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MARINE DEBRIS OCCURRENCE AND TREATMENT: A REVIEW

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Abstract

Marine debris produces a wide variety of negative environmental, economic, safety, health and cultural impacts. Most marine litter has a very low decomposition rate (as plastics, which are the most abundant type of marine debris), leading to a gradual, but significant accumulation in the coastal and marine environment. Along that time, marine debris is a significant source of chemical contaminants to the marine environment. Once extracted from the water, incineration is the method most widely used to treat marine debris. Other treatment methods have been tested, but they still need some improvement and so far have only been used in some countries. Several extraction and collection programs have been carried out. However, as marine debris keep entering the sea, these programs result insufficient and the problem of marine debris will continue its increase. The present work addresses the environmental impact and social aspects of the marine debris, with a review of the state of the art in the treatments of this kind of waste, together with an estimation of the worldwide occurrence and characteristics.

1. Introduction

“Marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment” [1, 2]. It consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds;

accidentally lost, including material lost at sea in bad weather (fishing gear, cargo); or deliberately left by people on beaches and shores [3].

The presence of marine debris is a cause for concern due to several reasons. It is known to be harmful to organisms and to human health [1, 4-6], it has potential to increase the transport of organic and inorganic contaminants [7-11], it presents a hazard to shipping, and it is aesthetically detrimental, and thus generating negative socio-economic consequences [12].

Litter can easily be mistaken as food by animals and cause health complications or even death. Many studies have investigated the ingestion of plastic items by marine animals, including fish [13], cetaceans [14], turtles [15] or seabirds [16, 17]. Fishing gear can become ocean pollutant as a result of accidental losses or dumping. Entanglement in abandoned fishing gear is another important threat not only for marine mammals [18, 19], but also for benthic biota [20].

The economic impact of marine debris is noticeable. At beaches, marine debris causes aesthetic problems, especially in touristic areas where they generally lead to a decline in tourist traffic and oblige the concerned municipalities to substantial cleaning costs. At sea, floating marine debris endanger the maritime traffic. Small items can block propellers and collisions are always possible with larger debris. In addition, litters trapped by fishing nets is becoming a recurring issue for fishermen [21]. A diagram that represents the lifecycle of marine debris is shown in Figure 1 (adapted from [22]): the produced plastic discards are accumulated during a period of time in the beaches and float or are washed to the seabed by water columns, suffering a fragmentation. The fate of the plastic is then its collection (via more encouraging), its decomposition (that will last hundreds of years) or ingestion by marine organisms. From this figure, it is important to note that the startup of new policies managing the discards is the only practical route for combating marine litter problem.

[Figure 1]

The material most commonly found in marine debris are glass, metal, paper and plastic (OSPAR, 2007), and, according to the publish literature, it is clearly apparent that, globally, plastic items are consistently the most abundant type of marine debris [3, 23-26].

1.1. Plastics in marine debris

Plastics are synthetic organic polymers that are malleable and can be molded into solid objects of diverse shapes. In addition, they are strong, lightweight, durable and inexpensive [27], properties that make them suitable for the manufacture of a wide range of products.

The main reason why plastics are hazardous to the marine environment is their resistance to degradation. The natural decomposition of plastic items in the sea occurs in an exceedingly long time, usually estimated between hundreds and thousands of years [28], therefore, plastics accumulate in the marine environment and persist for decades [29]. Chemical contaminants such as polychlorinated biphenyls (PCBs) and dioxins are released into the sea during this degradation. Furthermore, plastic items are fragmented into small pieces, becoming plastic micro-particles (with a diameter of less than 5 mm) [30], which are ingested by animals, thus being very harmful to marine life [31, 32].

Plastics have existed only for around a century [33], but since the development of the plastics industry, plastic products are the most abundant around the globe, hence representing 60-80% of the total marine debris [34]. A compilation on the proportion of plastics found in the marine debris was done 15 years ago [4]. Table 1 presents new data on the same subject published from then. An average value of > 65 % of plastics in the rubbish is found, denoting the importance of controlling the plastic deposition in all places around marine environment, such harbors, beaches, and those from the fishing and recreational activity.

