Article

Microplastics on Beaches in the Nautla-Vega de Alatorre Turtle Nesting Area, Veracruz

Clara Ivonne Ruíz-Reyes [1], Fabiola Lango-Reynoso [1,*], María del Refugio Castañeda-Chávez [1] and Angel Moran-Silva [2]

1 Tecnológico Nacional de México, Instituto Tecnológico de Boca del Río, Boca del Rio 94290, Mexico
2 Laboratorio de Crustáceos, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Av. de los Barrios 1, Hab Los Reyes Ixtacala Barrio de los Árboles/Barrio de los Héroes, Tlalnepantla de Baz 54090, Mexico
* Correspondence: fabiolalango@bdelrio.tecnm.mx

Abstract: The low cost of production and the widespread use of plastics has brought about a problem that is difficult to measure; microplastics are considered emerging pollutants because their presence can pose a risk to the environment. This study focuses on the characterization of microplastics (MPs) in the nesting area of green (*Chelonia mydas*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles, on the coastal municipalities of Nautla and Vega de Alatorre, Veracruz, Mexico. Five beaches along 15.5 km of coastline were analyzed and samples were taken in the intertidal zone. In this work, only microplastics in sizes from one to five mm were analyzed. A characterization of the potential sources of microplastics at the basin level was carried out and 94% of the samples analyzed presented MPs, the greatest amount was at site Playa Navarro (B32) (1.2 Item/kg dw), and in the high tide zone (4.86 ± 2.79 Item/kg dw). The predominant color of the MPs was white (42%), the most representative form were fragments (31%), while most of the MPs presented sizes of 4–5 mm (35%) followed by 1–2 mm (34%). The chemical composition of most of the MPs was polyethylene (55%). Regarding the sources of the MPs generation, livestock, agriculture, fishing, tourism, wastewater discharges, urban solid waste and, to a lesser extent, the plastic industry were identified. The mobilization factors of the MPs turned out to be the Colipa and Misantla rivers with runoff from the basin, wind, waves and marine currents.

Keywords: waste management; pollution sources; emerging pollutants

1. Introduction

Plastics are materials whose use is widespread, of which 460 million tons/year are produced worldwide [1]; however, once it has fulfilled the task for which it was designed, it is discarded, causing an environmental pollution problem. The UN [2] has reported that plastic represents 85% of the waste that reaches the oceans and it is estimated that by 2040, the annual volume could be between 23 and 37 million tons. The management of urban solid waste has been in deficient, with only 9% of plastics being recycled, causing at least 13 million tons of plastic to reach the seas each year [3] and due to factors, such as ocean currents and winds, plastics are mobilized until they reach the seas. Consequently, a large number of marine species face various risks due to entanglement and entrapment [4], such as suffocation and intoxication [5] due to larger plastics, while on the beaches through-out the world the presence of these residues causes visual pollution [6]; however, it is microplastics that have currently gained relevance; these particles smaller than 5 mm in size have been reported in coastal ecosystems of Mexico [7–11].

The main impacts of MPs have been recorded on marine fauna [12,13]. Various studies have reported on the content of these particles in different species of fish [14–16], such as mollusks [17], marine mammals [18], and sea turtles [17] among others. MPs can

adsorb on their surface many chemical contaminants, such as antibiotics, heavy metals, phthalates, dioxins, organochlorine contaminants (HCB, DDTs, PCBs), bisphenol A (BPA), and persistent organic pollutants (POPs) [19–22].

There are seven species of sea turtles in the world, of which six reach the coastal ecosystems of the Mexican territory. The Gulf of Mexico is an important area for the distribution of sea turtles, where they live throughout their life cycle, satisfying their needs for food, shelter, rest, and nesting. These species are considered priority for conservation and are protected by the official standard NOM-059-SEMARNAT-2018, in addition to being protected by various international treaties [23].

In this sense, the objective of this work is to study the abundance and characterization of microplastics in the intertidal zone of Nautla and Vega de Alatorre beaches, which are of ecological importance because they are the nesting areas for green turtles (*Chelonia mydas*). These could be impacted by microplastics that come from the upper parts of the basin; therefore, it is necessary to know the possible sources of origin of these pollutants since it has been estimated that 80% of this waste comes from activities on land, while the remaining 20% corresponds to the activities carried out at sea, such as fishing, maritime transport, oil platforms [7], and by marine currents.

