Science on Natural Resources and Environment
Journal homepage: tapchikhtnmt.hunre.edu.vn

STUDY ON PLASTIC WASTE STATUS IN MANGROVE FORESTS AT THE COASTAL AREA OF HAU LOC DISTRICT, THANH HOA PROVINCE

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Received 10 October 2020; Accepted 16 December 2020

Abstract

Plastic is one of the most handy materials that man has ever invented. With its cheap, durable, and convenient properties, plastic is used in almost all areas of life. Along with economic development, plastic waste is becoming a big challenge for the community and society, significantly affecting the environment, public health and marine ecosystems, including mangrove forests. Studies on marine plastic waste now mainly focus on the number of plastic waste collected without concentrating on the composition, nature, and fluctuations of plastic waste accumulation over time and season. Therefore, by the methods of sampling, determining volume and composition and moisture content of each group of plastic waste, the study was conducted in the mangrove forest at Da Loc commune, Hau Loc district, Thanh Hoa province. The research results showed that the average volume of plastic waste in the 1st sample collection was 14.64g/m^2, 3.47g/m^2, 15.02g/m^3 and 5.88g/m^2 in the 2nd, 3rd and 4th sampling times, respectively. The average density of plastic waste in mangroves was 0.93 items/m^2 and 0.25 items/m^{2}at the 1st and 2nd sample collection in the winter season. Whereas in the summer, the average density of plastic waste in the mangroves is 0.74 items/m^2 and 0.54 items/m^2 in 3rd and 4th sample collections. LDPE was the dominant component in mangroves at each sampling period, the LDPE's volume ranges from 0.81g/m^2 to 7.59g/m^2 on average, followed by PP with an average volume of 1.55g/m^2 - 7.0g/m^2, the third was PVC with an average volume from 0.12g/m^2 - 2.54g/m^2, followed by PET (0.14g/m^2 - 1.09g/m^2), PS (0.02g/m^2 - 0.79g/m^2). HDPE and OTHERS were not found in the mangrove during sampling sessions. And there was no more different moisture content of different types of plastic waste among samples collected in the mangrove.

Keywords: Plastic waste; Mangrove; Item; Moisture content; Composition

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1. Introduction

Plastic is a unique material with many benefits: it is cheap, versatile, lightweight, and resistant. This makes it a valuable material for many functions, however plastic pollution is having a negative impact on the health of humans, our wildlife and our oceans. Poor management of waste in many middle and low income countries means they dominate the sources of global ocean plastic pollution. Marine plastic waste is one of the most serious and urgent environmental problems globally today. Jenna *et al.* (2015) estimated that the amount of plastic waste entering the ocean was 4.8 to 12.7 million tons out of a total of 275 million tons of plastics produced from 192 coastal countries [1]. It is forecasted that by 2050, about 1,124 million tons of plastic can be produced in the world. Particularly, the top 5 countries discharging marine plastic waste are China, Indonesia, Philippines, Vietnam and Sri Lanka with the total amount of plastic waste generated up to 17.34 million tons/year, accounting for nearly 55% of the top 20 countries [2].

Plastic waste can cause physical and chemical impacts on the ecosystem and socio-economic impacts on local communities and regions. Physically, the presence of plastic waste in the environment will affect biodiversity, killing organisms due to traps or food chains. FAO (2002) reported that plastics on the mudflats in the mangroves impede the establishment of seeds and growth of seedlings. Such substantial negative effect of plastic waste on the mangrove ecosystems will affects the ecosystem services, the economic activities relying on those services, sustainable

livelihoods of local people and the well-being of communities [3]. It also reduces the habitats available to faunal groups [4]. Coastal birds, fishes and other aquatic organisms are also known to ingest plastic mistakenly as food [5]. More than 260 marine species have been recorded as entangled or eaten by plastic pieces at sea, an average of 2.1 pieces of plastic are found in each fish in the North Pacific [6]. Chemically, the research results have demonstrated certain effects on aquatic organisms due to the sustainable existence of the constituent, fragmented compounds of plastic waste. It is an intermediate component that transfers toxic pollutants from the environment into organisms. These substances enter the food chain potentially causing serious health effects [7]. In terms of socio-economics, plastic waste directly impacts on marine economic activities, causing losses in the cleaning of tourist beaches and navigable canals and affecting the tourist landscape. Plastic waste is also likely to cause injury even fatal to humans. UNEP (2014) reported that plastic waste causes financial damage of US$13 billion to marine ecosystems each year as concern grows over microplastics [8].