[Table 1]

1.2. Composition of the plastic marine debris

The most commonly used plastics are Polyethylene, Polypropylene and polyethylene terephthalate, therefore, they are the most frequently found in the marine environment too [35-

37]. Table 2 presents the data found in literature about the distribution of different types of plastics in the marine litter collected. It is important to note the very important and unexpected amounts of cellulose acetate (CA) used in cigarette filter manufacture that has been signaled as a very important problem in oceans.

[Table 2]

2. Quantities of collected marine debris

Until the 1970s, there were no scientific texts speaking about ocean pollution by plastic waste. More than forty years later, still there is not any accurate estimation of the amount of this residues present in the marine environment.

It is not possible to know the exact route of entry of these debris (rivers, air, pleasure craft, fishing or merchant ...). The estimated amount of these debris found in specific rivers ranging from less than 1 kg per day (Hilo, Hawaii) to 4,200 kg per day (Danube) [38, 39]. Most of marine debris entering the sea ends up accumulating on the seabeds (70%), and the rest remains on the shores (15%) and in the water columns (15%) [40].

Recent studies have shown that the amount of debris accumulated in the marine environment depends of the location, characteristics of the area, and the season of the year, especially when precipitations are strong and river flows are higher [41-43]. Depending of topography, rocky shore lines contain the most of the debris, followed by sandy beaches; and regarding to the season, the biggest density of debris has been found in autumn, and the lowest in spring [44].

2.1. General marine debris

There are very few studies focusing on the total amount of marine debris accumulated in the seas and oceans around the world [45]. Forty years ago, it was estimated that the total amount of debris accumulated in the oceans every year was around 6,360,000 tons [46].

In recent years, several initiatives have been carried out by various organizations for the collection of marine debris in different coastal areas. One of the most significant studies worldwide was "The UNEP Global Initiative on Marine Litter", a cooperative activity of UNEP/GPA and the Regional Seas Program (RSP). In this project it was carried out the collection of marine debris of twelve Regional Seas: Baltic Sea, Black Sea, Caspian, East Asian Seas, Eastern Africa, Mediterranean, Northeast Atlantic, Northwest Pacific, Red Sea and Gulf of Aden, South Asian Seas, Southeast Pacific, and Wider Caribbean, between 1989 and 2007. The total debris items collected were 103,247,609 [3].

Other similar projects are focused only in specific areas. At the surface of the Mediterranean Sea were estimated from 1.2 to 2000 items per km^2 [47]. The amount of marine debris located on sandy beaches, rocky shores and in coastal waters of the Coastal System of Coquimbo between summer 2002 and autumn 2005 were 6,906, 1,149 and 267 items, respectively. [48]. In 2003 and 2004, 54-94 items per km^2 of marine debris were recollected in the Pacific coast of northern Japan. In 2011, due to the Tohoku earthquake and tsunami, 233-232 items per km^2 were quantified [49]. The abundance of marine debris observed during transects in the Straits of Malacca and Bay of Bengal during May-June 2012 was 17,740 and 18,211 items, respectively [50]. In 2012, in South Korea, 42,595 tons of marine debris were collected from coasts, water column and seabeds. [45]. During the winter in 2013, the abundance of marine debris were investigated in the Western Indian Ocean on remote Alphonse Island, where a total of 4,743 items from 1 km of windward beach were removed [51, 52].

2.2. Plastic debris

Plastics can be found in a lot of products (shopping bags, food packaging, facial cleansers, household items…). The global annual production of plastics is around 280 million tons [53, 54]. Recent surveys estimate that between 4.8 and 12.7 million tons of plastic waste ends up in the world's oceans every year [55].

In a recent study [55] the waste estimates for the top 20 countries mismanaging plastic wastes is presented. These 20 countries or regions accumulate 83% of mismanaged plastic waste that could end up in the ocean. Among the 20 most polluting countries, China is the first one, USA is the number 20 and the EU as a whole is located in the number 18.Therefore, it is estimated that the reduction of this waste by 50% would result in a decrease of around 40% of the plastic inputs to the ocean.

