FACULTAD DE CIENCIAS DEL MAR

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

VERTICAL PROFILE CHARACTERIZATION OF MICROPLASTIC CONCENTRATION AT OPEN OCEAN IN CANARY REGION

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Course 2019-2020

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Trabajo fin de título para la obtención del título de Ciencias del Mar

ABSTRACT

Nowadays there is no doubt about the presence of microplastic in the ocean, both on the surface and in the sediments, having those a great impact on the marine environment and organisms. The types of plastic found vary in composition, physical properties and source of income to the ocean, what means that the different densities of each of them cause a different distribution in the water column.

This study analyses the accumulation of microplastic in the water column, up to 1152m depth in the Canary Islands. The results show accumulation at all depths, varying in distribution, quantity and colors according to the area. On total average, 47,59 fragments per liter and 3,93 fibers per liter were found on the stations, being 90% of those of blue color. Station M02 exhibit the maximum accumulation of microplastic, reaching 7194 fragments at 274m, and a total of 17711 from surface to 485 meter deep. So far, most studies mark the largest accumulation of microplastic on the ocean's surface, however, our results show a greater accumulation of up to 40% of the total microplastic analyzed in certain stations between 95 and 275 meters deep. Moreover, high concentration of microplastic was also found below 600m depth, obtaining 42,66 fragments per liter and 5,08 fibers per liter.

1. INTRODUCTION

1.1. Plastic Pollution

Plastics are synthetic organic polymers composed of long-chain molecules with a high average molecular weight [1] generally derived from fossil fuel feedstocks [2] or organic and inorganic raw materials [3]. Plastic industry has been growing up since 1950 due to social interest, reaching 348 million tons in 2017 [4] . This large-scale global production increment has made plastics become an important pollutant, which is translated to wide-spread environmental concern, as a consequence of its characteristics, specially their light weight and buoyancy, durability, resistance to chemical and physical degradation[5,6] and its capacity to adsorb chemical contaminants and toxins [6]. Further, 50% of the plastic is used just once before dumped, what results in an incredible plastic waste which could be enough to leave an identifiable imprint in the geochemical fossil record [7].

Plastic debris was first recorded in the 1970s in the Atlantic Ocean surface [8] and its concentration is been increasing since then, owing principally to a mismanaged and indiscriminate disposal of it [6,9]. Humanity dependence on plastic in daily life is expressed in its ubiquitous presence as litter in the marine environment. Land-based sources produce the 80% of the plastic debris that exists in the marine environment. Besides, approximately 10% of plastics produced end up in the ocean [10] and the 18% of these is attributed to fishing industry [11].

This plastic litter is very easily transported by wind and water hydrodynamics what makes it mainly present in every research sample collected of marine litter and coastal zone around the world [1,6] and can transport persistent organic pollutants (POPs) [12], non-indigenous species to new locations [13] and distribute algae associated with red tides [14].

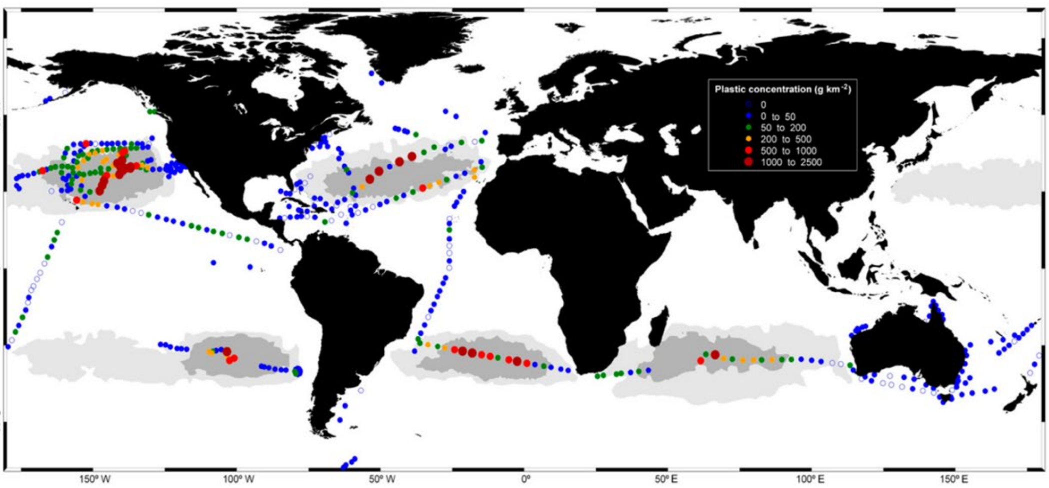


Fig. 1 Plastic debris concentration gkm^{-2} in surface water worldwide [15].

Further, although most plastic debris is not biodegradable, it tends to breakdown and fragment due to photodegradation (solar radiation) and to wave action, which derives in what is named as secondary sourced microplastics when those get to very small pieces [5,15,16]. According to National Oceanic and Atmospheric Administration (NOAA), microplastics are defined as synthetic polymer particles within a 1μm to 5 mm diameter [17–19] and larger plastic particles are referred as mesoplastic [20]. In addition, depending on the source of them to the ocean, these can also be primary sourced microplastics which are originated from a primary source and are directly released to the environment, such as textile industry or personal products [5,16]. Nevertheless, secondary microplastics are considered to be the main source of microplastic pollution in marine environment [21,22] and occur in oceans worldwide [23] leaving no doubt about its potential impact [24].

1.2. Impact of microplastic on marine environment

Polymers degrade very slowly via photo-catalysis when exposed to UV radiation, what makes them highly persistent [25]. For this reason, plastic debris has been accumulating during years in terrestrial environment, shorelines, open ocean and deep sea and in the most remote islands, being ubiquitous and abundant everywhere, and transforming planet´s surface, far beyond areas of human population [23].

Fig. 2 Rapa Nui´s beach in the South Pacific center. Author: Paula Dominguez.

The main problem is that even if plastic waste could be stopped at this moment, the already massive production that has been done, will persist as debris for centuries in our planet. Inappropriate waste management and improper human behavior has result in a release of plastics to the environment, where most that are found are single-use applications, which generally are disposed at landfill sites, storing the problem for the future [23]. Moreover, is thought that all the plastic that has been already thrown into the different environments, still remains either as whole items or fragments, because even it is a hypothesis, it is estimated that plastic takes hundreds to thousand years to get to total degradation [26].

On the other hand, plastic debris also tends to accumulate in the ocean, what includes shorelines, ocean surface and deep ocean sediments, being commonly found and observed from boats worldwide [27,28]. For example, in the North Atlantic Ocean shore, 2000 items of debris, of which more than a half are plastic, were thrown per linear kilometer per year [29]. Moreover, enclosed and semi-enclosed seas can have a higher plastic concentration, reaching six times more plastic for the Mediterranean Sea [29].

Besides, ocean surface has a large proportion of plastic debris, which is floating and mainly accumulating within the principal subtropical ocean gyres. North Atlantic and North Pacific are the subtropical gyres that suffer most of this plastic accumulation, having 20.328(±2,324) pieces/km^2 and 334.271 plastic fragments/km^2 respectively [30]. Moreover, it has been demonstrated that accumulation rates are much lower in the Southern Hemisphere, although these are rapidly increasing for the last decades [23].

