Kruskal-Wallis's Test	p.value = **0.118** > α (0.05)

The statistical analysis showed that there were no significant differences between locations for the 1-5 mm fraction.

3.1.3. Fraction of mesoplastics 5-25 mm.

- **Distribution of concentrations:**

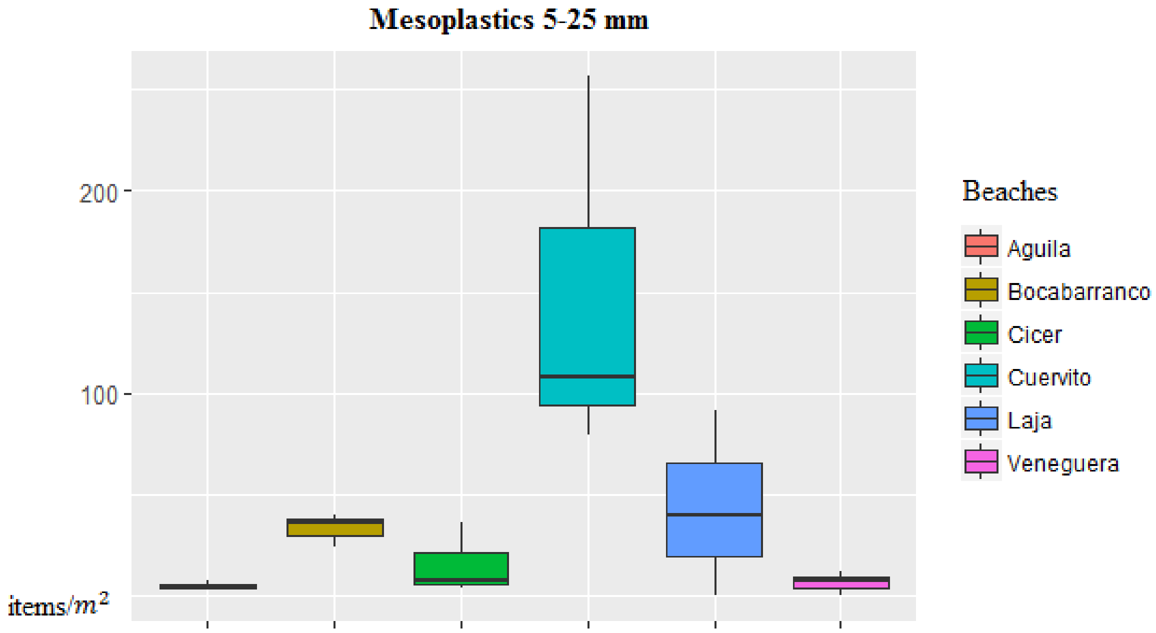

Fig. 13. Concentrations of mesoplastics for each beach (items/m^2).

- **Concentrations statistical analysis:**

Analysis of Variance Model	p.value = **0.008** < α (0.05)

Statistical analysis showed that there were significant differences in concentrations between beaches. Then, a *Tukey multiple comparisons of means* was done to find which beaches had differences (p.value < 0.05):

Tabla 4. Tukey multiple comparisons of means 95% family-wise confidence level.

Beaches	*p.value*
Cuervitos – Del Águila	0.012
Cuervitos - Cicer	0.033
Cuervitos - Veneguera	0.010

3.1.4 Correlation in the distribution of concentrations among the three fractions.

There iwas a clear correlation ($R^2 = 0.784$) between the distribution of larger fractions, microplastics (1-5 mm) and mesoplastics (5-25 mm), while for the smaller fraction of microplastics (0.01-1 mm) (microfibers) there was no correlation in the distribution of accumulation with the other two fractions (Fig. 14).

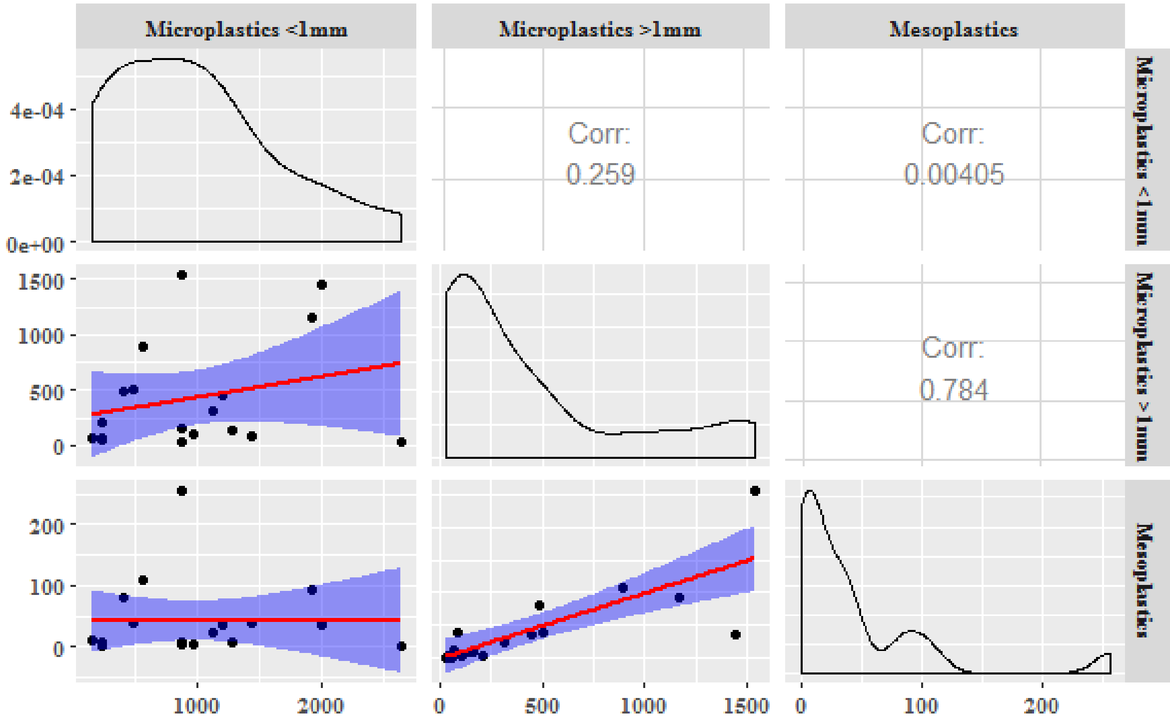

Fig. 14. Linear correlation between the average concentrations (items/m^2) of the three plastic waste fractions studied.