The ecological and economic value of mangroves is well documented but despite this, substantial loss of this resource is occurring. Poverty in many coastal communities and livelihoods opportunities has resulted in poor mangrove management. However, the greater impact on loss has included the over-exploitation by conversion to alternative uses including tourist resorts, agricultural use, industrial developments and shrimp ponds. Mangrove forests offer a degree of resilience to climate change and increasing extreme weather events. They can significantly reduce the risk of coastal flooding from storm surge; reduce the impact of typhoons and tsunamis. Mangroves have demonstrated considerable resilience over timescales commensurate with shoreline evolution. This notion is supported by evidence that soil accretion rates in mangrove forests are currently keeping pace with mean sea-level rise offering further protection to coastal communities. The loss of mangrove standings can be felt more intensely by communities that have degraded them or removed them for more short-term gains, marine plastic pollution is being recognised as having an increasing detrimental effect on the viability of the mangroves. Poor waste management across many middle- and low-income countries means they dominate the sources of global ocean plastic pollution. Mangroves appear to be very efficient barriers against redistribution of litter in the marine environment by wind and wave action and act as sink areas for collection.

Currently, plastic waste in mangroves has been studied by some scientists. However, those studies focused mainly on the accumulation of plastic waste in mangroves, and its negative effects on the development of mangroves [9, 4, 5, 10]. The assessment of the current plastic waste situation has not been deeply studied. Therefore, studies to assess the current situation of plastic waste in mangrove areas are urgently needed.

2. Research area

Hau Loc is a coastal district, which is 25 km away from the center of Thanh Hoa city. It is next to Nga Son district in the North, Ha Trung district in the South, Hoang Hoa in the West and faces the sea in the East. Therefore, Hau Loc has the advantage of the ocean economy. Research area is located at the coastal region of Hau Loc district, from Lach Sung gate (Len river's gate) to Lach Truong (Lach Truong river's gate). The length of the research area is 12 km, which is 1/10 of Thanh Hoa's coastline. The height of this area is from 0.8m to 2.0m above sea level. The coastal region of Hau Loc district is a hot spot of plastic pollution. Untreated plastic waste is scattered along the coastline and the mangrove. The research is conducted in the mangrove of Da Loc commune, Hau Loc district of Thanh Hoa province. On this site, various local economic activities, which is closely related to the mangrove ecosystem are carried out.

3. Research methods

3.1. Sample collection method

Step 1. Survey the field, locate mangrove area

Step 2. Form quadrat

In mangrove area, set up 3 quadrats with the area of 10 x 10 m. Each quadrat is 100 m apart, lies across the researched mangrove. Use bamboosticks to indentify quadrat for the following sample collection.

Step 3. Collect, weigh plastic waste in quadrat.

Collect all the plastic waste with mass above 2 cm in quadrant.

Determine the weight of collected waste

3.2. Method of determining the weight and content of plastic waste

- After being collected, waste is divided into 7 groups:

+ Group 1: PET (plastic bottles, plastic bags, food packaging,…)

+ Group 2: HDPE (detergent bottles, shampoo,…).

+ Group 3: V or PVC (toys, oil bottles,...).

+ Group 4: LDPE (Nylon bags, food packaging, lunch box,…).

+ Group 5: PP (bottle caps,...).

+ Group 6: PS (plastic utensils, single-use cups,…).

+ Group 7: Others

- After being sorted into groups, count and weigh every item and document the data

Weigh the groups of sorted plastic waste

After being sorted into 7 groups, waste would be weighed.

Mark the weighted waste to avoid mistakes in the drying process.