For sediment accumulation, one of the principal responsible of sea bed debris input are large rivers, which transport plastic due to their high flow and strong bottom currents [31]. Moreover, a wide variety of human activities such as tourism, contribute to this accumulation, but the prevalent activity that highly participates in plastic debris waste is fishing industry [32]. On the other hand, beach sediments also have plastic accumulation. Ivar do Sul *et al.* (2009) identified pre-production resin pellets accumulating in the shorelines, which in some cases exceed the 1000 pellets/m^2 along the high-tide mark. The presence of plastic debris can totally alter the physio-chemical properties of the sediment, for example an increment of permeability or a decrease in temperature which can also directly affect to marine biota, such as sex-determination in turtle eggs [30].

In addition, anthropogenic footprint is been also found widely dispersed in slope and abyssal depths [32]. Deep submarine extensions, which are a high sedimentation zones, and the accumulation of plastic debris in the upper part of submarine canyons, which currents decrease in deep areas, are an important influence in deep sea debris accumulation [33].

Nevertheless, microplastic can constitute the 80% of this plastic debris accumulation [34], which entails a bigger concern due to its difficulty to remove it from the environment and for its bioavailability for smaller organisms than larger items of plastic debris [30]. Similarly, an accumulation associated with wildlife is showed, leading to the big scale where anthropogenic debris has reach. Nowadays, there are plastics on birds and marine mammals’ stomachs and other organisms’ tissues, or these can be used by hermit crabs instead of shells [28].

1.3.Impact of microplastics on marine organisms

Microplastic has become a big concern because its small size which is within the optimal prey range for several animals in the food chain [35], what makes them available to a wide range of marine organisms [23,36]. In addition, these are present in both pelagic and benthic ecosystems [37] and have been found in guts of marine invertebrates, fish, turtles and other bigger marine animals (such as whales), including those species destinated to human consume and some that play very important ecological roles in the ecosystem [38].

As there is no enzymatic pathways to breakdown those ingested fragments of microplastic, these are never digested, which should make them bio-inert [8]. Thus, although plastics are known as biochemically inert [39], as it is mentioned before, these have industrial chemical additives that may be incorporated to plastic to change its properties or to extend their life providing resistance [37,40], making an introduction of potentially hazardous chemicals to biota when ingested by marine organisms [23,36] and other organic pollutants than microplastic fragments may absorb.

Moreover, if small zooplankton species ingest Persistent Organic Pollutant (POP) saturated microplastic, those may interfere with biologically important processes [23], and it could have a significant toxicological impact, depending on the microplastic size, time of residence in the organism and kinetics of repartition between the plastic and the organism tissues. As plankton constitutes the basis of the marine food web, the toxicological effects can have other serious effects in the world oceans [8]. However, there is no evidence of mortality by microplastic ingestion and its´ impacts on the survival rate of organisms [7].

On the other hand, microplastic properties are constantly changing, which alters its bioavailability [7]. It is been hypothesized that white and lightly-colored microplastic fragments can be easily mistaken as prey for planktonic organisms [41], for example, Herrera et al. (2019) came to the conclusion that blue colored microplastics could be mistaken as *Labidocera* sp. copepod, which is very common in Canary waters [42]. Moreover, low-density buoyant plastics are widely available for larval stages and other planktonic organisms that live within the euphotic zone [43,44].

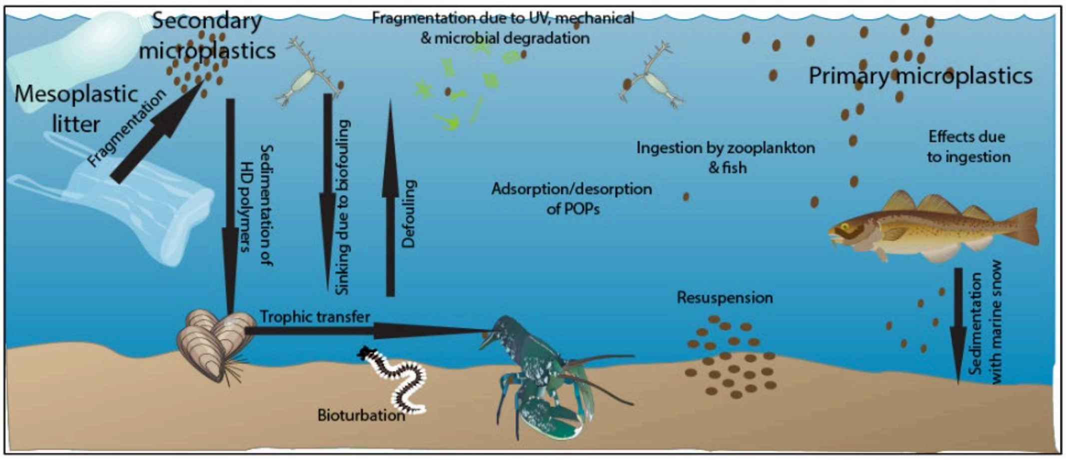


Fig. 3 Potential fate and pathways and biological interactions of microplastic [45].

Cole *et al*. 2013 demonstrated that microplastics are indiscriminately ingested via filter feeding plankton and generally egested as a pellet within a matter of hours [46]. Furthermore, these can be directly ingested by an organism due to its confusion with a prey or may result from eating lower trophic organisms that have themselves consumed microplastic [40,43], causing biomagnification along the marine food chain [15,39].

The principal effect microplastic might have once being ingested by small organisms is mechanical hazards, similar to the ones found in larger animals with macroplastic ingestion. Plastic fragments can block feeding appendages or hinder the passage of food [47] or cause pseudo-satiation resulting in reduced food intake [10,27]. This can also be associated to small plastic fibers which may clump and knot preventing egestion [48].

Reduced food intake can reduce the energy uptake from the diet, which may influence organisms' different behaviors, including those associated with risk versus benefit decisions [35,49] or predator–prey interactions. It has been demonstrated in the laboratory that microplastic ingestion reduces in a 40% the energetic intake of copepods [49]. If this energetical reduction is observed across the zooplankton communities due to microplastic consumption, this could have knock-on effects for pelagic ecosystems [7]. Hence, individual´s behavior changes are useful to be an early warning for ecosystem level effects [50].

Furthermore, these buoyant plastics can suffer the attachment of fouling organisms (biofouling) making an increasement of the particle density and its sinking. It is been seen that due to the relation particle´s total mass/surface area, macroplastic can stay longer in the ocean surface than microplastic, which tend to sink easier [51]. This macroplastics have a great potential to carry species due to its durability and travels to remote costs, making organisms to disperse [9]. Moreover, the rapid regional warming is making many species to move pole-ward to maintain within their range of temperature and plastics are being the main vectors to make this transport easier and more frequent, what makes potential invaders species to be higher too [23].

1.4. Microplastics in the water column

Plastic includes a wide range of pieces which vary in shape, properties, chemical composition, density and other characteristics [22,27]. Physical behavior of microplastic particles in the marine environment, mostly controlled by size and specific density, is the key to understand how these are distributed in the different marine habitats and the variation of import, export and residence time [22,51]. Moreover, microplastic fragments´ specific density varies depending on the type of polymer and manufacturing process, having a plastic density range values from <0.05gcm^{-3} for polystyrene foam to 2.1-2.3gcm^{-3} for Teflon [51].