3.2. Composition

For the smaller fraction (microplastics 0.01-1 mm), when analysing the samples, the only items that were certainly plastic, were the brightly coloured microfibers. Therefore, in this fraction, only those fibres that present total evidence of being plastic have been counted, assuming a great underestimation in this fraction.

As shown in Fig. 14 for the larger fractions most of the items were fragments from another bigger plastic pieces, reaching a 57% in larger microplastics (1-5 mm) and and 84% in mesoplastics (5-25 mm). Furthermore, were found a high percentage of resin pellets 14% (left) and of ear swabs 5% (right), these results are relevant to explain the origin of this marine litter.

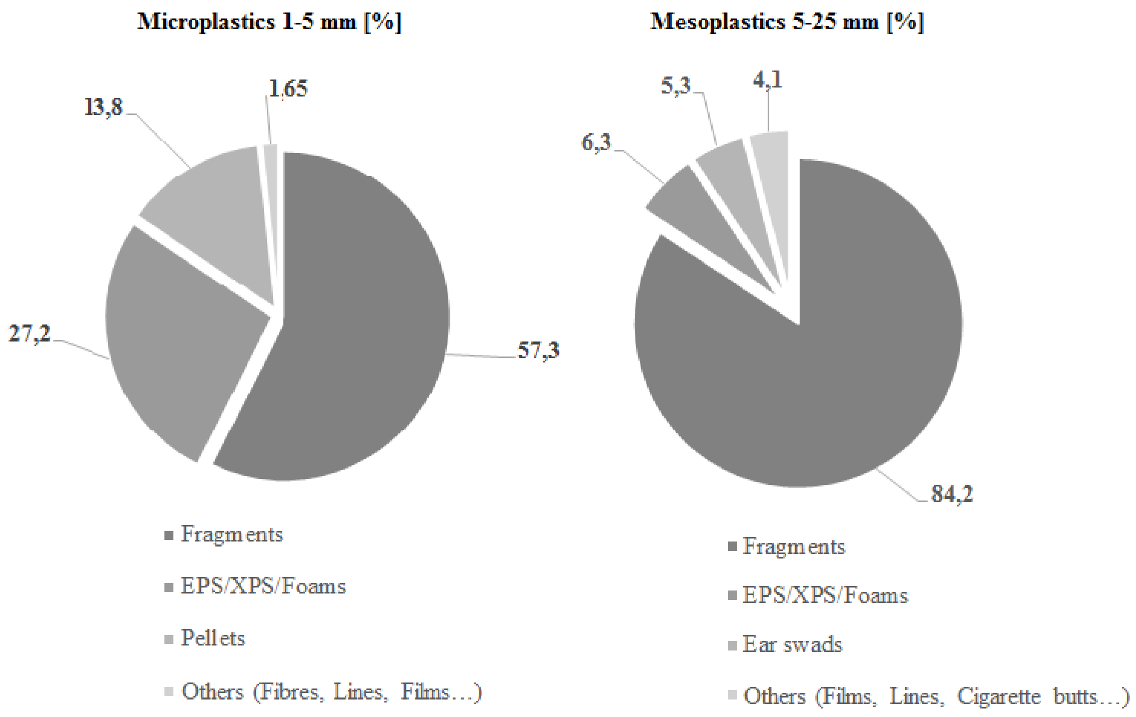

Fig. 15. Typology of the total of items sampled for each fraction.

3.3. Colours

For the smaller fraction (0.01-1 mm), we found a large percentage of blue microfibers with respect to the rest of colours, reaching a 50%. However, for the larger microplastics (1-5 mm) and mesoplastics (5-25 mm) most of the items were white (Fig. 15), it is due to the large percentage of EPS/XPE/Foams found (as showed in the Fig. 14).