2. Materials and Methods

2.1. The Study Area and Sampling Site

This work was carried out on beaches in the municipalities of Nautla and Vega de Alatorre, which are located in the central region of the coast of the State of Veracruz. The beacons marked by the Veracruzano Center for Research and Conservation of the Sea Turtle (CVICTM) were taken as location reference, Figure 1 shows the study area [24].
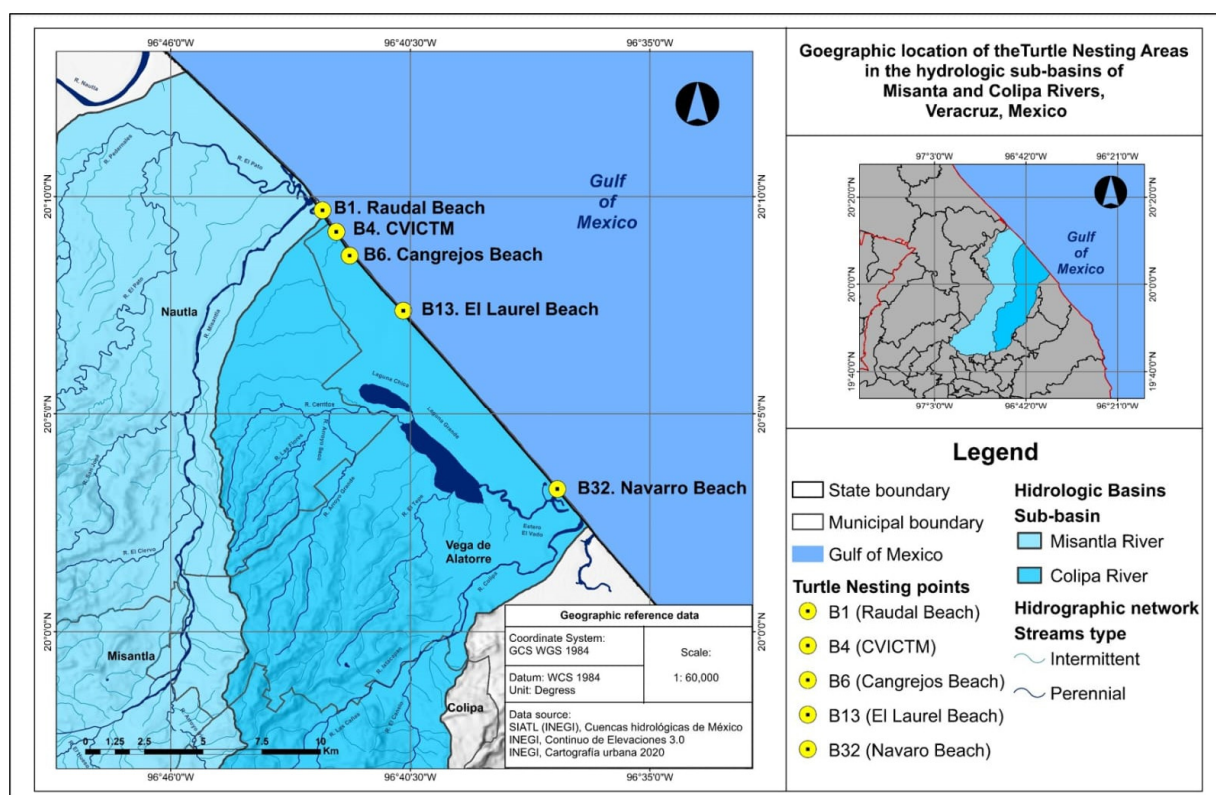

Figure 1. The five selected sites for microplastic sampling are shown.

Through a tour of the nesting area, the sites of interest were identified and chosen, considering different characteristics, such as easy access, public beaches, and two sites near river mouths. The five sampling sites were Raudal Beach, B1; Beach of the CVICTM, B4;

Cangrejos beach, B6; Laurel Beach, B13; and Navarro beach, B32. The study was carried out during the month of November 2021 where a total of three samples were collected in triplicate. To take the samples, three transects were traced in the intertidal zone, parallel to the coastline, identifying the low tide limit, the intermediate part and the high tide; the samples were taken with a wooden square 0.25 m high and 0.25 m wide. To collect the microplastics deposited by the last tide, a superficial 5 cm of sand was collected. The samples were labeled and preserved in reusable plastic bags until analysis.

2.2. Polymer Characterization

Once the samples were collected, they were transported for processing at the Aquatic Resources Research Laboratory (LIRA) where they were oven dried at 60° [9]. Sediment separation was carried out with sieves of different sizes to facilitate identification and eliminate the excess sand, the sizes of MPs identified in this study ranged from 1 to 5 mm. Through direct observation using an optical microscope, magnifying glass, and lamps, possible microplastics were identified. After the observation, the sample went through a flotation process in a $CaCl_2$ saline solution, with a density of 1.6 g/mg [8]. The possible plastics that emerged were taken with the help of metal tweezers [7].