Table 1. Polymer types among Microplastic Debris and Specific Densities. [22]

Polymer	Polymer density (g cm^{-3})	Polymer Number	Observations
Polyethylene (PE)	0.917−0.965	2 HDPE, 4 LDPE	Buoyant: Ocean surface
Polypropylene (PP)	0.9−0.91	5 PP	
Polystyrene (PS)	1.04−1.1	6 PS	Buoyant: Ocean surface
Polyamide (Nylon, PA)	1.02−1.05	7 OTHER	Used for textile and automotive industry [6]
Polyester	1.24−2.3	7 OTHER	Common in bottom sediment and benthos[23,52]
Acrylic	1.09-1.20	7 OTHER	
Polyethylene terephthalate (PET)	1.37-1.45	1 PETE	-Most common type in every depth. -Plastic bottles fabrication and packaging [6]
Polyurethane (PU)	1.2	7 OTHER	
Polyvinyl chloride (PVC)	1.16-1.58	3 PVC	-Detergent bottles, shampoo bottles, medical equipment [53]

Density differences can make plastics being buoyant or sink [27,44], which contributes to its distribution. Several investigations showed that highest concentrations of microplastic where found at bottom sediments [22], where 56.9% of the total number of synthetic fibers, as expected, were polyester which has a high specific density so are likely to be found in the benthos[23]. All of the studies conducted so far analyze the microplastic accumulation on surfaces and sediments. However, there are very few research studies which indicate microplastic accumulation along the water column, for example, Choy *et al.* 2019 and Egger *et al.* 2020 [6,54].

On the other hand, there are other fragments extremely light according to their density, such as foamed polystyrene particles with a density of 0.05gcm^{-3} that are mainly controlled and distributed by the windage [51], what means that wind can play a significant role in low density microplastic transport.

Microplastics serve as active collectors of various toxins and chemical pollutants as long as they extend and transport across the oceans [6,8,22,51] and are important pollutant vectors to remote regions [18]. These pollutants are low concentrated in seawater and are known as Persistent Organic Pollutants (POPs). However, high concentrations of POPs are found in micro and mesoplastics, due to their predominant hydrophobicity which facilitates the union of POPs via partitioning, making microplastics have several orders major concentration than the sea water around them [8] and becoming highly concentrated pools of POPs dissolved in microplastic bioavailable to organisms [17,55].This means that microplastic have the ability to accumulate these pollutants and transfer this to marine biota [5]. Furthermore, POPS are biochemically stable, what makes them difficult to degrade in environments or organisms, helping to the accumulation through the food chain [56].

There are four main groups of Persistent Organic Pollutants founded and usually investigated in microplastics due to their widespread presence: polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichlorodiphenyl-trichloroethane (DDT) and its breakdown products (DDD and DDE) and chlordanes. Moreover, it was discovered that PAHs´ concentrations were greater than other pollutants´, and that it was no correlation between PAHs and the remaining POPs, suggesting that PAH source and pathways to microplastic is not the same as others. That is to say that PAHs source to microplastic is through the manufacturing process and other POPs are accumulated into plastic once those get into the ocean [57].
Rochman et al (2013) found that PCBs were greater in plastic particles ingested by organisms than in plastic virgin pellets, which led to the conclusion that plastic litter is an accumulation point for these pollutants [58].

2. OBJECTIVES

The main objective of this study is to characterize microplastic debris accumulation in the water column at open ocean in the Canary Islands, from Gran Canaria to el Mar de las Calmas El Hierro. Moreover, this study is principally focused on the water column from ocean surface to approximately 600m depth, including a punctual study below 500m, which reaches 1100m depth. Microplastic debris accumulation was also related to physical particle properties and ocean parameters, expecting its influence on plastic distribution.

3. MATERIALS AND METHODS

3.1. Open ocean sampling

During the VULCANA-II-1119 oceanographic cruise lead by the Spanish Institute of Oceanography (IEO) in November 2019, in situ samples were collected while navigating through the Canary Islands in four different stations (Figure 2: M01, M02, M03 and M04). Besides, during the sea campaign of PLOCAN in December 2019, another northerner station was carried out in the fix stations called European Station for Time series in the Ocean Canary Islands (ESTOC) (Figure 2).

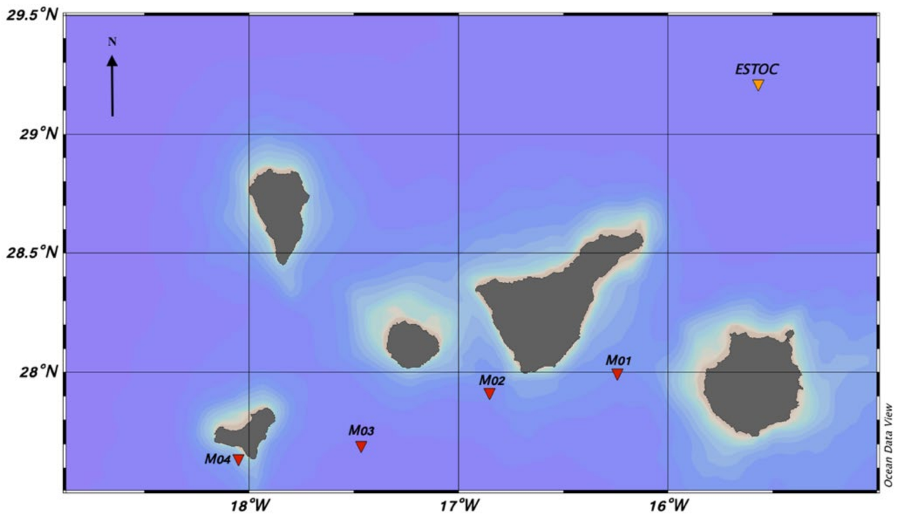


Fig. 4 Location of the sampling stations carried out during VULCANA-II-1119 (red triangles) and PLOCAN-ESTOC (orange triangle) oceanographic cruises.

Conductivity, temperature and pressure data were collected using a SeaBird 911-plus CTD equipped with dual temperature and conductivity sensors, with accuracies of 0.001ºC and 0.0003 S/m respectively, continuously recording data with a sampling interval of 24 Hz. CTD sensors were calibrated at the SeaBird laboratory before and after the cruises.

Discrete water samples for microplastics in the water column were collected using a rosette of 24-12-L Niskin bottles. The depth of the collections was decided by small changes in the water density, where was thought that the microplastics could be accumulating. Due to the small concentration of microplastic in the column water, six bottles were closed at each depth. Moreover, one of the 24 Niskin bottles of the rosette were modified to include a net of 100 µm which was collecting through all the water column while the rosette was rising. This special Niskin bottle filtered 237,6 liters per 100m depth through the water column.

Once the rosette was on-board, the full water capacity of 6 Niskin bottles (72 liters) were filtered for each sample through a 30x30cm net of 100 µm pore. The result was cleaned up into the filtration system, which was formed by a water sucking pump and a Whatman GF/F of 47mm diameter filter, where the microplastics and other fragments got stocked. Finally, these particles container filters were moved into a petri-dish and stored in a -80ºC freezer until its analysis at the laboratory.

3.2.Visual Microplastic Characterization

For the visual identification of the microplastic samples, a routine stereomicroscope type binocular loupe, model SZB250, brand VWR®, was used. Samples were counted one by one differentiating between fragments and fibers, and the different colors of them, obtaining different results depending on depths and locations.