The 192 countries with coast in the Atlantic, Pacific, Indian, Mediterranean and the Black Sea generated 2,500 million tons of solid waste in 2010, of which 270 million were plastic waste. Coastal areas generated 99.5 million tons of plastic waste, of which 31.9 million were mismanaged waste, i.e., more than 30 %. Of these, around 8 million tons entered the ocean in 2010 [55].

The annual input of plastics in the oceans increases every year. It is estimated that in 2015 around 9.1 million tons will be accumulated. By 2025, the annual input of plastics to the sea would be about double what it was in 2010. By then, the total amount of plastic debris accumulated in the oceans around the world is estimated around 155 million tons [55].

3. Extraction and disposal of marine debris

Marine debris is collected mostly by boats. Usually, each port has a waste manager which is responsible for collecting the waste generated by both, port facilities and boats. The amount collected depends on the fishing activity in the area and is not uniform.

Every year, various programs for Coastal Cleanup are carried out, in which a large amount of marine debris are collected from various coastal areas by numerous volunteers, but this is not enough. Over recent years, Korea has carried out a program for removal and collection of marine debris, which seems insufficient, but may shed some light on the problems of ocean pollution.

3.1. Floating marine debris

The Korean coast is bursting of floating and submerged marine debris [56]. Most of the waste that ends up in the worldwide oceans is transported by rivers or water canals. In order to prevent this, a floating debris containment boom has been developed.

This containment mechanism used by Korea in order to prevent marine debris to end up in the ocean consist on a floating portion that is located on both sides of a plate, they have a streamlined shape and are made of reinforced polystyrene foam compressed to reduce the hydrodynamic force of residues colliding on it. From the bottom there is a net, in order to prevent the passage of any object that, due to the current, can be in the water column. Later, from a bulldozer located on a boat, the marine debris accumulated in the containment barrier are collected. The other end of the barrier is connected to a large float which is tied with a string to the seabed. The installation of the barrier in the right place is very important to assure an effective operation, bearing in mind that, due to the current, floating debris accumulates between the boat and the containment barrier.

Every year, this barrier is installed during the season of heavy rain, when around 1300 tons are collected, representing around 10% of the total marine debris recovered. In addition to this process, several programs of cleaning and collection of marine debris are carried out in the Korean coast [57].

3.2. Marine debris accumulated in the seabed

3.2.1. Probing equipment

In many shallow coastal waters, exploration on the seafloor were carried out by two divers with snorkel towed behind a small boat [58]. On depths of 100 m, a side scan sonar (SSS) was used together with a bottom trawl net [59-62]. For greater depths, between 50 and 2700 m, manned submersibles were used [59].

An equipment called "Tow-Sled" suitable for drilling in the seas, with moderate depths (between 500-1000 m) has been developed in Korea. It is a kind of sleigh equipped with lights, cameras and long-range acoustic positioning system, which provides information on the amount, type and location of marine debris. This system is attached to the boat with a steel cable, and moves towed by it thanks to two skates solder on each side of the equipment base [63].

3.2.2. Recovery equipment

Choosing the right equipment for the removal of the debris accumulated on the seabeds depends on where the operation is going to take place, as it could be a rocky or sandy area. Marine debris collection was carried out by a crane located on a boat with interchangeable hooks, which may be curved to prevent debris slide or articulated to narrow rocky. This method is operated in Korea around 130-150 days a year, and collects about 350 tons of marine debris annually.

4. Pollutants contained in the marine debris

Persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and organochlorine pesticides are present in aquatic systems worldwide as a consequence of their wide-spread usage, long-range transport, and persistence. Individual POPs have characteristic patterns of distribution depending on regional patterns of usage and their physico-chemical properties. An international group of research units are trying to monitor the POPs contamination worldwide, by using beached plastic resin pellets [64]. This scheme, International Pellet Watch, has been in operation since 2006.