3.3. Method of determining moisture content of groups of plastic waste

The moisture content of plastic waste is calculated by ratio of water (%) within an unit of waste. Humidity calculation is based on following formula:

$$x_w = \frac{m_r - m_s}{m_r} \cdot 100\% \quad (1)$$

In which:

X_w - Moisture content, (%);

m_r - Mass of solid waste before being dried, (kg);

m_s - Mass of solid waste after being dried, (kg).

❖ ***Process to dry groups of plastic waste***

- Location to conduct experiment: Hanoi University of Natural Resource and Environment's lab.

- Time of experiment: Form July 15, 2020 to August 15, 2020

- Dried all collected plastic waste in the lab.

➢ *Prepared experiment tools*

Placed the oven at 105^{o}C

Marked the number of trays

Placed the trays into oven at 105^{o}C for 30 minutes

Removed the trays from the oven then put them into a desiccator cabinet at room temperature.

Noted the weight of the trays

➢ *Dried the plastic waste*

Due to the characteristics of plastics, we dried plastic waste at 60^{o}C.

Time for drying: 24 hours

Took trays of plastic waste out then put them into a desiccator cabinet for 30 minutes

➢ *Weighed the amount of plastic waste after being dried*

Weighed the amount of plastic waste after being dried

Noted the mass of weighed waste

❖ ***Calculated the moisture content of every group of plastic waste***

Use formula (1), data of waste before being dried and after being dried will be the moisture content of plastic waste

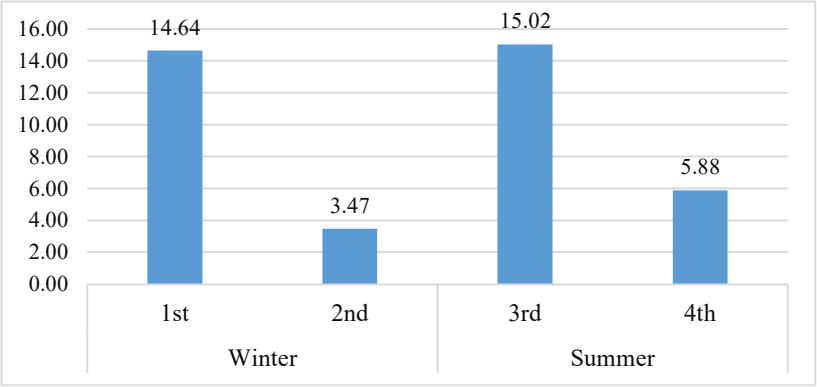
(The 2nd, 3rd, 4st sample collection will be conducted in the same manner as the 1st sample collection)

4. Research Results and Discussion

4.1. The state of plastic waste distribution in coastal region of Hau Loc district, Thanh Hoa province

4.1.1. Fluctuation in the mass of plastic waste between sample collections

Results of collecting and weighing plastic waste in mangroves in coastal region of Hau Loc region:



Unit: g/m^2

Figure 1: Amount of plastic waste collected at different sampling times

The average volume of plastic waste (g/m^2) in the 1st sample collection is 14.64g/m^2, the 2nd one is 3.47g/m^2, the 3rd is 15.02g/m^2 and the 4th is 5.88g/m^2. The main types of plastic waste collected are water bottles, plastic bags, ropes, freight lines, fishing nets, sponge floats.

The 1st and 2nd sample collection are in winter. The 1st sample collection has a larger amount of weight on the area of plastic waste than one of 2nd sample collection. This difference is due to the fact that on the 1st sample collection, the scenery of researched sight is intact, yet in the 2nd sample colletion is conducted after 7 days and in the same sight as the 1st sample collection. Therefore, waste collected in the 2nd samples collection is less than the 1st sample collection.

The 3rd and 4th sample collection are carried out in the summer. The 3rd and 2nd are 2 months apart and are carried out in the same location. However, the weight of waste in areas of the 3rd and 1st is the same due to the long period between two sample collections, which leads the amount of plastic waste returning to its original state. The 4th is carried out after 7 days and in the same location. Yet, the amount of samples collected in quadrat 1, 2, 3 is less than previous collections due to the close period of time between 2 sample collections.