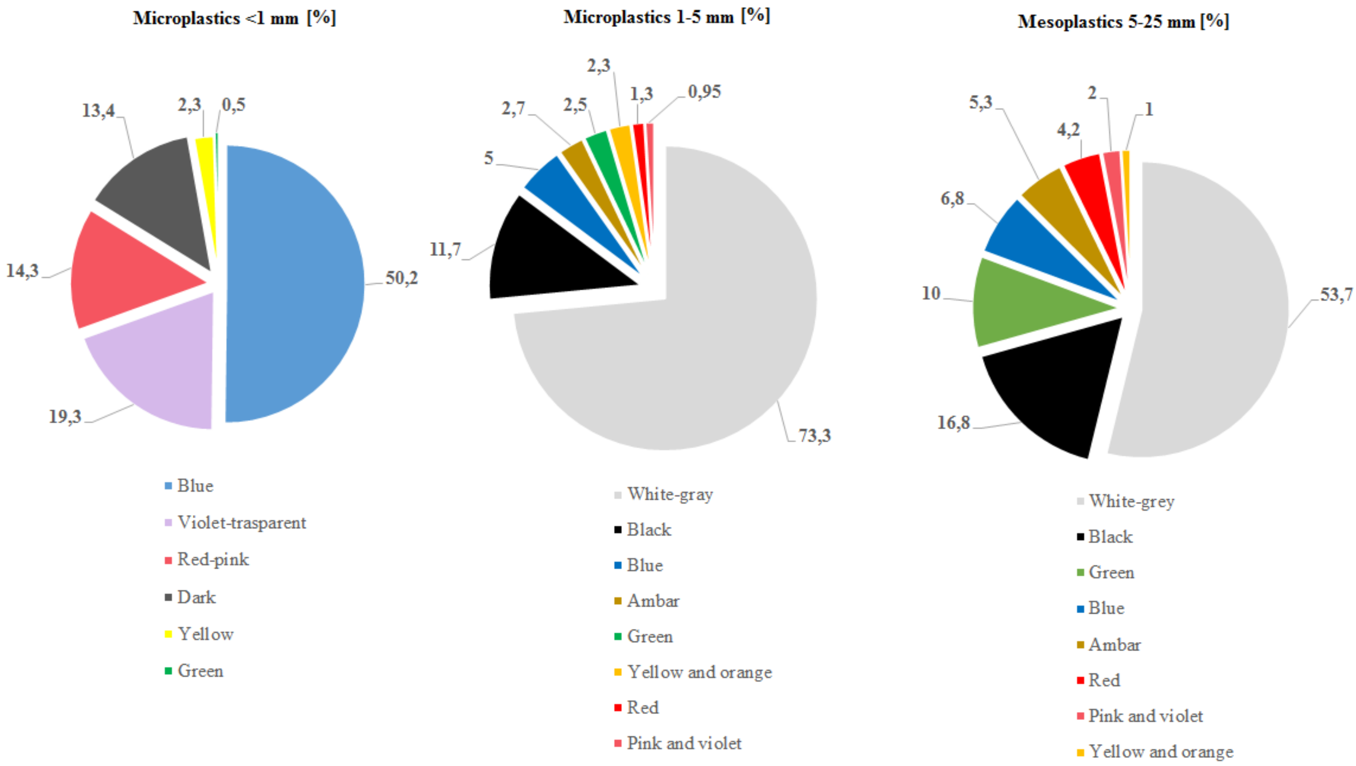

Figure 16. Percentage of colours for each fraction.

3.4. Characterization of the variables defined for the wastewater discharges.

Based on the criteria mentioned in material and methods section, we chose 18 wastewater discharges to study, the distribution of which is shown in the Fig. 16. Then, of these 18 waterwaste discharges, 11 were not administratively authorized and 9 had no treatment, 8 had secondary treatment and only 1 had tertiary treatment.

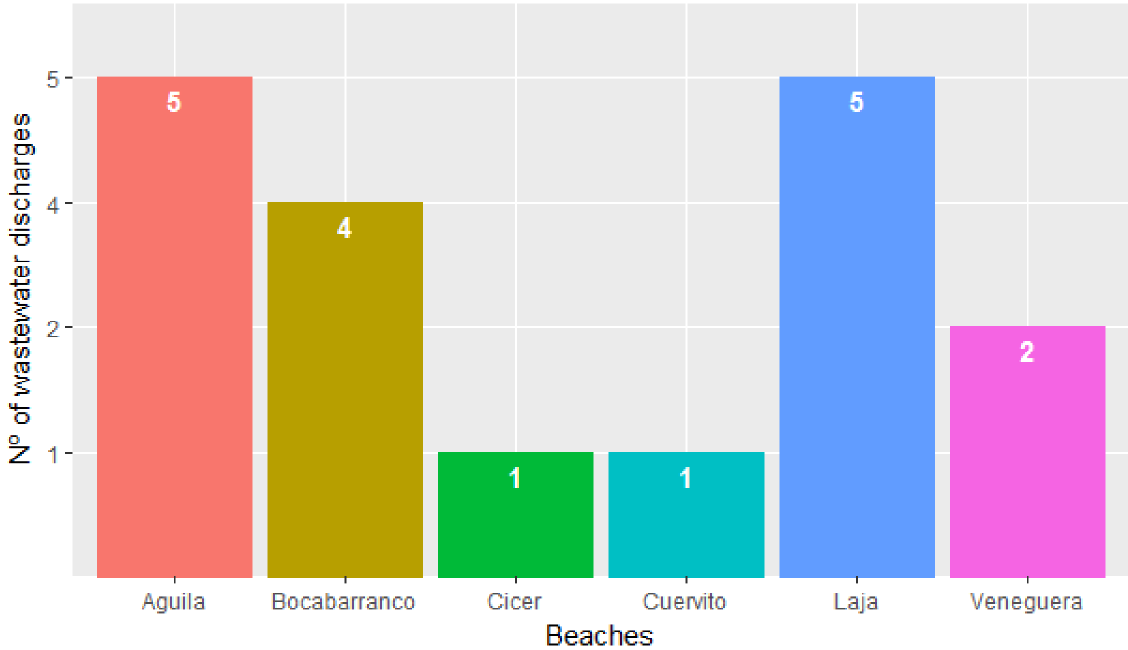

Fig. 17. Distribution by beach of the analysed wastewater discharges from which the statistical analysis was done.

The database obtained is shown in Table 5, the total flow rate (FTot) of all wastewater discharges related to each beach has been calculated. Based on this, the proportion that would correspond to each wastewater discharge has been calculated according to the nature of the effluent; obtaining partial flow rates, being:

- *FBrine*: proportion of the flows of wastewater discharge of brine in m^3/hour.

$$FBrine = \frac{\sum_{i=1}^{Brine} Flow\ rate\ of\ brine\ wastewater\ discharge}{FTot}$$

- *FUrbW*: proportion of the flows of wastewater discharge of urban wastewater in m^3/hour.

$$FUrbW = \frac{\sum_{i=1}^{UrbW} Flow\ rate\ of\ urban\ wastewater\ discharge}{FTot}$$

- *FIndW*: proportion of the flows of wastewater discharge of industrial wastewater in m^3/hour.

$$FIndW = \frac{\sum_{i=1}^{IndW} Flow\ rate\ of\ industrial\ wastewater\ discharge}{FTot}$$

- *FTot:* total flow rate in m^3/hour.

$$FTot = \sum FBrine + FUrbW + FIndW$$

In addition, the average distance of the set of wastewater discharges in each beach was calculated, being:

- *DBrine*: average distance of wastewater discharge of brine in Km.
- *DUrbW*: average distance of wastewater discharge of urban wastewater in Km.
- *DIndW*: average distance of wastewater discharge of industrial wastewater in Km.