Other studies have been also reported the importance of the amounts of pollutants contained in the different marine environment. Table 3 presents some results of the most relevant studies performed in the last decade. PCBs, heptaclorocyclohexanes (HCHs), dichlorodiphenyltrichloroethanes (DDTs) and poly-aromatic hydrocarbons (PAHs) are considered, as they have been found in different media. As can be seen in this Table, an important amount of POPs can be found in the plastic pellets, which can aggravate the effects of intake of them by the marine fauna. Average values found in literature would give approximately 45 ng PCBs/g, 5 ng HCHs/g, 20 ng DDTs/g and 2500 ng PAHs/g-pellet. Of particular concern is the case of the high levels of DDTs found in the California beaches as well as the high values of PAHs in all studies found. Nevertheless, the concentrations are highly variable between the samples, and more research is needed in this sense.

Different studies are in progress on the sorption capacity of plastic debris for hydrophobic organic chemicals [65-68], pointing out the necessity for new policies contemplating this important problem.

5. Marine debris treatment

Marine debris, once removed from the sea, is removed by an incineration process. This process is the most commonly used for processing the marine debris. However, over recent years, projects of treatment and recovery of this debris, such as recycling or fuel production have been carried out.

5.1. Pre-treatment

The pre-treatment process is very important, independently on how such debris are treated thereafter, since marine debris contains salt and other contaminants. This process includes: sorting, cutting, separating lead, grinding and cleaning of salts and sludge. The cleaning process ensures mechanical stability, reduce the sodium content and other salts, and improve the quality of the material. The method used, type and sequence of the pre-treatment steps varies based on the main process for the treatment of this waste.

5.2. Treatments

5.2.1. Fuel production from marine debris (RDF)

Marine debris has high calorific value (4000 – 6700 kcal/kg). This feature makes it suitable for using as fuel. The analysis of the physical properties of refused-derived fuel (RDF) show that marine debris contains a high percentage of carbon and hydrogen (C: 73.58%, H: 6.304%, N: 0.338%, S: 0.391%, others: 19.387%). Most of this debris are plastics, which can be transformed into RDF.

There is an RDF production plant that was developed in 2000 as a pilot plant. This facility included a pre-treatment process, had a capacity of 50 kg/h of debris and extruded solid fuel. The process had several steps: grinding, water cleaning, dryer, silo and injection molding extrusion [56]. The RDF obtained could be used also as a raw material in the recycling industries for manufacturing of new plastic items.

5.2.2. Marine debris recycling

Most of the marine debris, such as different types of plastics, can be recycled and used as raw materials in the production of other items. The production process for these items would be the same as with the virgin materials, but requiring a cleaning stage for removing salts.

Polystyrene buoys are the most widespread waste in the aquaculture industry. To reduce and recycle this type of debris, a volume reduction system has been developed. This system is able to process 100 kg/h of waste buoys and recover raw material suitable for the production of recycled items. The process includes several steps: separation of embedded organisms, grinding, salts and sludge cleaning, drying, storage and molding injection. Twenty one local governments in Korea, where there is a large volume of marine debris, have thermal extrusion facilities for polystyrene buoys currently in operation. Between 40 and 80 tons of this waste are treated each year by each one of these installations. In addition, there are small portable systems that can be carried on trucks. These system is able to process 30 kg/h, and have been developed to treat buoys discarded at remote places [56].

The fiberglass reinforced plastic (FRP) vessels are another remarkable type of waste in the aquaculture industry. In 1980, 65,000 vessels were built with this material. The lifecycle of this vessels is 25 years, which are normally abandoned on harbors, shores and rivers [69]. In 2008, a pilot direct melting system was developed, which was able to process 30 kg/h of this type of waste. The capacity of this system is going to be upgraded to process 150 kg/h, around 1000 vessels per year or up to 2 tons per plant [63].