From the results of the sample collections, it can be seen that the accumulation of plastic waste in the mangrove habitat tends to recirculate, with a sufficiently long time (according to the sampling time above, 4 months apart from samples collection), the accumulated waste in the habitat tends to return to the original state. Therefore, it shows that the amount of cumulative plastic waste in the habitats will increase over time and be difficult to control.

4.1.2. Fluctuation in items of plastic waste in sample collection

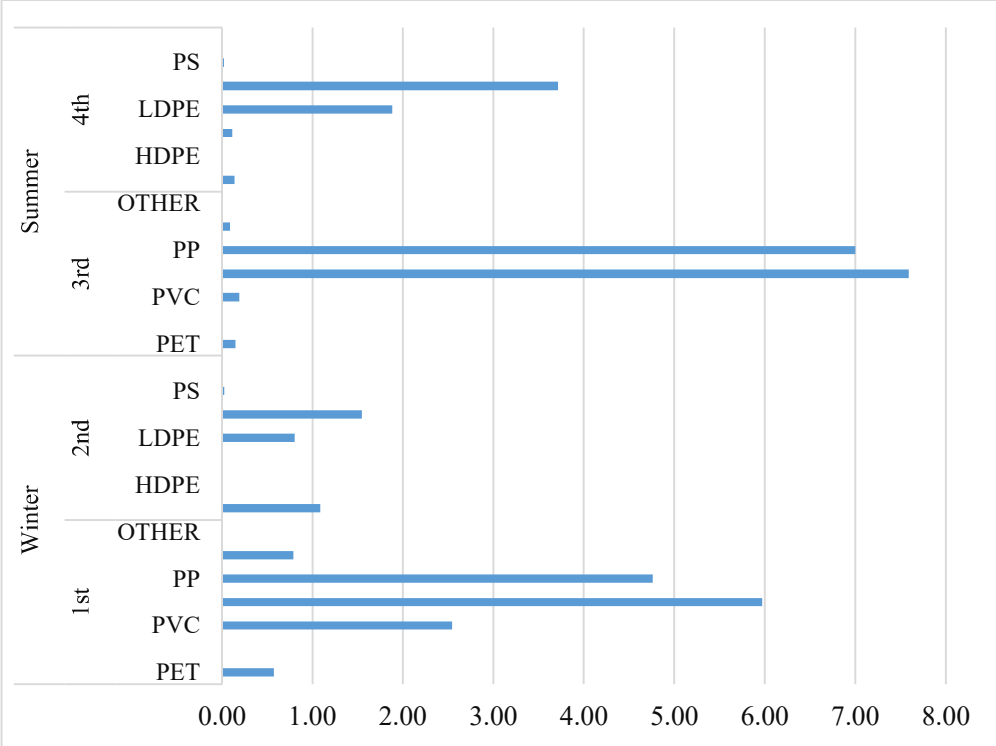
The 1st, 2nd, 3rd, 4th sample collections are carried out in the same location in mangrove in the coastal region of Hau Loc district. The 1st, 2nd sample collections are carried out in the winter. The 3rd and 4th sample collections are carried out in the summer.

Table 1. Number of items of plastic waste at different sampling times

Sampling time		Items of plastic waste							Total
		PET	HDPE	PVC	LDPE	PP	PS	OTHERS	
Winter	1st	06	0	03	175	84	10	0	278
	2nd	02	0	01	34	38	01	0	76
Summer	3rd	02	0	03	134	76	06	0	221
	4th	04	0	04	89	59	06	0	162

The 1st sample collection collected a total of 278 plastic waste items (average density 0.93 items/m^2); the 2nd sample collection obtained a total of 76 garbage items (average density 0.25 items/m^2); the 3rd sample collection collected a total of 221 plastic waste items (average density 0.74 items/m^2); 4th sample collection collected a total of 162 plastic waste items (average density 0.54 items/m^2).