According to what was proposed by Laglbauer et al. [25], microplastics were classified into rigid fragments, fibers, foams, films (flexible), and pellets. Regarding the color, the classification used is the one reported by Boerger et al. [26], where they consider the following color categories: white, blue, gray, yellow, orange, green, pink, red, purple, black, transparent, and brown. In order to identify the chemical composition, a transformed Fourier infrared spectroscopy method [10] was used with a Perkin-Elmer FT-IR unit(Perkin-Elmer, Shelton, CT, USA), Frontier model with diamond crystal. The data from the readings were collected in the range of 4000–400 cm^{-1} with a resolution of 4 cm^{-1} and 30 scans. The spectrum was compared with the ATR Polymer Introductory Library database.

To identify the sources of the plastic pollution in the study area, it was necessary to delimit the area of influence; this was done through the delimitation of hydrographic basins. The delimitation was carried out with the National Institute of Statistics and Geography (INEGI) land use cartography and the Arcmap software (version 10.3.0.4322).

2.3. Statistic Analysis

The comparison was made between the sampling sites and between the beacons. Initially the Shapiro–Wilks test was used in order to check the normality of the data. The Kruskal–Wallis test was used using PAST software [27].

*2.4. Factors of Microplastic Mobilization*

Once the economic activities were identified, they were related to the main plastics used in each one; thus, identifying the main terrestrial and marine sources that affected the turtle nesting area. On the other hand, through a bibliographic review, the main factors of microplastic mobilization in the study area were identified.

3. Results

During the sampling, the presence of larger plastics was observed. Of the 45 samples analyzed, 94% presented microplastics with sizes of 1–5 mm, 95% of the MPs were identified in the observation stage while the remaining 5% in the flotation process. Most of the microplastics were of secondary origin (93%).

3.1. Polymers Identification

Using the FT-IR technique, 77% of the MPs underwent a chemical composition analysis and eight categories of materials were found: high-and low-density PE (55%), PS (26%), PP (9%), PVC (4%), PA (3%), PET (1%), PBT (1%), and a particle identified as resin (1%). Figure 2 shows the spectra of some polymers found.
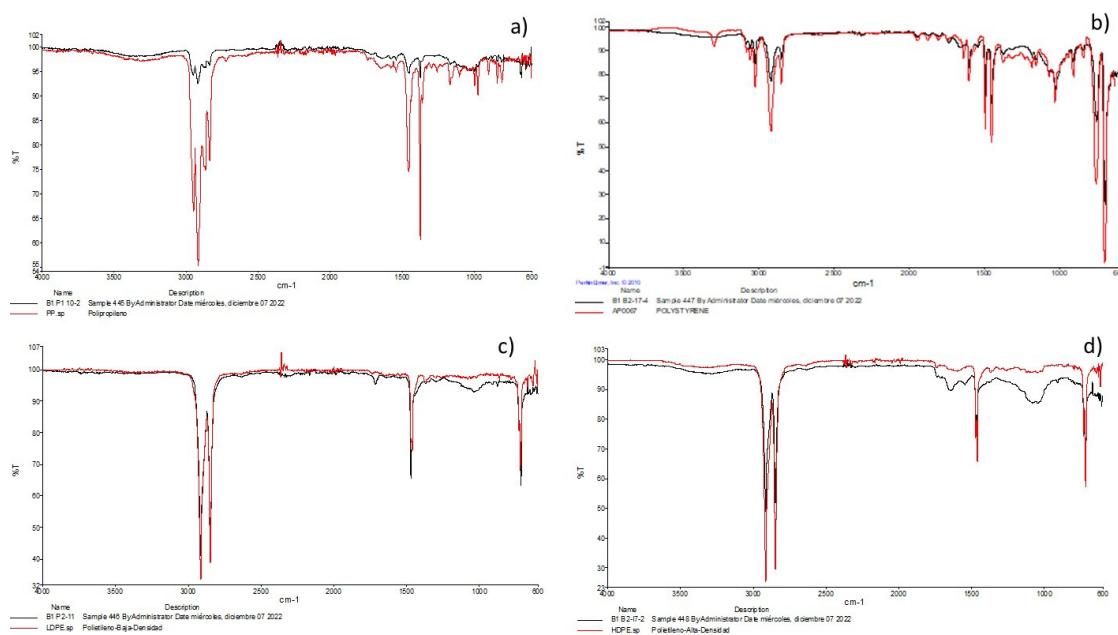
Figure 2. Infrared spectra of different chemical compositions (**a**) spectrum of polypropylene (PP), (**b**) polystyrene (PS), (**c**) low-density polyethylene (PEBD), (**d**) high-density polyethylene (PEAD).

3.2. Microplastics in the Sampling Sites

As shown in Table 1, the site with the highest abundance in Item/kg dw was site B32 (1.32 ± 0.46), followed by site B1 (1.21 ± 0.87), while the remaining sites presented amounts of less than 1 Item/kg dw: B4 (0.71 ± 0.46), B6 (0.56 ± 00.47) and B13 (0.82 ± 0.35).