5.2.3. Incineration of marine debris

Pyrolysis and combustion have always been considered as attractive alternatives for waste disposal, since these techniques provide a reduction in volume of waste and also involve profitable energetic and/or chemical products. Thermal decomposition of waste can take place both in controlled conditions (incinerators, cement kilns…) and non-controlled conditions, for example, during fires or open-air burning. The substances emitted during non-controlled plastic thermal degradation may create a serious hazard for human health and for the environment.

Some marine debris cannot be recycled or reused. On most countries, incineration is the most widely used process to treat marine debris. In this process, the production of air pollutants requires special attention, since incomplete combustion of these can generate harmful gases. Furthermore, due to chlorine, generation of dioxins in this process is important and must be measured.

Until now plastic fractions of marine debris have been landfilled because it was considered as a waste product with low value; however, today it is known that this waste has a great value and it is suitable for recycling, mainly by chemical or energy recovery, especially attractive for polyolefin waste [70].

Thermal treatment of chlorinated wastes it is a problematic way of recovery. Besides hydrogen chloride, chlorinated aromatic compounds are evolved during pyrolysis or combustion of chlorinated polymers, such as chlorobenzenes (CBzs), chlorophenols (CPhs), chlorobiphenyls (PCBs) and, polychlorodibenzo-p-dioxins and polychlorodibenzofurans (PCDD/Fs) [71]. This could be especially alarming when the process is uncontrolled. Illegal recycling, open burning at landfills or accidental fires involves a serious damage to health and to environment.

Generally, the flue gas treatment systems are complex and expensive, and their technology needs improvement [72]. Most incineration plants have not a cleaning system necessary to eliminate salts from marine debris, and the percentage of ashes generated in this process is relatively high. In addition, several islands, such as Sochung (Korea), have some difficulties to treat marine debris due to long distance between the shore and the plant, causing issues for transport the marine debris [63]. In order to improve the incineration process, a new system has been developed in Korea that can treat up to 100 kg/h. This system uses activated carbon for the removal of dioxins, slaked lime for the removal of HCl or SOx and a back filter to remove heavy metals, dioxins and dusts. It has been proved that the concentration of dioxins discharged to the atmosphere by this incineration process of marine debris satisfies the emission limits [56]. The ash generated after the incineration process is less than 5% of treated marine debris.

6. Plans and actions adopted in related to marine debris

6.1. Internationally

The Ocean Conservancy launched the International Coastal Cleanup (ICC) plan in 1986. In this plan 97 countries and regions participated, and large amount of marine debris was collected [73]. The target of this plan was to obtain information about the type and quantity in which these residues are found in the marine environment. Since 1993, Brazil, Norway, United Kingdom, Chile, Australia, Uruguay and the United States have been performing a marine debris survey program associated to the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) [74]. Since 1996, the Environmental Protection Agency (EPA) of the United States has been assessing the state of marine debris in the Gulf of Mexico, using a standardized recording sheet [75]. Taiwan began to make plans related to marine debris collection in 1997, when the government adopted Coastal Environment Cleanup Operation Guidelines [76]. Korea began to develop plans and actions to removed marine debris in 2003 [63]. The Honolulu Strategy was approved in 2011 by the United Nations Environment Program (UNEP). The UNEP suggested that member nations adopt those measures [77].

6.2. Nationally

Nowadays, some coastal municipalities in most countries have implemented a number of measures to prevent marine debris to end up in the ocean, such as the payment of rewards to tourists in car parks near sea areas for not littering, compensations to fishing boats that collect marine debris, commercial and recreation fishing fees, penalties for the discharge of polluting substances in the sea, etc. The purpose of these measures is the reduction of waste from entering into the sea. Additionally, the collected money is intended to support the financial and technical development for the installation of waste management plants in fishing boards, recreational crafts and large vessels, as well as funding projects for beaches and coastal waters cleaning.

An important measure that is having good result is the restriction on the use of plastic bags. It is intended that people use only the necessary bags. Consequently, governments decided to face in new bagging fees instead of allowing supermarkets to provide free bags. Taiwan has reduced the consumption of plastic bags on a 58.34% with this initiative [78]. Other countries, as is the case of France, have banned the use of plastic bags in stores from January 2016.