4. RESULTS AND DISCUSSION

4.1.Samples characterization

Figure 5 shows several images of collected samples, which demonstrate the presence of fragments and groups of fibers at different depths, ranging from surface to 1152 meters deep. Moreover, Fig.5E shows interlocked zooplankton along with fibers or other possible plastic fragments. For this reason, it can be assumed that they coexist in the same environment, giving rise to possible confusion when it comes to ingestion by these or other bigger organisms.

In the case of ESTOC, the differences found in the accumulation of fibers and fragments with respect to other stations are quite significant. This is observable in image Fig.5I, where at first glance in the samples, it can be seen much lower concentration.

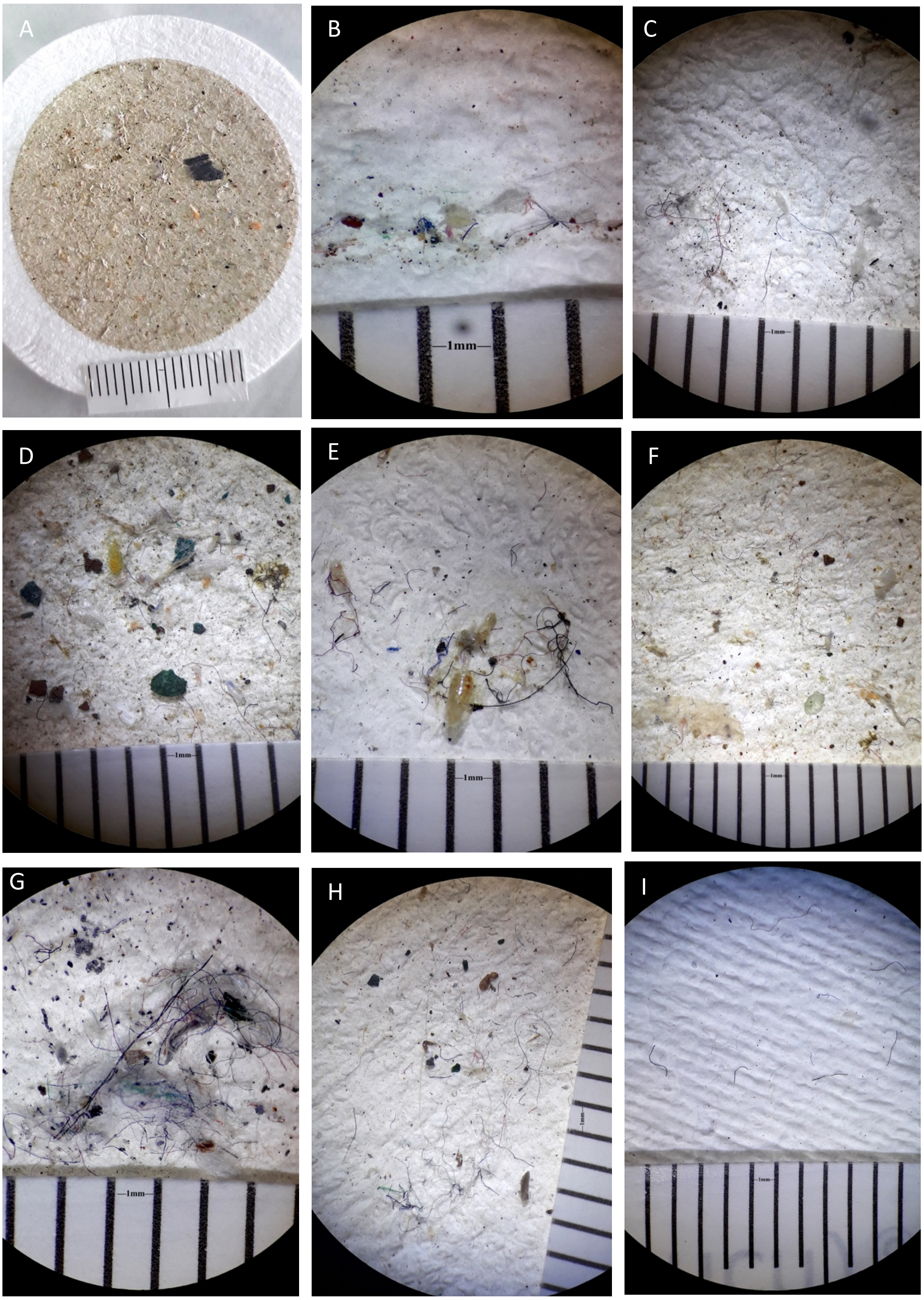


Fig 5. Whatmann GF / F 47 mm glass fiber filters. Every samples are magnified and taken under a binocular microscope. A) Station M01, water column. B) Station M02, 485m. C) Station M03, 223m. D) Station M03, water column. E) Station M04, 4m. F) Station M04, water column. G) Station M0402, 900m. H) Station M0402, 1152m. I) Station ESTOC, 150m.

4.2. Microplastic vertical distribution

Microplastic accumulation through the water column varies depending on the station (Figure 6). It can be sort of ambiguous due to the variability of microplastic distribution, as it doesn´t present a similar pattern in the different stations.

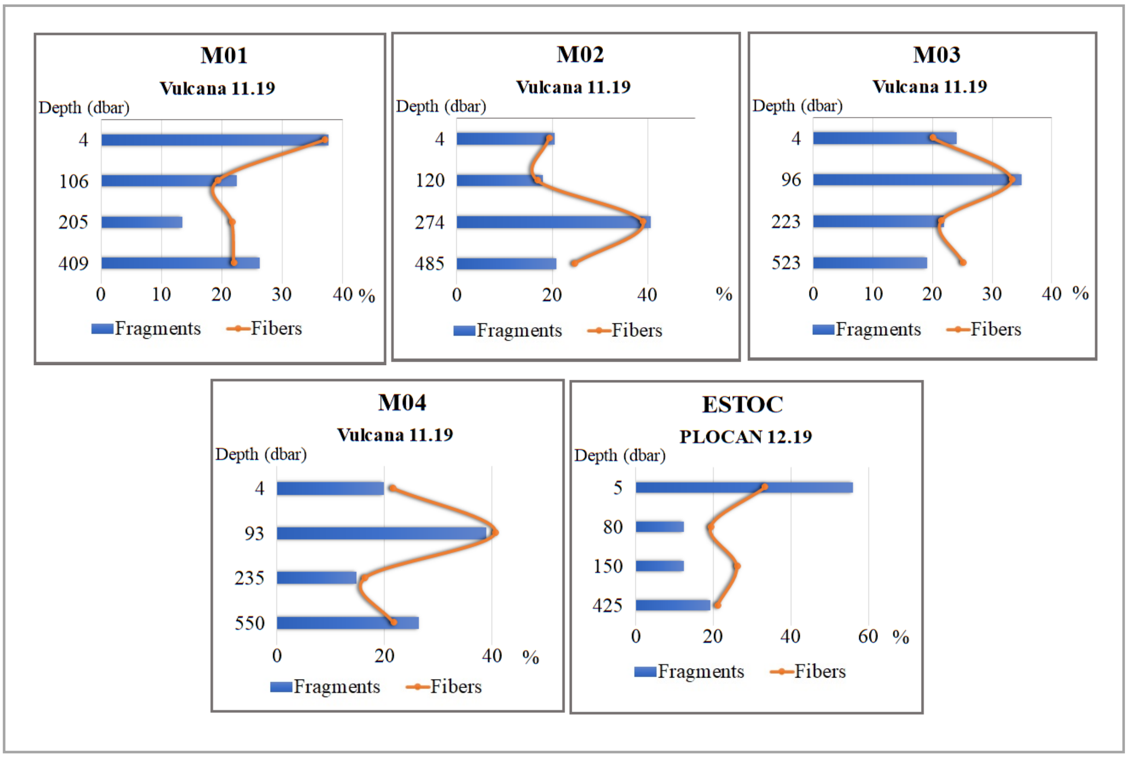


Fig. 6 Microplastic distribution through the water column at the different stations.