Table 5. The database obtained for the characterization of the variables defined for the wastewater discharge for each beach.

Beach	*FBrine*	*DBrine*	*FUrbW*	*DUrbW*	*FIndW*	*DIndW*	*FTot*
Bocabarranco	0.25	2.32	0.75	0.18	0	0	1327.14
Bocabarranco	0.25	2.32	0.75	0.18	0	0	1327.14
Bocabarranco	0.25	2.32	0.75	0.18	0	0	1327.14
Cicer	0	0	1	3.60	0	0	23.50
Cicer	0	0	1	3.60	0	0	23.50
Cicer	0	0	1	3.60	0	0	23.50
La Laja	0.11	2.53	0.09	3.50	0.87	1.60	28300.30
La Laja	0.11	2.53	0.09	3.50	0.87	1.60	28300.30
La Laja	0.11	2.53	0.09	3.50	0.87	1.60	28300.30
Cuervitos	0	0	1	5.40	1	5.40	355
Cuervitos	0	0	1	5.40	1	5.40	355
Cuervitos	0	0	1	5.40	1	5.40	355
Del Águila	0.79	2.09	0.36	2.49	0	0	1398
Del Águila	0.79	2.09	0.36	2.49	0	0	1398
Del Águila	0.79	2.09	0.36	2.49	0	0	1398
Veneguera	0.15	5.60	0.85	4.30	0	0	75.3
Veneguera	0.15	5.60	0.85	4.30	0	0	75.3
Veneguera	0.15	5.60	0.85	4.30	0	0	75.3

To carry out the *Principal Component Analysis*, the first thing that was done was to centralize and scale the explanatory components (flow rate, distance and nature of the wastewater discharges) because their values are very variable.

As can be seen in the following graph (Fig. 17), the beaches also differ according to the explanatory variables mentioned above. In the case of La Laja, it is characterized by obtaining the highest values for *FTot* (total flow rate) and *FIndW* (industrial waterwaste discharge flow rate) and Bocabarranco for having the highest value for *FBrine* (brine water discharge flow rate).

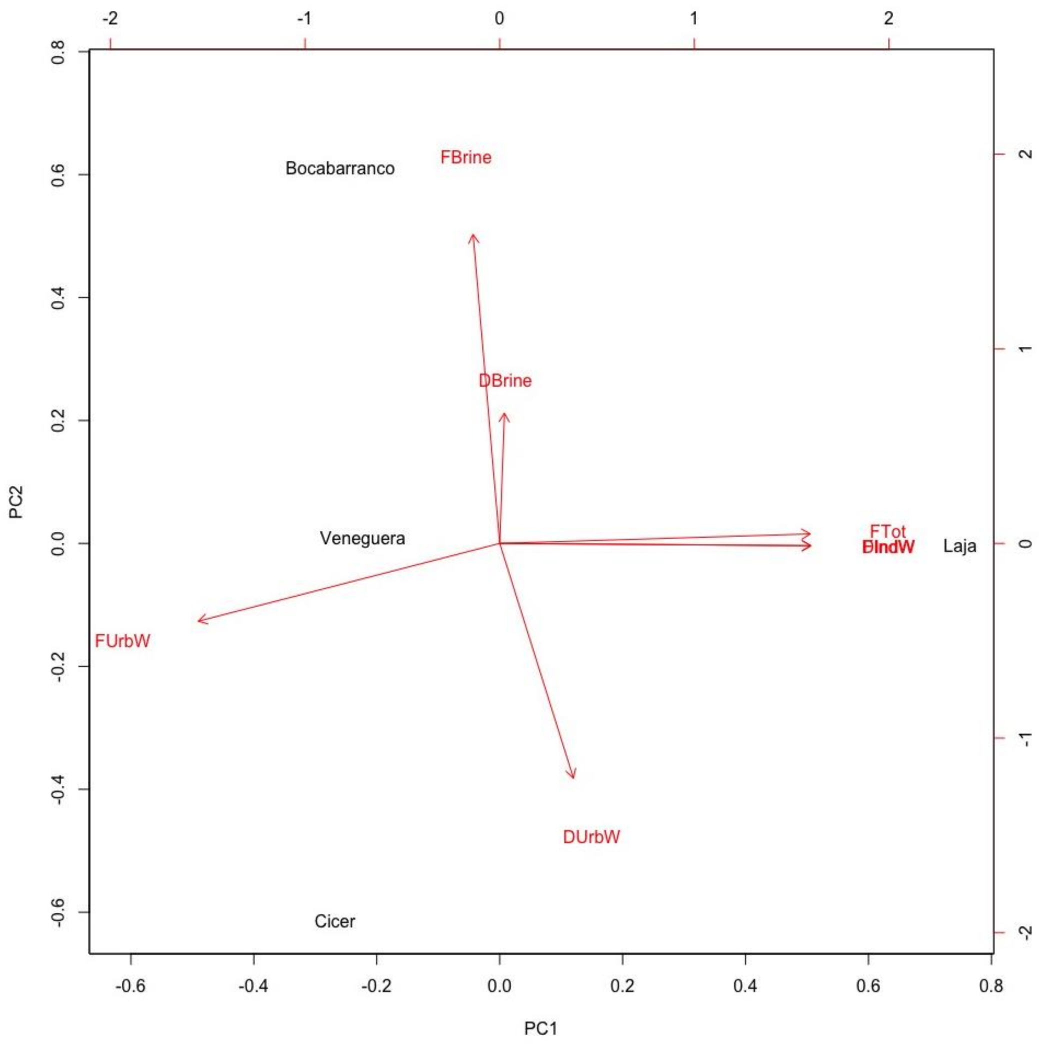

Fig. 18. Graph representing the importance by components (explanatory variables named) as a function of the standardized variance.