The results of average density of plastic waste items/m^2 of this study are quite close to the results of studies at Adriatic and Ionian Beaches (average 0.67 items/m^2) [11]; 0.61 items/m^2 have been recorded in several countries in the northern Mediterranean [12]; The density of items recorded in this report is lower than those obtained elsewhere, e.g. 1.51 items/m^2 recorded on the coastline of Slovenia [13]; 3.85 items/m^2 are recorded on the coast of China [14];



(Unit: g/m^2)

Figure 2: Amount of plastic waste composition at different sampling times

❖ ***The 1st sample collection***

In the studied mangroves, LDPE plastic waste has the volume of 5.97g/m^2. PP plastic waste with the second largest average volume/m^2 is 4.76g/m^2. PVC waste with the 3rd largest average/m^2 volume is 2.54g/m^2. PS plastic waste is 0.79g/m^2. PET plastic waste is 0.57g/m^2. HDPE and OTHER plastic waste was not found in the mangrove.

❖ ***The 2nd sample collection***

In the studied mangroves, PP plastic waste has an average volume of 1.55g/m^2. PET plastic waste has the second largest average volume/m^2 of 1.09g/m^2. LDPE plastic waste has the 3rd largest

average volume/m^2 of 0.81g/m^2. PS plastic waste is 0.03g/m^2. HDPE, PVC and OTHER plastics were not found in mangrove habitat.

❖ ***The 3rd sample collection***

The 3rd sample collection is conducted 4 months apart from the 2nd sample collection in the same quadrant.

In the researched mangrove, LDPE plastic waste has the largest average volume of 7.59g/m^2. PP plastic waste with the second largest average volume/m^2 of 7.0g/m^2. PVC waste with the 3rd largest average/m^2 volume of 0.19g/m^2. PET plastic waste with the volume of 0.15g/m^2 and PS's volume is 0.09g/m^2. HDPE and OTHER plastic waste were not found in the mangrove.

❖ ***The 4th sample collection***

The 4th sample collection is conducted 7 days after the 3rd sample collection in the same location.

In the researched mangrove, PP plastic waste has the largest average volume/m^2 of 3.71g/m^2. LDPE plastic waste has the second largest average volume/m^2 of 1.88g/m^2. The 3rd largest average volume of PET plastic waste is 0.14g/m^2. PVC waste's volume is 0.12g/m^2 and PS plastic waste's volume is 0.02g/m^2. HDPE and OTHER plastic waste were not found in the mangrove.

When it comes to composition, LDPE plastic waste is always the most collected waste in all sample collections, specifically, the average amount of plastic waste/m^2 ranges from 0.81g/m^2 to 7.59g/m^2. PP plastic waste has an average amount of plastic waste/m^2 ranging from 1.55g/m^2 to 7.0g/m^2. The 3rd rank is PVC plastic waste, the average volume of plastic waste/m^2 fluctuates from 0.12g/m^2 to 2.54g/m^2, followed by PET plastic waste with an average plastic waste volume/m^2 ranging from 0.14g/m^2 to 1.09g/m^2, plastic waste PS has an average plastic waste volume/m^2 ranging from 0.02g/m^2 to 0.79g/m^2. HDPE and OTHER plastic waste were not found in the mangrove.

4.1.3. Determining moisture content of collected plastic waste

Sample collection			**Moisture content of plastic waste**						
			PET	**HDPE**	**PVC**	**LDPE**	**PP**	**PS**	**OTHER**
Winter	1st	Wet weight (g/m^2)	0,573	0	2,543	5,973	4,763	0,79	0
		Dry weight (g/m^2)	0,513	0	2,293	4,823	4,2	0,73	0
		Moisture (%)	10,47	0	9,83	19,25	11,83	7,59	0
	2nd	Wet weight (g/m^2)	1,087	0	0	0,807	1,55	0,027	0
		Dry weight (g/m^2)	0,997	0	0	0,65	1,447	0,023	0
		Moisture (%)	8,28	0	0	19,42	6,67	12,5	0
Summer	3rd	Wet weight(g/m^2)	0,15	0	0,193	7,59	7,0	0,09	0
		Dry weight (g/m^2)	0,14	0	0,17	6,103	6,283	0,083	0
		Moisture (%)	6,67	0	12,07	19,59	10,24	7,41	0
	4th	Wet weight (g/m^2)	0,14	0	0,117	1,883	3,713	0,023	0