However, there are a few remarkable things, such as, in stations M03 and M04, where approximately the 40% of the total microplastics found in each station, are just below the mixed layer, at 100-meter depth (Figure 6). On the other hand, at station M01 and ESTOC, most of the microplastics where found at the ocean surface and in M02, at 274-meter depth.

Until now, little is known about the sinking behavior of microplastic and its degradation time scales [59] . Free vertical sinking of individual particles depends on particle properties (e.g. density, shape and size range), expecting different behaviors on them [60]. Plastic density might be variable when particles exposed to weathering and biofouling processes, generating bigger uncertainty about how plastics behave in a natural marine environment, out of laboratory conditions [59].

In this study, a relation between microplastic accumulation through the water column and the potential density vertical profile was considered. For this aim, Brünt-Väisälä parameter was used, which describes density changes in the vertical profile. This allows to detect stability zones in the water column, which are where the parameter presents higher values, being here where microplastic might tend to accumulate easier.

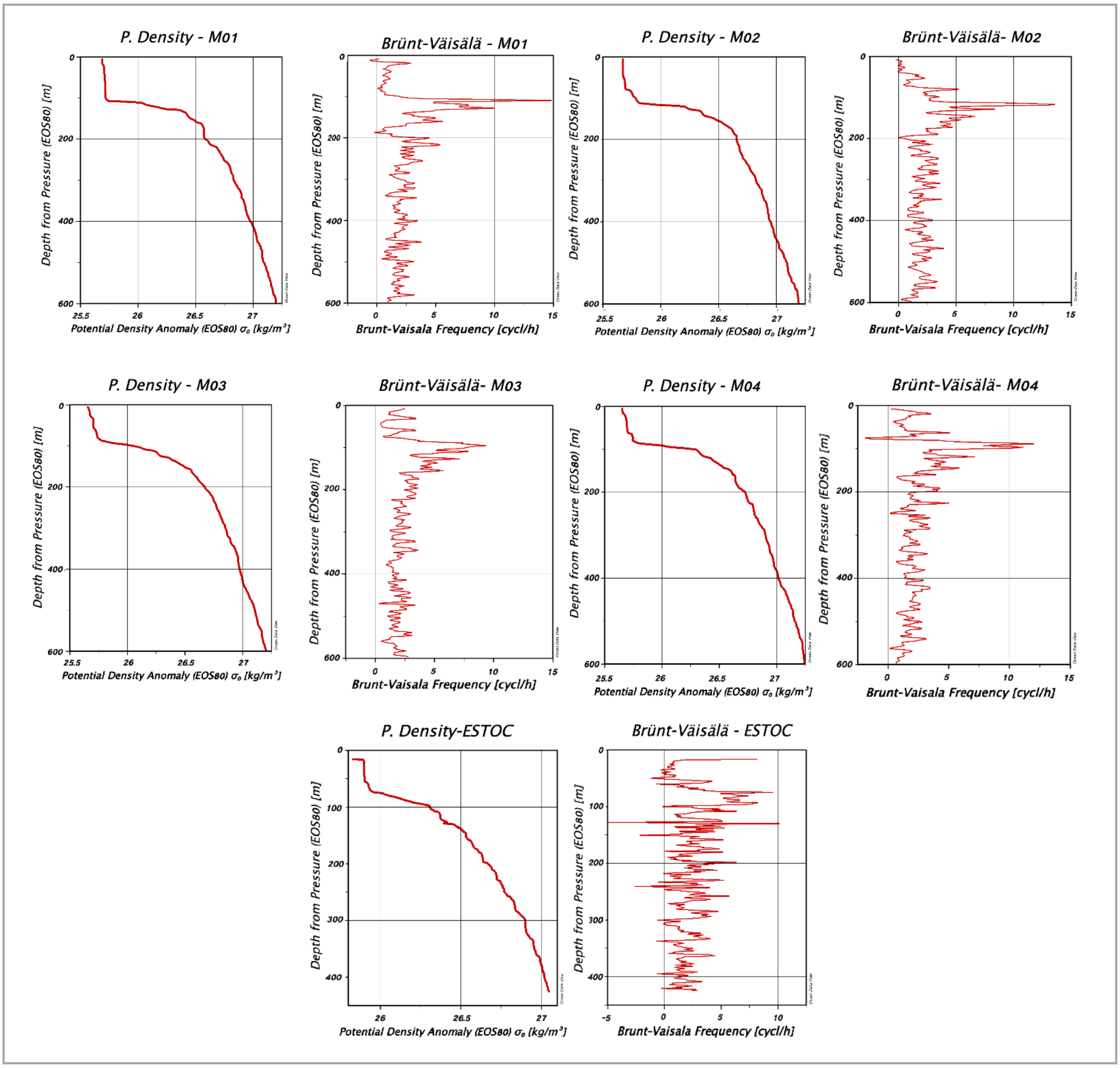


Fig. 7 Density vertical profile and Brunt-Väisälä parameter in every station.

Analyzing the potential density vertical profile and Brunt-Väisälä parameter (Figure 7) is observed that for every station except ESTOC, there is a stability zone just below the mixed layer at 100-meter depth approximately. However, in ESTOC the mixed layer finishes shallower, being the first stability zone at more or less 80-meter depth. Moreover, there is another Brun-Väisälä peak at 130-meter depth, which marks other stability zone at this depth.

Thus, it can be observed whilst comparing both types of graphics (Figure 6 and 7), that for example in M03 and M04, coincides the depth at which the stability zone is marked, with the one where microplastic abundance was higher in that station. Nevertheless, for other stations, such as M01 or ESTOC, the density stability zone in the water column has nothing to do with where most of the microplastic was found, in this case, in the ocean surface at 4-meter depth.

4.3. Fragment color distribution

In each sample, both for fragments and fibers, an average between the different depths was done for the color distribution representation. Color characterization is important because this has an important influence on some species´ selection as a prey [61] and might have it on how microplastics affect to algae growth [62].

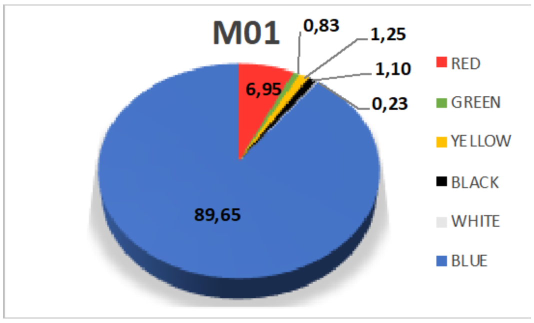


Fig. 8 Fragment color distribution in M01.

As observed in figure 8, most of the fragments found are blue (approximately 90% of them in every sample). This is in agreement with what is found in the bibliography, where blue fragments are the most usual in collected ocean samples [63,64].
For this reason, the following figures will be illustrated without the percentage of blue fragments, which are given as a number (table 2).