7. Suggestions and further changes to reduce marine debris

Marine debris is a real issue in the oceans around the globe. To fight this problem, government departments could try to improve their advertising and even provide incentives to people who recycle [44].

Education is also important in order to improve the actual condition of oceans and could change the habits of people in an effective way, especially starting during childhood [4]. Education about the importance of recycling and caring for the marine environment must be incorporated into the study programs, and schools should organize activities every year to clean nearby beaches [44]. Further events should also be organized to educate people in how to treat the environment properly after and during leisure activities on nature.

An important part of marine debris is attributed to the fishing industry. It has been suggested that fishermen should follow some guidelines for waste disposal at ports, to use bait containers and implement programs for fishing nets recycling [79].

8. Conclusions

It is important to raise awareness among people about the importance of this issue and remind them what is thrown into the sea does not disappear. However, despite efforts at global, remind them that those items abandoned in the sea do not degrade easily and are very detrimental for marine environmental. Marine debris continue to pose a growing threat to the oceans, rivers, seas and coasts around the world, as well as the requirement for waste extraction and treatment of these wastes and the consequent costs that they lead to.

As a consequence, there is an growing need to tackle the issue through more effective laws and regulations enforcement, coordinated and expanded outreach of educational campaigns, and the employment of strong economic instruments such as fines for those who litter in the oceans or coasts and incentives for prevention and waste reduction [3].

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LIST OF FIGURES

Table 1. Proportion of plastics (per number of items collected) in marine debris.

Locality	Litter type	Percentage of debris items represented by plastics	Reference
Central and Western part of the Mediterranean Sea	Floating debris	> 47.5	[80]
European coasts	Sea floor	> 70	[61]
Salt marshes in Carteret Country (North Carolina)	Floating debris	45,6	[81]
Sand Island, Midway Atoll	Beach	65,7	[82]
Two Sub-antartic Island beaches	Beach	94-95	[83]
Azores (NE Atlantic): Faial Island	Beach	93,14	[84]
Northern South China Sea	Floating debris	44,9	[85]
	Sea floor	47	
	Beach	42	
20 Korea beaches	Beach	66,7	[86]
2 beaches of Niterói, RJ, Brazil	Beach	52	[87]
Cliffwood Beach, New Jersey	Beach	42,5	[88]
North Eastern Mediterranean	Sea floor	73	[89]
Belgian coastal waters	Beach	95,5	[90]
	Floating debris	95,7	
	Sea floor	95,7	
W&S Greece	Water column, sea floor	55,9	[91]
*Baltic Sea, (4 countries)	Beach, floating debris, sea floor	< 60	[3]
*Black Sea (2 country)	Beach, floating debris, sea floor	> 65	[3]
*Caspian Sea (1 country)	Beach, floating debris, sea floor	> 60	[3]
*East Asian Seas (8 countries)	Beach, floating debris, sea floor	> 64	[3]
*Eastern Africa (4 countries)	Beach, floating debris, sea floor	> 58	[3]
*Mediterranean (11 countries)	Beach, floating debris, sea floor	> 56	[3]
*Northeast Atlantic (11 countries)	Beach, floating debris, sea floor	75,01	[3]
*Northwest Pacific (3 countries)	Beach, floating debris, sea floor	> 60	[3]
*Red Sea and Gulf of Aden (2 countries)	Beach, floating debris, sea floor	> 55	[3]
*South Pacific (5 countries)	Beach, floating debris, sea floor	> 50	[3]
*South Asian Seas (3 countries)	Beach, floating debris, sea floor	> 65	[3]
*Wider Caribbean (21 countries)	Beach, floating debris, sea floor	> 63	[3]

Table 2. Composition of plastics recovered from the marine environment.