Sample collection			Moisture content of plastic waste						
			PET	HDPE	PVC	LDPE	PP	PS	OTHER
		Dry weight (g/m^2)	0,13	0	0,103	1,52	3,327	0,02	0
		Moisture (%)	7,14	0	11,43	19,29	10,41	14,29	0

❖ ***The 1st sample collection***

LDPE plastic waste has the highest moisture content of 19.25%, PP plastic waste has the second highest humidity with 11.83%, followed by PET plastic waste with the humidity of 10.47%, followed by PVC plastic waste with 9.83%, and PS plastic waste with 7.59%. In the 1st sample collection, HDPE and OTHER types of plastic were not detected in the sampling quadrant, so the moisture content of these resins could not be determined.

❖ ***The 2nd sample collection***

LDPE plastic waste has the highest moisture content of 19.42%, PS plastic waste has the second highest humidity with 12.5%, followed by PET plastic waste with the humidity of 8.28%, followed by PS plastic waste with 6.67%. In the 2nd sample collection, HDPE and OTHER types of plastic were not detected in the sampling quadrant, so the moisture content of these resins could not be determined.

❖ ***The 3rd sample collection***

LDPE plastic waste has the highest moisture content of 19.59%, PVC plastic waste has the second highest humidity with 12.07%, followed by PP plastic waste with the humidity of 10.24%, followed by PS plastic waste with 7.41%, and PET plastic waste with 6.67%. In the 3rd sample collection, HDPE and OTHER types of plastic were not detected in the sampling quadra nt, so the moisture content of these resins could not be determined.

❖ ***The 4th sample collection***

LDPE plastic waste has the highest moisture content of 19.29%, PS plastic waste has the second highest humidity with 14.29%, followed by PVC plastic waste with the humidity of 11.43%, followed by PP plastic waste with 10.41%, and PET plastic waste with 7.14%. In 4th sample collection, HDPE and OTHER types of plastic were not detected in the sampling quadrant, so the moisture content of these resins could not be determined.

The humidity of different types of plastic waste between sample collections and two seasons is similar, and LDPE plastic waste has the highest humidity at each sampling period, the humidity ranges from 19.25% to 19.59 %. Second place is PS plastic waste with humidity ranging from 7.41% to 14.29%, and third place is PVC plastic waste with humidity ranging from 9.83% to 12.07%, followed by PP plastic waste with humidity ranging from 6.67% to 11.83%, and PET plastic waste with humidity ranging from 6.67% to 10.47%. HDPE and OTHER grade plastic waste were not found in the mangrove during sampling sessions.

5. Conclusion

Results on the state of plastic waste in mangrove of Da Loc commune, Hau Loc district, Thanh Hoa province show that:

The average volume of plastic waste g/m^2 in the 1st sample collection is $14.64g/m^2$, $3.47g/m^2$, $15.02g/m^3$ and $5.88g/m^2$ in the 2nd, 3rd and 4th sampling times, respectively. The amount of plastic waste accumulation in the mangrove tends to circulate over a period of about 4 months.

The average density of plastic waste in mangroves was 0.93 items/m^2 and 0.25 items/m^2 at the 1st and 2nd sample collection in winter season. Whereas in the summer, the average density of plastic waste in the mangroves is 0.74 items/m^2 and 0.54 items/m^2 in 3rd and 4th sample collections.

LDPE was the dominant component in mangroves at each sampling period, the LDPE's volume ranges from $0.81g/m^2$ to $7.59g/m^2$ on average, followed by PP with an average volume of $1.55g/m^2$ - $7.0g/m^2$, the third was PVC with an average volume from $0.12g/m^2$ - $2.54g/m^2$, followed

by PET (0.14g/m^2 - 1.09g/m^2), PS (0.02g/m^2 - 0.79g/m^2). HDPE and OTHERS were not found in the mangrove during sampling sessions.