Table 2. Blue color percentage for each sample.

Station	M01	M02	M03	M04	ESTOC
Blue Fragments %	89,65	88,14	80,73	86,84	89,14

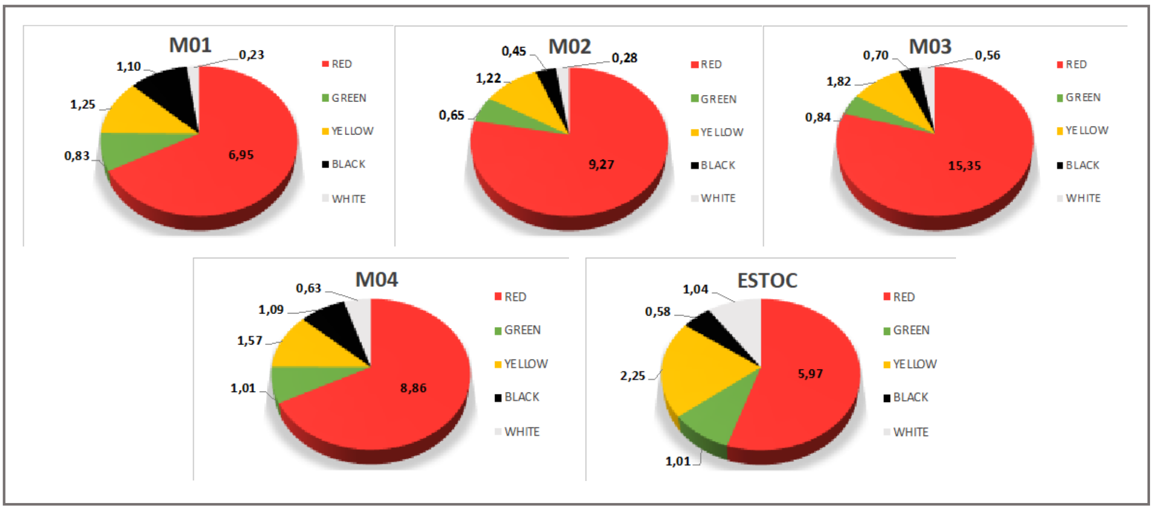


Fig. 9 Fragment color distribution in each station without blue.

Thus, is observed that after blue fragments, red are the most common ones, with a percentage that varies in a range between 6 and 15% depending on the station (Figure 9). The fraction of other colors that were found in samples, as yellow, green, black or white, was much lower.

Most of the studies analyze how microplastic presence in the environment and its ingestion affect to zooplankton or higher trophic levels, but there are very few that study how they affect to primary producers. Colored microplastics reflect light of its color wavelength, making algae surrounded by suspended microplastic have more to absorb. Chlorophyll a and chlorophyll b in green algae are the main photosynthetic pigments which absorb blue, red and orange wavelengths, so is expected to have bigger increment on algae growth in the once exposed to this microplastics. However, this occurs just under low concentrations of microplastic, whilst if a concentration increment is made, a significant inhibition on algae growth is induced [62].

On the other hand, some studies remark the abundance of light colored microplastic, especially light blue, translucent and white. A probable reason for this is the degradation process that every microplastic suffers, which produces bleaching due to ageing [61].

4.4. Fiber color distribution

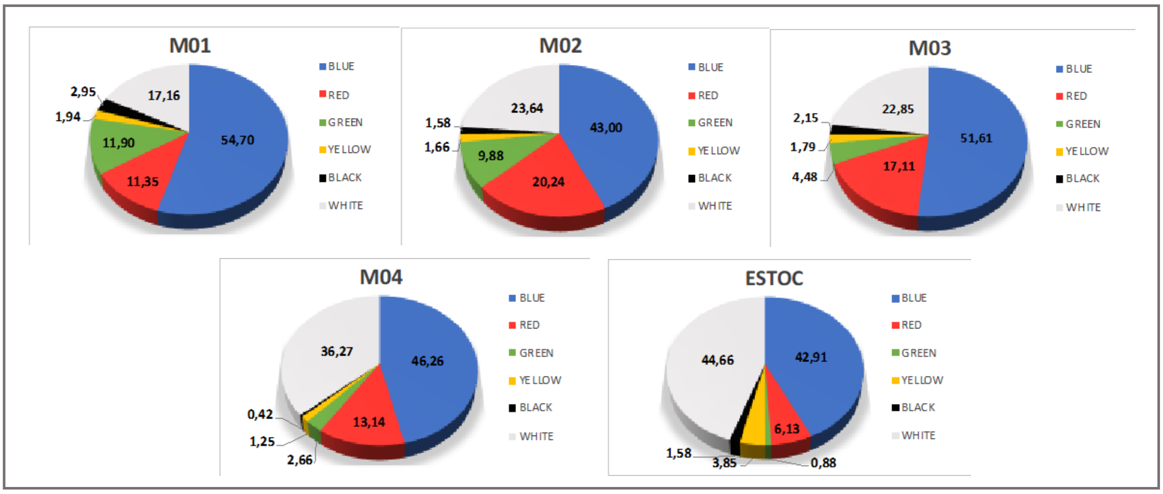


Fig. 10 Fiber color distribution in each station.

As seen in figure 6, fibers follow a similar distribution that fragments, so it wouldn´t be unusual to find a similar color distribution. However, even that blue is in almost every sample (except ESTOC, figure 10) the predominant color, it is quite remarkable that white fibers have also a great predominance, being around the 40% in each station. This may be related to the process of degradation of fibers, causing a large number of them to lose their color.

Cole et al. (2014) stated that in terms of shape, fibrous microplastics were the most abundant in water-column samples around the world [22,65]. Although this could be representative of the samples, it is important to consider that fiber identification may be much easier than other microplastic shape identification, such as fragments, as these can be confused with other marine natural particles [64,65].

4.5. Punctual study below 600-meter, station M0402

In this study, a punctual analysis of microplastic abundance below the 600-meter depth was done and named station M0402. The geographical location of M0402 is the same as M04, although sampling depths were changed. Here, the collected samples reached the 1152-meter depth, founding great concentration of fragments and fibers (table 3). This might not be enough to affirm that microplastics are globally distributed through the water column, but it is the first step to understand that those are not simply found on the surface and in sediment and that the problem they present is much greater than previously thought.

Table 3. Total fragment and fibers per liter for M0402 station.

Station	Total Fragments	Fragments /L	Total Fibers	Fibers/L
M0402	10751	42,66	1282	5,08

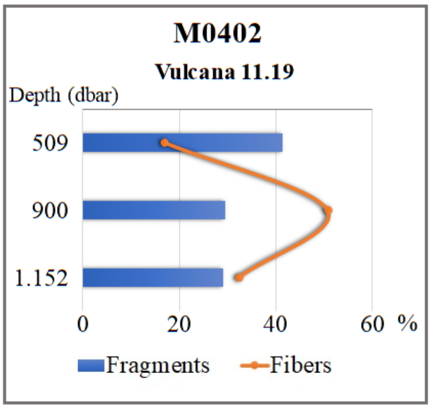
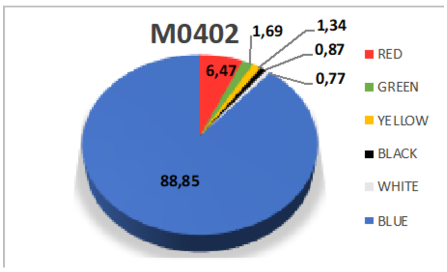


Fig. 11 Microplastic distribution in M0402 in percentages.