4. Discussion

This study is new in terms of the objectives it addresses. On the one hand, it is the first time that the variation of micro and mesoplastic accumulation around all the coastal slopes of Gran Canaria has been monitored, and in addition, it is the first time that the amount of microplastics in the 0.01-1 mm fraction, accumulated on Canarian beaches, has been investigated.

For the largest fraction of plastics (1-5 mm and mesoplastics), both the concentrations found and the typology of the residues found were similar to the main groups of plastic residues recorded in several studies carried out all over the world (Rezania et al., 2018) and in the Canary Islands (Baztán et al., 2014; Herrera et al., 2018a). As we commented previously in Fig. 15, most of the items found for these fractions (microplastics 1-5 mm and mesoplastics) were fragments from larger plastic pieces, obtaining a percentage of 84% in mesoplastics, while in microplastics (1-5 mm) they were 57%. The second most frequently found group was that of EPS and XPS, reaching a high percentage of 27% in microplastics (1-5 mm) while in mesoplastics it was 6%. The study by Eriksen et al. (2014) found that most of the floating macroplastic in the oceans was polytyrene foam and abandoned fishing buoys, which would explain the very high values found for this group. In addition, this would explain why most of the residues for both fractions were white or greyish in colour, which is characteristic of EPS and XPS (see Fig. 16).

On the other hand, in the larger fraction of microplastics (1-5 mm) there was a high percentage of resin pellets, almost 14% of total waste. As described by Herrera et al. (2018a), there is no plastics industry in the Canary Islands that uses these transparent spheres, therefore, it could be concluded from these results that the Canary Islands are receiving a large amount of exogenous pollution through the Canary Current (Van Sebille et al., 2012)

The accumulation patterns in fractions larger than 1 mm, showed that the beaches located on the northern and northwestern slopes, Bocabarranco, Cicer, La Laja and Cuervitos, present the highest average concentrations, while the beaches located on the southern slope, Del Águila and Veneguera, present the lowest concentrations (see table 2). These results coincide with those obtained in the studies carried out by Baztán et al. (2014) and Herrera et al. (2018a) in which it was concluded that the quantity and distribution of these fractions in the Canary Islands is determined by the predominant wind and wave directions (North and Northeast) and the Canary Current (Northeast).

The statistical analysis verifies that in the concentrations of mesoplastics there are significant differences between the beaches (p.value < 0.05), specifically, between Cuervitos and the beaches proposed as control (Veneguera and Del Águila), which supports the hypothesis raised about the exogenous origin of these wastes.

However, in the statistical analysis for the larger fraction of microplastics (1-5 mm) it is obtained that there are no significant differences between the beaches (p.value > 0.05). This result does not correspond to the hypothesis of an exogenous origin, since no differences are observed in the concentrations found on the beaches located on the north/northeast slope with respect to those located on the southern slope. In this case, it is likely that the low number of replicates and the great variability between them does not allow for differences to be observed, for which purpose a more frequent study of the sampling should be considered, and the number of replicates should be increased.

A comparison of the bloxplot graphs for these fractions in Figs. 12 and 13 shows a clear correlation in the distribution of concentrations. This deduction is checked in Fig. 14, in which it is verified that this linear correlation exists (R^2= 0.784). Therefore, the hypothesis that the largest fraction of microplastics and mesoplastics tends to accumulate on the Canary Islands coasts following the same pattern should be proposed, probably due to their similarity in morphology.

However, for the smaller fraction of microplastics (0.01-1 mm), microfibers, the distribution pattern in the accumulation of microplastics on the beaches differs greatly from the other two fractions (microplastics 1-5 mm and mesoplastics) (see Figs. 11, 12 and 13.

For microfibers, the highest average concentrations were observed in La Laja (2000 ± 604 items/m^2), Bocabarranco (993 ± 395 items/m^2) and Cicer (1413 ± 533 items/m^2), a fact that is noteworthy, since, as mentioned above, the beach that obtained the highest accumulation values for the other two fractions was Cuervitos (see table 2).

In Fig. 14, it is observed that microfibers do not have an accumulation tendency similar to the other two fractions; obtaining very low correlations (R^2= 0.259 with microplastics >1mm and R^2= 0.004 with mesoplastics).
This difference in concentration distribution raises the idea that microfibers tend to accumulate differently from larger plastics. The cause of this could be explained by several hypotheses depending on its origin.

As hypothesis 1, if it were assumed that microfibers have an exogenous origin, it could be assumed that they are being transported in the open ocean in a different way from the rest of the plastic waste.

As hypothesis 2, assuming that the microfibers have an endogenous origin in the islands, it could be deduced that they are being dumped into the sea via ravines and/or via wastewater discharges and/or are being accumulated on the beaches due to the users of these.

Statistical analysis shows that the number of microfibers also shows significant differences between beaches (p.value < 0.05). In this case, in La Laja there are differences with respect to Del Águila and Veneguera; and Cicer with Veneguera. With these results, hypothesis 1 could be assumed.

However, La Laja also has differences with Cuervitos, an interesting result given that both have the same orientation and location, as mentioned above, Cuervitos obtains higher concentrations for both microplastics 1-5 mm and mesoplastics. This result indicates that there is a hitherto uncertain variable that would explain the distribution of microfiber accumulation. This could be explained by hypothesis 2, where the entry of microfibers into beaches due to anthropogenic pressure, such as the number of users, ravines and wastewater discharges, has to be taken into account.

If we take table 1 again, we can see that La Laja is not located at the mouth of a ravine and does not have a high level of users. Therefore, we could hypothesize that the high value of microfibers found on this beach could be related to the emission of microfibers via wastewater discharges.