The study results also showed that the humidity of different types of plastic waste between sample collections and two seasons was similar, in which LDPE had the highest humidity at each sampling period, ranging from 19.25% to 19,59%, followed by PS with humidity between 7.41% - 14.29%, the 3rd place is PVC with humidity ranging from 9.83% - 12.07%, followed by PP (6.67% - 11, 83%), PET (6.67% - 10.47%).

REFERENCES

[1]. Jenna R. Jambeck, Roland Geyer, Chris Wilcox, Theodore R. Siegler, Miriam Perryman, Anthony Andrady, Ramani Narayan, Kara Lavender Law (2015). *Plastic waste inputs from land into the ocean.* Science 347 (6223): 768 - 771.

[2]. UNEP (2018). *World Environment Day 2018: Overview.*

[3]. FAO (2002). *Rehabilitation, conservation and sustainable utilization of mangroves in Egypt.* Consultancy Report for Food and Agriculture Organizatio n by James Spurgeon, Jacobs GIBB Ltd., 0168 (A), p. 51.

[4]. Bulow, E.S. & Ferdinand, T.J. (2013). *The Effect of Consumptive Waste on Mangrove Functionality: A Comparative Analysis.* Centro de Incidencia Ambiental, Panama. p. 33.

[5]. Kantharajan, G., Pandey, P.K., Krishnan, P., Bharti, V.S. & Deepak Samuel, V. (2018). *Plastics: A menace to the mangrove ecosystem of megacity Mumbai, India*. ISME/GLOMIS Electronic Journal 16(1): 1 - 5.

[6]. Macfadyen, G., Huntington, T. and Cappell, R. (2009). *Abandoned, lost or otherwise discarded fishing gear.* UNEP Regional Seas Reports and Studies 185, FAO Fisheries and Aquaculture Technical Paper 523.

[7]. Jiang J.Q. (2018). *Occurrence of microplastics and its pollution in the environment: A review*. Sustainable Production and Consumption, Volume 13, p.16 - 23.

[8]. UNEP (2014). *UNEP year book 2014*.

[9]. Cole, M., et al. (2011). *Microplastics as contaminants in the marine environment: A review*. Mar. Pollut. Bull. 2588e2597.

[10]. Cecilia Martin, Hanan Almahasheer, Carlos M. Duarte (2019). *Mangrove forests as traps for marine litter.* Environmental Pollution 247: 499 - 508.

[11]. Thomais Vlachogianni, Tomaso Fortibuoni, Francesca Ronchi, Christina Zeri, Cristina Mazziotti, Pero Tutman, Dubravka Bojanić Varezić, Andreja Palatinus, Štefan Trdan, Monika Peterlin, Milica Mandić, Olivera Markovic, Mosor Prvan, Helen Kaberi, Michael Prevenios, Jerina Kolitari, Gulielm Kroqi, Marina Fusco, Evangelos Kalampokis, Michael Scoullos (2018). *Marine litter on the beaches of the Adriatic and Ionian Seas: An assessmentof their abundance, composition and sources*. Marine Pollution Bulletin 131, pp.745 - 756.

[12]. T. Vlachogianni, M. Skocir, P. Constantin, C. Labbe, D. Orthodoxou, I. Pesmatzoglou, D. Scannella, M. Spika, V. Zissimopoulos, M. Scoullos (2019). *Plastic pollution on the Mediterranean coastline: generating fit-for-purpose data to support decision-making via a participatory-science initiative*. Sci. Total Environ., 711 (2019), p. 135058.

[13]. Betty J.L. Laglbauer, Rita Melo Franco-Santos, Miguel Andreu-Cazenave a, Lisa Brunelli, Maria Papadatou, Andreja Palatinus, MatejaGrego, Tim Deprez (2014). *Macrodebris and microplastics from beaches in Slovenia*. Marine Pollution Bulletin 89, pp.356 - 366.

[14]. Chen, H., Wang, H., Guo, H., Lin, H., Zhang, Y., (2019). *A nationwide assessment of litter on China's beaches using citizen science data*. Environ. Pollut. P.113756.