Table 1. This table shows the amount of Item/kg dw and Item/m^2, as well as their characterization in color, size, shape, and chemical composition for the microplastics from the different sampling points.

Sample	Raudal Beach (B1)	CVICTM Beach (B4)	Cangrejos Beach (B6)	Laurel Beach (B13)	Navarro Beach (B32)
Coordinates	20°09′41.2″ N 96°42′31.0″ W	20°09′11.4″ N 96°42′11.9″ W	20°08′38.6″ N 96°41′53.5″ W	20°07′23.0″ N 96°40′39.7″ W	20°03′16.2″ N 96°37′07.5″ W
Item/kg dw	1.21 ± 0.87	0.71 ± 0.46	0.56 ± 0.47	0.82 ± 0.35	1.32 ± 0.46
Items/m^2	65.77 ± 48.95	37.33 ± 26.53	28.44 ± 23.7	42.66 ± 17.88	62.22 ± 61.69
Size	1–2 (32%)	4.01–5 (55%)	4.01–5 (40%)	4.01–5 (41%)	1–2 (54%)
Shape	Fiber (43%)	Foam (36%)	Fragment (32%)	Fragment (50%)	Film (31%)
Color	White (53%)	White (41%)	Transparent (40%)	White (44%)	White (37%)
Chemical composition	PE (64%) PS (26%) PP (5%) PP (5%)	PS (33%) PE (30%) PP (15%) PVC (15%) PET (6%)	PE (49%) PP (36%) PS (14%)	PE (66%) PS (17%) PP (17%)	PE (57%) PS (21%) PP (9%) PA (9%) PBT (3%)

Regarding the color, the most representative, in general, was white (42%), followed by transparent (16%), and blue (14%). Regarding the shape, five classification categories were found, which can be seen in Table 1. Fragments represented 42%, fibers 28%, foams 21%, films 13%, and pellets 7%. Figure 3 shows the average number of microplastics classified by color, shape, and type.
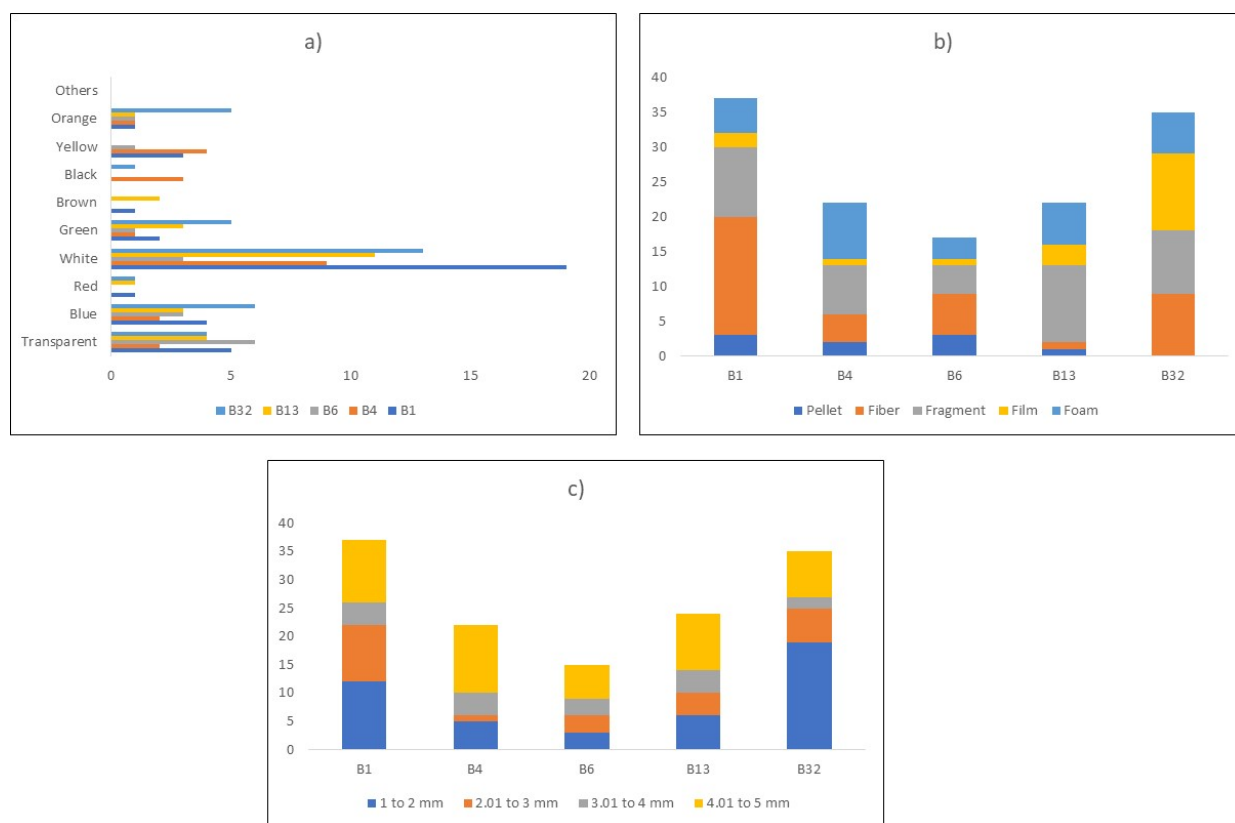
Figure 3. (**a**) Classification of microplastics by color in the five study sites where the most representative is white, (**b**) classification of PMs by shape; the most abundant forms were fragments and fibers, and (**c**) classification of microplastics by size, where the average number of microplastics is shown in each area.