As commented in the introduction, there are many investigations that corroborate this fact in different parts of the world (Prata, 2018), insisting that the quantity of microfibers emitted into the marine environment is directly related to the flow of the emissary and that the most frequent colour of the microfibers is blue followed by transparent and black (Gago et al., 2018), as has been found in the present work (see Fig. 16).

In a descriptive way, if we analyse Fig. 18, we can observe a clear difference between the beaches according to the number of emissaries related to them and their characteristics. La Laja has the higher total flow influenced by large industrial wastewater. While Bocabarranco would be characterized by the influence of the higher flow of brine wastewater.

Given the lack of periodic sampling to complement the data found, both in sediments and in the outlets of these wastewater discharges, it has not been possible to generate a statistical model that verifies that the distribution of microfibers on the island is mainly due to the influence of wastewater discharges. However, the fact that the beach with the highest concentrations of microfibers obtains the highest total flow value and is, with Del Águila, one of the beaches with the highest density of emissaries, could be a hypothesis that explains the distribution of the accumulation of microfibers from endogenous contamination, mainly influenced by wastewater discharges.

5. Conclussion

1- The typology and colours of the three plastic waste fractions studied (microplastics 0.01-1 mm, microplastics 1-5 mm and mesoplastics) were similar to found in previous studies in the Canary Islands and all over the world.
2- The exogenus origin of plastic residues (1-25 mm) was confirmed due to the presence of high amount of resin pellets.
3- Maximum mean concentrations of 2000 ± 604 items/m^2 were found for microplastics 0.01-1 (microfibers), 975 ± 533 items/m^2 for microplastics 1-5 mm and 148 ± 95 items/m^2 for mesoplastics.
4- The distribution of the concentrations for the larger fractions (microplastic 1-5 mm and mesoplastic) are influenced by the predominant directions of wind, waves and current. There were higher concentrations on the north/northeast slopes.

5- The smaller fraction of microplastics 0.01-1 mm (microfibers) obtained a different distribution pattern than the other two fractions (microplastic 1-5 mm and mesoplastic), suggesting a possible endogenous contamination from wastewater discharges.
6- Future studies are needed to corroborate if the microfiber's contamination is locally produced, and it is related to wastewater discharges.

Acknowledgements

Thanks to the EOMAR team for their enormous support, especially to Alicia Herrera, Ico Martinez and May Gomez for their great motivation and perseverance, indispensable to carry out the recent work.

6. References

Arthur, C., Baker, J., Bamford, H., 2009. Proceedings of the International Research Workshop on the Occurrence , Effects , and Fate of Microplastic Marine Debris. Group 530.

Barnes, D.K.A., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Baztán, J., Carrasco, A., Chouinard, O., Cleaud, M., Gabaldon Jesús, E., Huck, T., Jaffrès, L., Jorgensen, B., Miguelez, A., Paillard, C., Vanderlinden, J., 2014. Protected areas in the Atlantic facing the hazards of micro-plastic pollution : First diagnosis of three islands in the Canary Current. Mar. Pollut. Bull. 80, 302–311. https://doi.org/10.1016/j.marpolbul.2013.12.052

Besley, A., Vijver, M.G., Behrens, P., Bosker, T., 2017. A standardized method for sampling and extraction methods for quantifying microplastics in beach sand. Mar. Pollut. Bull. 114, 77–83. https://doi.org/10.1016/j.marpolbul.2016.08.055

Besseling, E., Foekema, E.M., Franeker, J.A. Van, Leopold, M.F., Kühn, S., Rebolledo, E.L.B., Heße, E., Mielke, L., Ijzer, J., Kamminga, P., Koelmans, A.A., 2015. Microplastic in a macro filter feeder : Humpback whale *Megaptera novaeangliae*. Mar. Pollut. Bull. 95, 248–252. https://doi.org/10.1016/j.marpolbul.2015.04.007

Carbery, M., Connor, W.O., Thavamani, P., 2018. Trophic transfer of microplastics and mixed contaminants in the marine food web and implications for human health 115, 400–409. https://doi.org/10.1016/j.envint.2018.03.007

Cauwenberghe, L. Van, Janssen, C.R., 2014. Microplastics in bivalves cultured for human consumption. Environ. Pollut. 193, 65–70. https://doi.org/10.1016/j.envpol.2014.06.010

Christian, N., Sobral, P., Lia, J., Thiel, M., 2017. Science of the Total Environment *Amberstripe scad Decapterus muroadsi (Carangidae)* fi sh ingest blue microplastics resembling their copepod prey along the coast of Rapa Nui (Easter Island) in the South Paci fi c subtropical gyre. Sci. Total Environ. 586, 430–437. https://doi.org/10.1016/j.scitotenv.2017.01.175

Cozar, A., Echevarria, F., Gonzalez-Gordillo, J.I., Irigoien, X., Ubeda, B., Hernandez-Leon, S., Palma, A.T., Navarro, S., Garcia-de-Lomas, J., Ruiz, A., Fernandez-de-Puelles, M.L., Duarte, C.M., 2014. Plastic debris in the open ocean. Proc. Natl. Acad. Sci. 111, 10239–10244. https://doi.org/10.1073/pnas.1314705111

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., 2014. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLoS One 9, 1–15. https://doi.org/10.1371/journal.pone.0111913

Gago, J., Carretero, O., Filgueiras, A. V., Viñas, L., 2018. Synthetic microfibers in the marine environment: A review on their occurrence in seawater and sediments. Mar. Pollut. Bull. 127, 365–376. https://doi.org/10.1016/j.marpolbul.2017.11.070

Heinonen, M., Koistinen, A., Talvitie, J., Mikola, A., 2017. How well is microlitter puri fi ed from wastewater ? e A detailed study on the stepwise removal of microlitter in a tertiary level wastewater treatment plant 109, 164–172. https://doi.org/10.1016/j.watres.2016.11.046

Herrera, A., Asensio, M., Martínez, I., Santana, A., Packard, T., Gómez, M., 2018. Microplastic and tar pollution on three Canary Islands beaches : An annual study. Mar. Pollut. Bull. 129, 494–502. https://doi.org/10.1016/j.marpolbul.2017.10.020

Herrera, A., Garrido-amador, P., Martínez, I., Samper, M.D., López-martínez, J., Gómez, M., Packard, T.T., 2018. Novel methodology to isolate microplastics from vegetal-rich samples. Mar. Pollut. Bull. 129, 61–69. https://doi.org/10.1016/j.marpolbul.2018.02.015

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. the ocean 347.