In figure 11, it is observed that fiber concentration at 900m is much greater than in other depths. The fact that there is quite a great concentration of fibers and fragments at such a depth is remarkable, as there is no any published study that has talked about it before at Atlantic ocean. For this reason, further studies below 500m depth are recommended to manage a better understanding of plastic distribution.



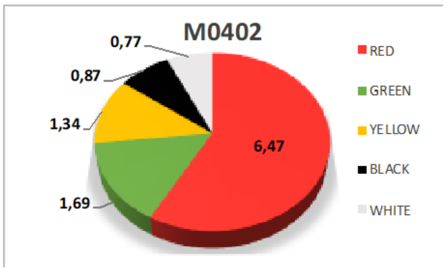


Fig. 12 Fragment color distribution in M0402.

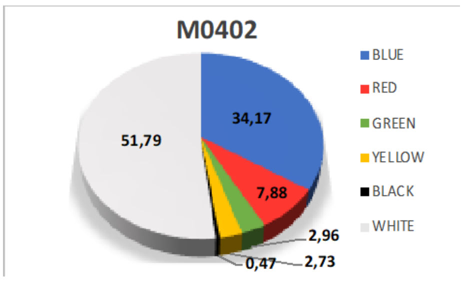


Fig. 13 Fiber color distribution in M0402.

Fragment and fiber color distribution in M0402 is similar to what is found in the rest of stations, which samples were collected shallower. This might lead to the idea that color distribution is not related to depth, but to microplastic characteristics and fragmentation or distribution processes.

4.6. Geographical variability in the concentration of microplastics

The quantity of fragments and fibers present is variable, obtaining the following data for each station (table 4).

Table 4. Total fragment and fibers per liter for each station.

Station	Total Fragments	Fragments /L	Total Fibers	Fibers/L
M01	13665	51,76	1084	4,11
M02	17711	67,09	1265	4,79
M03	14814	56,11	1071	4,06
M04	10589	40,11	1202	4,55
ESTOC	6043	22,89	571	2,16
Total Average	12564,4	47,59	1038,6	3,93

Besides the vertical distribution in each station, it is important to understand how microplastic fragments and fibers are distributed through the Canary Islands, as those are not static, but they flow with the Canary currents and ocean dynamics. The plastic pollution found on this region and its coast is mainly inland generated, and it is due to the transport of pollutants from the open North Atlantic Ocean through the Canary Current and wind, as well as the production of the population of the islands itself [66].

For this reason, numerical data were represented in percentages (Figure 14).

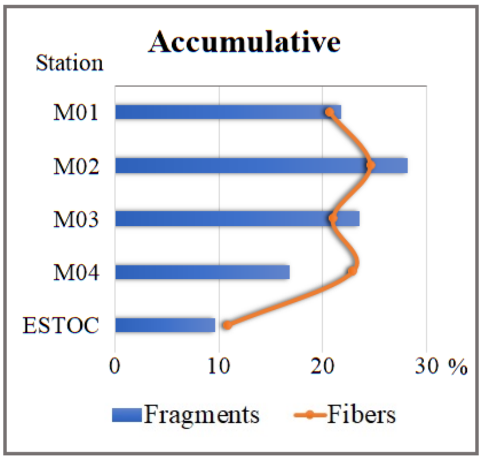


Fig. 14 Microplastic concentration comparison between stations.

The presence of the Canary Islands in the passage of the Canary Current and Trade winds flow is a characteristic of the study area which probably, distinguishes this system from those with similar characteristics [67]. These physical characteristics make the islands part of the eastern boundary upwelling region of the subtropical gyre, having a large nutrient input into the surface that leads to high productivity [68]. Moreover, the topography of the islands produces a net downstream transport of the current, although there is a significant seasonal variability of it [69], and it is thought that the planktonic community might be adapted to that variability of the upwelling regime [68]. Previous studies suggest that upwelling systems can provide a source of deep water where microplastic abundance is expected to be lower [64].

A comparison between the different stations was done, from North Gran Canaria (station ESTOC), to El Mar de las Calmas at El Hierro (station M04).The results show that the three stations with higher concentration of microplastics were M01, M02 and M03 (Figure 14) with approximately the 25% of total microplastic for each, being M02 the greatest. On the other hand, ESTOC is the station where less of the microplastics were found, as it is located far north of the islands.

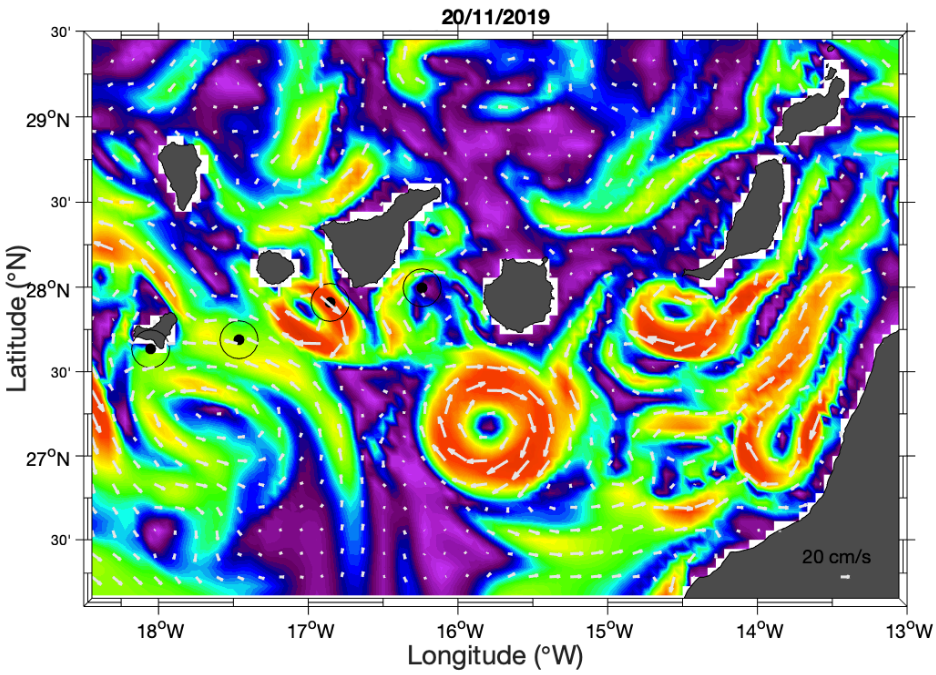


Fig. 15 Surface Current distribution in 2019 November 20th. Source: Eugenio Fraile (IEO).

As mentioned before, M02 was the station where microplastic was more abundant. In figure 15, it is observable that on 2019 November 20th, M02 was situated in the edge of an anticyclonic eddy. Eddies are mesoscale vortices of water which have a high dynamic influence over the first 700 m of the water column, mainly on the transport of heat, salt

and water masses [70]. Therefore, in high activity eddy zones and even more, with the presence of anticyclonic eddies, microplastics tend to accumulate and these high concentrations could remain in the area more time that without the presence of these mesoscale structures [71].
Eddies position and their interaction determines if a water mass is going to be retained within the upwelling system or dispersed to the open ocean [72], so these can directly influence the accumulation or spreading of materials inside the water mass. For this reason, Brach *et al.* attribute the distribution of plastic debris at the ocean surface to the presence of eddies [73].