3.3. Microplastics in Tidal Zones

Regarding the tidal zone, a greater number of MPs were identified at high tide (4.86 Item/kg dw), in the intertidal zone an average of 1.46 Item /kg dw were found, while at low tide they 2.53 Item/kg dw were identified.

The white color predominated at high tide (42%) and intertidal (50%), while at low tide the most representative color was transparent (31%); the predominant size in the three zones was 4–5 mm. Fragments were the most abundant form at high tide (31%) and intertidal (32%), on the other hand, at low tide, a higher percentage of fibers were identified (29%). Polyethylene was the most found chemical composition in the three zones as observed in Table 2. On the other side, the main shapes of microplastics were classified and it had a size < 5 mm as is shown in Figure 4.

Table 2. Characterization of microplastics in the different tidal zones.

Sample	High Tide	Intertidal	Low Tide
MPs/kg dw	4.86 ± 2.79	1.46 ± 1.40	2.53 ± 2.26
MPs/m^2	76.8 ± 42.84	23.46 ± 22.51	41.6. ± 37.8
Size	4.01–5 (44%)	4.01–5 (40%)	4.01–5 (38%)
Shape	Fragment (31%)	Fragment (32%)	Fiber (29%)
Color	White (42%)	White (50%)	White (31%)
Chemical composition	PE (50%)	PE (59%)	PE (66%)
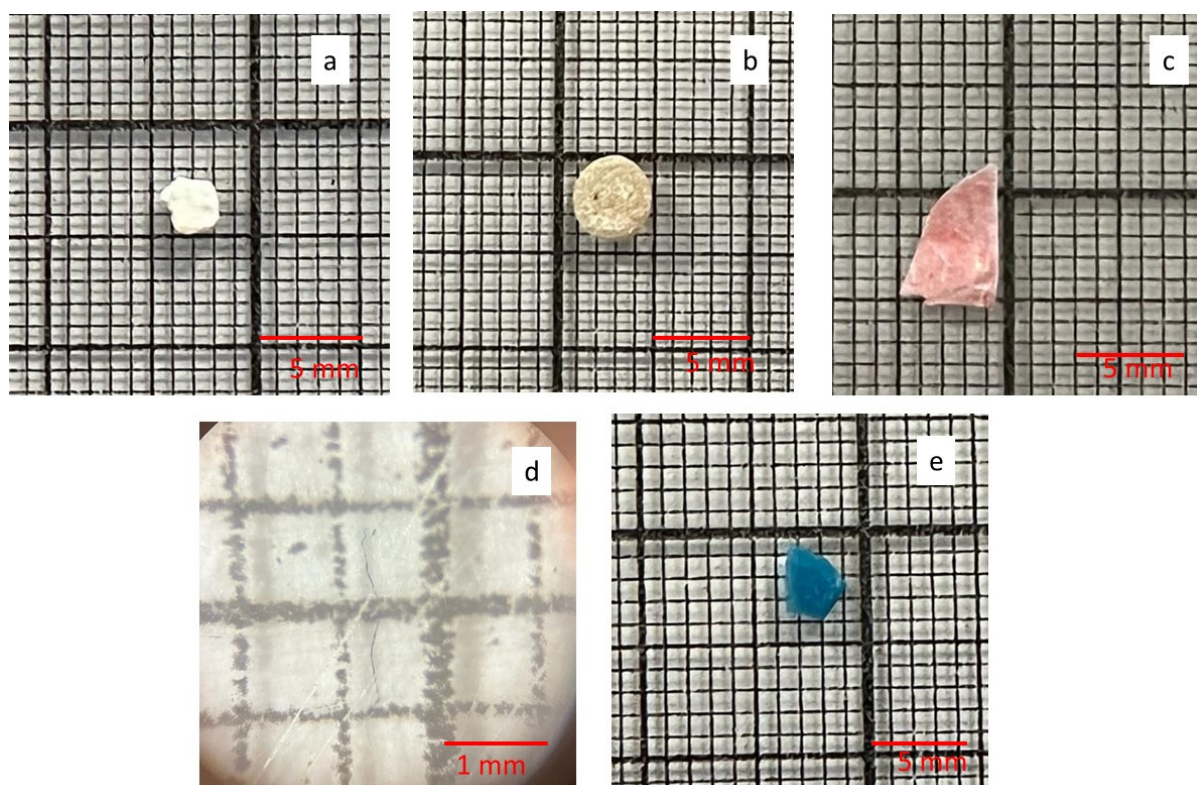
Figure 4. Shapes of microplastics found: (**a**) foams, (**b**) pellets, (**c**) films, (**d**) fibers, and (**e**) fragments.