Lebreton, L.C.M., Van Der Zwet, J., Damsteeg, J.W., Slat, B., Andrady, A., Reisser, J., 2017. River plastic emissions to the world's oceans. Nat. Commun. 8, 1–10. https://doi.org/10.1038/ncomms15611

Lee, J., Hong, S., Song, Y.K., Hong, S.H., Jang, Y.C., Jang, M., Heo, N.W., Han, G.M., Lee, M.J., Kang, D., Shim, W.J., 2013. Relationships among the abundances of plastic debris in different size classes on beaches in South Korea. Mar. Pollut. Bull. 77, 349–354. https://doi.org/10.1016/j.marpolbul.2013.08.013

Nelms, S.E., Duncan, E.M., Broderick, A.C., Galloway, T.S., Godfrey, M.H., Hamann, M., Lindeque, P.K., Godley, B.J., 2018. Marine Science 73, 165–181.

Prata, J.C., 2018. Microplastics in wastewater : State of the knowledge on sources , fate and solutions. Mar. Pollut. Bull. 129, 262–265. https://doi.org/10.1016/j.marpolbul.2018.02.046

Rezania, S., Park, J., Fadhil, M., Mat, S., Talaiekhozani, A., Kumar, K., Kamyab, H., 2018. Microplastics pollution in di ff erent aquatic environments and biota : A review of recent studies 133, 191–208. https://doi.org/10.1016/j.marpolbul.2018.05.022

Rochman, C.M., Hoh, E., Kurobe, T., Teh, S.J., 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3, 1–7. https://doi.org/10.1038/srep03263

Rochman, C.M., Kurobe, T., Flores, I., Teh, S.J., 2014. Science of the Total Environment Early warning signs of endocrine disruption in adult fi sh from the ingestion of polyethylene with and without sorbed chemical pollutants from the marine environment. Sci. Total Environ. 493, 656–661. https://doi.org/10.1016/j.scitotenv.2014.06.051

Thompson, R.C., Swan, S.H., Moore, C.J., Vom Saal, F.S., 2009. Our plastic age. Philos. Trans. R. Soc. B Biol. Sci. 364, 1973–1976. https://doi.org/10.1098/rstb.2009.0054

Van, A., Rochman, C.M., Flores, E.M., Hill, K.L., Vargas, E., Vargas, S.A., Hoh, E., 2012. Chemosphere Persistent organic pollutants in plastic marine debris found on beaches in San Diego , California. Chemosphere 86, 258–263. https://doi.org/10.1016/j.chemosphere.2011.09.039

Van Sebille, E., 2015. The oceans' accumulating plastic garbage. Phys. Today 68, 60–61. https://doi.org/10.1063/PT.3.2697

Van Sebille, E., England, M.H., Froyland, G., 2012. Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. Environ. Res. Lett. 7. https://doi.org/10.1088/1748-9326/7/4/044040

Annex

Table 6. Characteristics analysed for the 35 outfalls studied related to each sampling area with a radius of 5 km.

Beach	Id.	Character	Continuity	Authorized	Effluent traetment	Distance	Efluent (m^3/h)
Bocabarranco	1	Water Brine	Regular	No	No	2.9	8.34
Bocabarranco	2	Urban Wastewater	Irregular	No	No	1.8	No Information
Bocabarranco	3	Urban Wastewater	Regular	No	2	0.18	993
Bocabarranco	4	Water Brine	Regular	No	No	0.9	10.8
Bocabarranco	5	Water Brine	Regular	No	No	1.3	No Information
Bocabarranco	6	Water Brine	Regular	Yes	No	3.5	315
Cicer	1	Urban Wastewater	Regular	No	2	3.6	23.5
Cicer	2	Urban Wastewater	Irregular	No	Desbaste	3.5	No Information
Cicer	3	Urban Wastewater	Irregular	No	No	0.2	No Information
La Laja	1	Urban Wastewater	Regular	No	2	4.5	540
La Laja	2	Urban Wastewater	Irregular	Yes	Desbaste	3.8	No Information
La Laja	3	Urban Wastewater	Irregular	No	Desbaste	1.8	No Information
La Laja	4	Industrial Wastewater	Regular	Yes	No	1.6	24574.3
La Laja	5	Water Brine	Regular	No	No	1.6	1050
La Laja	6	Brine Water + Urban Wastewater	Regular	Yes	2	1.6	2000
La Laja	7	Water brine	Regular	Yes	No	2	No Information
La Laja	8	Industrial Wastewater	Irregular	Yes	No	2	0.36
La Laja	9	Urban Wastewater	Irregular	No	No	3.6	No Information
La Laja	10	Urban Wastewater	Irregular	No	Desbaste	4.4	No Information
La Laja	11	Brine Water + Urban Wastewater	Regular	Yes	2	4.4	136
Cuervitos	1	Urban Wastewater	Irregular	No	Desbaste	3.5	No Information
Cuervitos	2	Brine Water + Urban&Industrial Wastewater	Regular	Yes	2	5.4	355
Del Águila	1	Brine Water + Urban Wastewater	Regular	Yes	2	0.86	204