Moreover, there is a different concentration of plastic debris accumulation between cyclonic and anticyclonic eddies [74]. In the northern hemisphere, an anticyclonic eddy is one whose direction is clockwise, while a cyclonic eddy would be one whose movement is counterclockwise. Traditionally, it is thought that anticyclonic eddies catch the material drifting to the surface, while cyclonic eddies expel this material [74]. For this reason, M02 microplastic abundance can be directly related to its position on an anticyclonic eddy, since microplastic concentration in anticyclonic eddies have been found to be more than 9 times higher than the ones found in cyclonic eddies [73].

Undoubtedly, the discovery of the induction of cyclonic and anticyclonic eddies to the leeward side of the islands through satellite images, changed the perception of the oceanographic-type processes that occur around the Canary Island, explaining lots of processes that occur in the canary islands due to the important mesoscale activity [67].

5. CONCLUSIONS

In conclusion, results show that microplastics have become an important pollution problem in the Canary Islands, being ubiquitous and highly abundant in every collected sample, which might have a great impact on Canary ecosystem´s and organism's health.

It is affirmable that there is a great abundance of fibers and fragments distributed in the open ocean in the Canary Islands, in which 47,59 fragments/L and 3,93 fibers/L have been obtained on average in a range of depths from surface to 550 meters. The number of fragments observed is higher than fibers, but it has not been possible to analyze their chemical composition yet, although fibers have in general bigger sizes than fragments. There is also the predominance of blue fragments (90% of total) and fibers over other colors.

In addition, in the specific study below 600 meters depth (up to 1152 m) named as M0402 station, it is observed that the distribution of microplastic is also present in deeper areas of the water column, having on average between 500 and 1152 meter, 42,66 fragments/L and 5,08 fibers/L. These data represent 14,61% of the fragments and 19,80% of the fibers in relation to the total of all the samples, which shows that below 600 meters there is still a large amount of microplastic. For this reason, it would be recommendable to continue with the study of its possible accumulation in the water column at deeper areas.

As for microplastic distribution in the water column, it has not been possible to define a specific pattern since each station showed different results. However, obtained results may be related to the mesoscale activity produce by the islands, comparing the microplastic accumulation with the convergence areas in the region. The geographical distribution shows that the station with the highest concentration was M02, which may be due to the presence of an anticyclone eddy at the time of sample collection that favors the accumulation of microplastics.

6. ACKNOWLEDGMENTS

This study could not have been done without support of the Instituto Español de Oceanografía (IEO) for letting me participate in the VULCANA-II-1119 cruise carried out in November 2019 in the context of VULcanología CAnaria SubmariNA (VULCANA-II, IEO-2019-2021) project funded by IEO. We would like also to thank the Oceanic Platform of the Canary Islands (Plataforma Oceánica de Canarias, PLOCAN) for their support and sharing their research facilities with us.

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Descripción detallada de las actividades desarrolladas durante la realización del TFT

Para la realización del TFT fueron varias las actividades realizadas. En primer lugar, acudí a la campaña oceanográfica VULCANA 11.19 del Instituto Español de Oceanografía durante 15 días para recoger las muestras. Estas muestras se recogieron durante dos días, al principio de la campaña, en diferentes estaciones. Para ello, se lanzó la roseta en diferentes puntos de las Islas Canarias (M01, M02, M03 y M04), cerrando 6 botellas Niskin a cada profundidad seleccionada según la variación de densidad de la columna de agua que iba mostrando el CTD. Una vez la roseta estaba completa con 4 profundidades por estación y una botella Niskin con una malla de filtrado para toda la columna de agua, se subió a bordo del buque oceanográfico y se filtró el agua de dichas botellas. Así, se recolectó en una sola malla, lo recogido en 6 botellas de una misma profundidad.

Posteriormente, dicha malla se limpió sobre un tren de filtrado, obteniendo cinco muestras en filtros Whatmann a diferentes profundidades de cada una de las cuatro estaciones muestreadas. Además de un estudio puntual por debajo de los 600m, llamado estación M0402.

Las muestras se congelaron a -80ºC hasta que comenzó el proceso de análisis en el laboratorio, de forma que los organismos que pudiera haber en las muestras no se deterioraran, estropeando la muestra y asegurando así una conservación adecuada.

Así mismo, las muestras de la estación ESTOC se recogieron durante la campaña oceanográfica de PLOCAN 12.19, siguiendo la misma metodología. Finalmente, se obtuvieron un total de 29 muestras, donde seis de ellas corresponde a un filtrado completo de la columna de agua.

En segundo lugar, analicé las muestras mediante contaje de fragmentos y fibras en cada una de ellas, y su clasificación por colores, de forma que quedaran bien descritos los microplásticos presentes, pudiendo analizar su distribución tanto en la columna de agua, como en la geografía canaria.

Por último, llevé a cabo las gráficas para mostrar los resultados, así como la interpretación de estos y la redacción de los demás apartados del TFT. Para ello, fue necesario una gran búsqueda de bibliografía sobre el tema, la cual realicé principalmente a través de Scopus, Web of Science y ScienceDirect.

Formación recibida (cursos, programas informáticos, etc.)

En cuanto a los cursos recibidos, la Dra. Daura Vega impartió uno sobre el programa Mendeley. Este ha sido de gran utilidad a la hora de realizar el TFT, facilitando la clasificación y citas de las referencias utilizadas, así como la bibliografía introducida.

Por otra parte, participé en un curso de Agilent vía online sobre Buenas prácticas en Cromatografía de Gases.

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

En cuanto al nivel de integración en el departamento, yo he estado realizando las practicas en PLOCAN por lo que mi contacto con el Departamento de Química de la Universidad ha sido Daura Vega. Dentro de PLOCAN, las relaciones con el personal han sido muy buenas. En todo momento han intentado ayudarme todo lo posible, tratando de obtener los mejores resultados y siempre con un trato muy amable y respetuoso.

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

El aspecto positivo que más destacaría es la oportunidad de acudir a una campaña oceanográfica, la cual me sirvió para empezar a ampliar mis conocimientos en un entorno más laboral, así como para aplicar algunos conceptos aprendidos durante la carrera. Además, es un tema de gran interés y actualidad que destaca por el gran impacto que esta teniendo hoy en día y su influencia en el futuro.

En cuanto a aspectos negativos, remarcar las complicaciones que ha podido traer la pandemia mundial causada por el COVID-19 a la hora de llevar a cabo el TFT, impidiendo la posibilidad de abarcar una mayor investigación por falta de tiempo. Sin embargo, tanto desde la Universidad como por parte de mi tutora Daura Vega y PLOCAN, se han mostrado siempre comprensivos y colaboradores ante esta causa.

Valoración personal del aprendizaje conseguido a lo largo del TFT

En mi opinión, el TFT me ha servido para obtener una visión más real sobre el problema de los microplásticos a nivel local en las islas canarias. Además, al ser un estudio reciente cuya investigación es muy novedosa, el TFT ha despertado mi interés sobre este tema y la motivación para seguir aprendiendo al respecto.

Por otra parte, en la campaña oceanográfica aprendí la importancia del trabajo en equipo en la oceanografía, ya que se caracteriza por ser una ciencia multidisciplinar en la que se trabaja con profesionales de varios sectores.