3.4. Statistic Analysis

The test yielded a *p* of (0.0033) for B4 and *p* (0.0008) for B13, which indicates that the data did not behave normally so the Kruskal–Wallis test considered a 95% significance and a *p* = 0.000 was obtained, which indicated that there were no statistically significant differences between the different sampling sites.

The comparison of medians between the tidal zones was also carried out using the Kruskal–Wallis test with a 95% significance, which yielded a *p* of 0.001055, which indicates that there are significant statistical differences between the tidal zones. To verify which are the different zones, the Mann–Whitney U test was used, which confirmed that the high tide zone had different values from the intertidal zone (*p* = 0.00042) and low tide (*p* = 0.017).

This indicates that the characteristics of the selected sites did not affect the microplastics found since there are statistically significant differences. This may be due to the transport factors that mobilize the MPs along the coastal zone; however, statistical differences are found according to the zone tide, which can be influenced by the characteristics of microplastics, such as their shape, size, and weight, among others.

4. Discussion

The high tide of the beaches of Nautla and Vega de Alatorre present a lower abundance of microplastics compared to the study reported by [11] carried out on the beaches of Rosarito California, which obtained 206–408 Item/kg dw, and with respect to the color, white was identified as the most representative; this was also reported by [7,8,10,28] as shown in Table 3. The color of the microplastics is very important since some species tend to confuse plastic debris with their food [29]; however, when exposed to the sun it is likely that it has been degraded and does not present its original color. Of the plastics found, 42% ranged in size from 4 to 5 mm, which varies according to what is reported in other studies carried out on beaches, where sizes of 1–2 mm are mainly reported [7,8,30–33]. Smaller plastics facilitate availability for ingestion in different species as they confuse it with their food [34]. The high demand for textile products generates large amounts of fragments or

microfibers, this may explain their presence in the study area [35–37]. Some studies carried out in turtle nesting areas, such as that of [38] have reported a higher abundance of MPs, while a study carried out directly in deeper nests (60 cm) [39] reported a similar abundance to that of the present study 3.85 item/kg dw.

Table 3. Studies of microplastics on beaches in Mexico.

Site	Item/m^2	Item/kg dw	Size	Shape	Color	Polymer	Author
Tuxpan, Veracruz	-	93.27	-	Rigid (80%)	White (30%)	PE (74%)	Rosado-Piña et al., 2018 [28]
Zipolite, Oaxaca	-	0.7–1.29 MP	1–2 mm (89%)	Fiber (87%)	Blue (53%)	-	Cruz-Salas et al., 2020 [30]
La misión, Baja California	141–1657	-	1–2 mm (47%)	Fragments (33%)	White (47%)	PS (47%)	Cruz Salas et al., 2020 [30]
Mazatlán, Sinaloa	4–36	0.31 a 6.87	-	Fragments (59–80%)	White (48–54%)	PE (39%) PP (39%)	Ríos-Mendoza et al., 2021 [10]
Rosarito, Baja California	-	206–408	-	Fiber (91.9%)	Black (59%)	-	Piñón-Colin et al., 2018 [11]
Coatzacoalcos, Veracruz	-	212.1 ± 101.8 M	0.5–1 mm (51.6%)	Fragments (47%)	White (70%)	-	Álvarez et al., 2020 [8]
Holbox, Quintana Roo	49.37 ± 45.55	0.80	-	Fragments (65%)	White		Cruz-Salas et al., 2022 [7]
Nautla and Vega de Alatorre, Veracruz	76.8 ± 42.8	4.86 ± 2.79	4–5 (42%)	Fragments (31%)	White (53%)	PE (50%)	Present study

The predominant chemical composition was PE, which coincides with the studies reported by [10,28]. The polymers found in the different sites coincide with those most used in livestock and agriculture, mainly PE, PEBD, PEADS, and PS. According to the FAO, the agricultural and livestock sector uses up to 10.2 million tons of plastic products per year worldwide [40]. Regarding the sources of mobilization of microplastics, they are mainly the Misantla and Colipa rivers, which are considered rapid responses [41,42]. There are considerable slopes that allow the dragging of sediments from the upper part, which would cause the residues to wear down and fragment until they reach the mouths; however, the transport and deposit of sediment in rivers has a high degree of temporal and spatial variability [43].