Del Águila	2	Urban Wastewater	Irregular	No	No	0	No Information
Del Águila	3	Urban Wastewater	Irregular	No	No	0.4	No Information
Del Águila	4	Urban Wastewater	Irregular	No	No	1	No Information
Del Águila	5	Water brine	Regular	No	No	2.6	600
Del Águila	6	Water brine	Regular	No	No	2.8	300
Del Águila	7	Pool Wastewater	Irregular	No	No	3.2	No Information
Del Águila	8	Urban Wastewater	Regular	Yes	2	3.2	147
Del Águila	9	Urban Wastewater	Regular	No	3	3.4	147
Del Águila	10	Urban Wastewater	Irregular	No	No	4.4	No Information
Veneguera	1	Urban Wastewater	Regular	No	2	4.3	64.3
Veneguera	2	Urban Wastewater	Irregular	No	2	5.5	203.62
Veneguera	3	Water brine	Regular	No	No	5.6	11

- **Descripción detallada de las actividades desarrolladas durante la realización del TFT**

  - Planificación. Una vez aclarado el tema de mí trabajo de investigación, durante la primera semana se realizaron una serie de sesiones para planificar las actividades a realizar y su respectiva temporalización.
  - Tareas de investigación sobre el procedimiento de procesado, muestreo, clasificación y cuantificación de residuos marinos plásticos. Durante 3 semanas se me comendó realizar una búsqueda de información bibliográfica acerca del tema, teniendo en cuenta tanto artículos científicos como normativas nacionales e internacionales.
  - Planificación y Muestreo de fracción mayor y menor de Microplásticos y Mesoplásticos en playas.
  Una vez estudiada la metodología de muestreo, se realizó un muestreo de prueba en el cual adquirí los conocimientos necesarios para realizar eficientemente los muestreos de cara a mi trabajo de investigación.
  Entre el 1 y el 5 de febrero de 2018, se muestrearon las playas estudiadas en el TFT: Playa Bocabarranco, Playa Cicer, Playa La Laja, Playa Cuervitos, Playa Del Águila y Playa Veneguera.
  - Procesado de muestras de playa de Mesoplásticos y Microplásticos (ambas fracciones). Con las muestras obtenidas durante el muestreo, realicé durante una semana prácticas en el laboratorio relacionadas con el procesado de las diferentes fracciones de residuos (con las muestras de prueba). Posteriormente, dedicaría durante los siguientes meses (alrededor de 2 meses) esta tarea a diario para la obtención de mis datos en mi trabajo de investigación.
  A partir de mis anotaciones a la hora de la realización repetida de esta tarea, pudimos darnos cuenta de ciertas mejoras que implementamos en un protocolo:

  "Herrera, A.; Martinez, I.; Gómez, M.; Rapp J.; Álvarez, S.;Gestoso, I.; Canning-Clode, J. 2018. Muestreo y procesamiento de muestras de micro y mesoplásticos recogidas en playas. Universidad de Las Palmas de Gran Canaria, Agência regional para o desenvolvimento da investigação, tecnología e inovação. Informe preparado como parte del proyecto PLASMAR (co-financiado por fondos FEDER como parte de POMAC 2014-2020).14pp."

  - Cuantificación y clasificación de muestras de playa de Mesoplásticos y Microplásticos (ambas fracciones). De la misma manera que el procesado de las muestras obtenidas durante el muestreo, realicé durante una semana prácticas en el laboratorio relacionadas con la cuantificación y clasificado de las diferentes fracciones de residuos (muestras de prueba). Posteriormente, dedicaría durante los siguientes meses esta tarea a diario para la obtención de mis datos en mi trabajo de investigación.
  - Redacción del trabajo escrito. Una vez obtenidos los resultados, dediqué dos semanas al procesado de los datos y un mes a la redacción del trabajo escrito.

- **Formación recibida (cursos, programas informáticos, etc.)**

  A lo largo del transcurso de las prácticas asistí a varias charlas relacionadas con mi tema de prácticas, entre ellas, las ponencias realizadas durante el Simposio Internacional de Vigo. Por otro lado, he aprendido a manejar una Lupa Leica con cámara incorporada para la identificación, clasificación y cuantificación de las fracciones más pequeñas de Microplásticos. Además, he tenido la posibilidad de afianzar mis conocimientos en ciertos programas estadísticos, tales como el Excel y el R Studio.

- **Nivel de integración e implicación dentro del departamento y relaciones con el personal.**

  Mi nivel de integración e implicación en el trabajo de investigación se vio favorecido por la actitud de mis tutores y compañeros de laboratorio con respecto a mí. He tenido la gran suerte de obtener una gran relación con todos ellos ya que desde el primer momento me han tratado como uno más y me han ayudado en todo lo posible. A todo ello les estoy muy agradecido, y por tanto mi nivel de implicación en las actividades realizadas ha sido la mejor posible por mi parte.

- **Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT**

  Tal y como he comentado anteriormente, uno de los aspecto más positivos y destacables de mi dedicación al TFT, es la posibilidad de integrarme tan bien dentro de un grupo de investigación. Tener la posibilidad de vivir dicho mundo desde dentro de un grupo de investigación y con tan buenas condiciones ha moldeado mi perspectiva sobre mi futuro y mis capacidades. Dicho de otro modo, me ha animado a seguir con mi camino unidireccional hacia la investigación.

- **Valoración personal del aprendizaje conseguido a lo largo del TFT.**

  La realización del TFT ha supuesto para mí una mejora en mis competencias técnicas con respecto al trabajo en laboratorio, así como en mis habilidades de comunicación oral y escrita, autonomía, sentido de la responsabilidad e implicación personal con respecto al cumplimiento de determinados plazos (referidos a fechas de muestreo y procesado) y a un horario. Además he tenido la oportunidad de mejorar mi capacidad de trabajo en equipo, ya que la colaboración entre diferentes investigadores es prescindible para la obtención de buenos resultados. Por otro lado, académicamente hablando, esta experiencia ha supuesto para mí la oportunidad de aprender y repasar ciertas nociones referidas a la ecología, fisiología y contaminación marina y a la oceanografía.