The basins that have influence on the study area are the Misantla River and the Colipa River hydrological sub-basins as shown in Figure 5, which in turn are part of the RH27A Río Nautla hydrological basin. The municipalities that are found in the delimitation of the sub-basins are: Chiconquiaco, Colipa, Landero and Coss, Miahuatlán, Misantla, Nautla, and Vega de Alatorre. With respect to the land uses of the sub-basins, the predominance of induced grassland was identified, which is related to livestock activity [44,45]. With respect to agricultural use, the main crops are orange, lemon, cherry coffee, banana, watermelon, and corn [46]. The terrestrial sources of generation were identified as agriculture, livestock, tourism, management of urban solid waste, and wastewater discharges, among others, such as tire wear and the plastic industry. The marinas were artisanal fishing and boats.
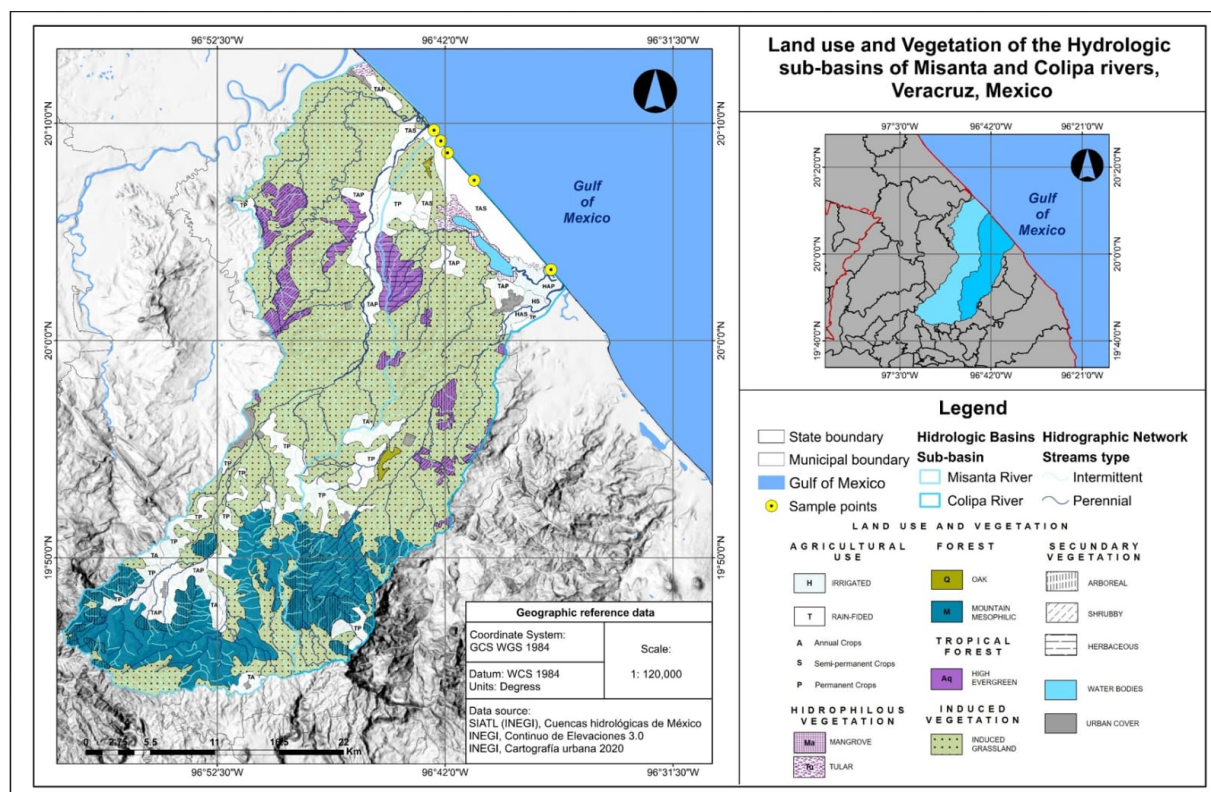
Figure 5. Land use and vegetation map of the Misantla River and Colipa River sub-basins.

4.1. Agriculture and Livestock as a Source of Plastics

As a result of the main economic activities carried out in these municipalities a wide variety of plastic items are used. Regarding livestock, they have various applications (plastics for silage (PEAD), ropes (PP, PE, and PA), product bottles (PEAD and PET), food wrappers (PE and PP) and food containers (PET and PEAD). In agriculture, materials, such as mulch (PE), water pipes (PVC), irrigation pipes (PVC), substrate bags (PE, PP), agrochemical bottles (PET and HDPE), trays (PE, HDPE), and seedbeds (PP and PS) to name a few. In the study areas these wastes are usually deposited in open-air dumps, which can be moved by the wind and/or water until they reach the coasts.

4.2. Solid Urban Waste

The population located in the municipalities of the study area is equivalent to 125,751 people [47], which generate a total of 30,300.9 tons of urban solid waste (RSU) per year. According to Instituto Nacional de Estadística y Geografía (INEGI) [48] the plastic present in the RSU corresponds to 9.2%, which would be equivalent to 2787.68 tons of plastic per year, which are mostly disposed of in open-air dumps or burned or deposited on abandoned land so that the waste can be mobilized through the basin by water currents, by the wind, or mechanically fragmented.

4.3. Wastewater Area

Another important source of contribution of microplastics in the study area is the discharge of wastewater. Although there are treatment plants, they are not in operation, and the microplastics in the wastewater come mainly from clothes washing. The most representative of this source of plastic contamination are the fibers of polystyrene clothing; however, cosmetics also provide many MPs in the form of microspheres.

4.4. Fishing

In the area of Nautla and Vega de Alatorre there are different fishing cooperatives that market the resources of the coastal lagoons in the traditional way on the beaches. Within the fishing devices that are made with plastic are nets, lures, fishing lines, coolers, and containers, and on the coastline you can also appreciate artisanal fishing. However, the impact due to plastics is also caused by small and large boats, which can dispose of their waste in the sea and by action of the currents reach the study area.

4.5. Other Sources of Plastic

Although there are no industries dedicated to the manufacture of plastics in the study area, microplastics of primary origin were found in the form of pellets or also known as mermaid tears. This may be mainly due to the leakage of microplastics from the industry established in other states, such as Tamaulipas or central and southern Veracruz [49]. These microplastics are mobilized by various factors, such as wind, runoff, and surface currents.

On the other hand, tires [50] are an important source of secondary contribution of microplastics, since when worn on the pavement they leave small fibers that can be mobilized by the wind or by runoff.

4.6. Wind, Waves, Tides and Currents

The coastal dynamics and the hydrodynamic factors, characteristic of the Nautla beaches, play an important role in the mobilization of microplastics. The season in which the sampling was carried out (autumn) is when the strongest winds occur and come from the north and north-northeast sectors. Regarding the waves, persistent waves arrive with a northeast component and the most intense ones with a north component (especially from autumn to winter), [45] refers that the sedimentary dynamics is longitudinal from north to south. Sediment transport is induced by sedimentary deposition from waves in the wash zone and inland transport by wind. Due to the size and weight of the microplastics, they can follow the sedimentary dynamics, being moved in the same direction and being deposited in the dune area.

Regarding marine currents, the circulation is from north to south from September to March and from south to north during the remaining months, reaching an average monthly speed of 0.70 ms^{-1} [51]. This indicates that the transport of microplastics can come from southern or northern states and countries depending on the season.

4.7. Rivers in the Study Area

The study area is located between the mouths of the Colipa and Misantla rivers. The Misantla river is considered a rapid response [41], that is, those that in the presence of significant rains, producing sudden floods. These rivers carry sediment and waste from the upper parts to the mouth, for which they could be an important contribution of waste. There are also different runoffs that can contribute, 1% of the territory is made up of perennial bodies of water that are located along the main channel, varying in altitudes from 1 to 72 m above sea level [42]. Yonko and collaborators [52] mention that they found a greater amount of microplastics after considerable rains so it could be a factor that affects the study area.

The activities that influence the contribution of plastics are livestock, agriculture, generation of urban solid waste, wastewater discharges, fishing, and tourism, among others. Another source that contributes to the amount of microplastics present in the intertidal zone are marine currents, mainly polymers, such as PE and PP that float on the sea surface due to their density, which is less than that of water [53]. In the case of the study area, in the autumn season, the marine currents move from north to south [51], this could be the reason why primary MPs were identified, which could have come from the port of Tuxpan or Tamaulipas. The contribution of fibers may be due to the synthetic material in the clothing that is released during laundry, in addition to the fact that most of the municipalities that are in the basins do not have wastewater treatment plants.

5. Conclusions

This is the first report into microplastics in the intertidal beaches of the nesting area of Nautla and Vega de Alatorre. Although the abundance of microplastics is lower than those in other studies, it is not reported at what concentration there may be an impact on turtles. It is therefore necessary to monitor the area and identify various problems around both macro and micro plastics, including the presence of contaminants, such as agrochemicals, pesticides, and phthalates that can be vectorized by microplastics. The technique used in the elaboration of this work was chosen to obtain the greatest amount of data, because one of the limitations for a comparison of the results are the units that are reported so it is necessary to standardize a technique. An improved monitoring of these contaminants will allow for a comparison with different studies, taking into account that it is important that public policies emerge for the management of plastic waste and although the state of Veracruz has prohibited single-use plastics, such as bags and straws, it is still important to legislate on the use of Styrofoam and PET bottles.

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