		Percentage of debris items represented by plastics					
LOCALITY	**LITTER TYPE**	**CA**	**PE**	**PP**	**PET**	**PS**	**Reference**
Seine River	Surface water	-	26	35,2	20,7	10,8	[92]
Sand Island, Midway Atoll	Surface water	-	56	30	-	-	[82]
3 South African beaches	Beach	-	82	11	-	-	[93]
sandy beaches in Australia, Oman, United Arab Emirates, Chile, Philippines, Azores, USA, South Africa, Mozambique and the U.K.	Beach	-	6	7	56	-	[94, 95]
*Baltic Sea, (4 countries)	Beach, floating debris, sea floor	37,4	< 20	< 17	6,5	-	[3]
*Black Sea (2 country)	Beach, floating debris, sea floor	22,4	< 22	< 10	20,9	3,3	[3]
*Caspian Sea (1 country)	Beach, floating debris, sea floor	-	< 50	< 50	14,6	-	[3]
*East Asian Seas (8 countries)	Beach, floating debris, sea floor	17,5	< 40	< 25	6,3	-	[3]
*Eastern Africa (4 countries)	Beach, floating debris, sea floor	6,7	< 43	< 23	10,2	-	[3]
*Mediterranean (11 countries)	Beach, floating debris, sea floor	29,1	< 20	< 12	4,1	-	[3]
*Northeast Atlantic (11 countries)	Beach, floating debris, sea floor	16	< 30	< 26	7,9	4,8	[3]
*Northwest Pacific (3 countries)	Beach, floating debris, sea floor	24,3	< 31	< 24	3,4	2,7	[3]
*Red Sea and Gulf of Aden (2 countries)	Beach, floating debris, sea floor	9,3	< 30	< 15	4,6	13,2	[3]
*South Pacific (5 countries)	Beach, floating debris, sea floor	5,2	< 35	< 27	8,1	3,0	[3]
*South Asian Seas (3 countries)	Beach, floating debris, sea floor	10,9	< 45	< 15	3,6	-	[3]
*Wider Caribbean (21 countries)	Beach, floating debris, sea floor	2,9	< 32	< 20	16,8	5,7	[3]

*during 2005/2006/2007 ICC

Table 3. POPs contained in different marine litter around the world.

Location	Plastic sample	Contaminants (ng/g-pellet)				Reference
		PCBs	HCHs	DDTs	PAHs	
Australia (17 locations)	PE and PP pellets	0.1 - 294	n.a. - 20.71	0.52 - 421	-	[96]
New Zeland´s North Island (6 locations)		0.25 - 157	n.a. - 28.94	3.17 - 47.03	-	
Canary (Fuerteventura, El Cotillo)b	Plastic resin pellets	9	0,6	4,1	-	[97]
Oahu (Kahuku Beach)[a]		0,7	0,4	0,8	-	
Oahu (Wawamalu beach)[a]		0,1	1,6	0,7	-	
Oahu (Waimanalo Bay)[a]		1,5	0,2	0,9	-	
Hawaii (Kamilo beach)[a]		9,9	0,6	3,4	-	
Barbados (Martins Bay)[a]		1,7	0,8	3,1	-	
Cocos (Bob's Folly Beach)[a]		6,5	1,7	3,4	-	
St. Helena (Sandy Bay)[a]		7	19,3	3,4	-	
Kehoe Beach, CA (USA)	Polyethylene pellets	86	0.15 - 0.94	95,7	-	[98]
Seal Beach, CA (USA)		48	0.25 - 0.45	37,2	-	
Dungeness Spit, WA (USA)		32	0.29 - 0.35	5,09	-	
Quincy Bay, MA (USA)		416	0,57	6,83	-	
Costa Nova (Portugal)		27	0.55 - 0.56	1,69	-	
Forth Estuary (UK)		87	0.52 - 0.92	2,16	-	
Kato Achaia (Greece)		5	1,04	9,41	-	
Izmir (Turkey)		53	0.83 - 1.12	27,6	-	
Mumbai (India)		43	1.77 - 2.20	9,58	-	
Chennai (India)		141	3,24	29,8	-	
Rayong (Thailand)		6	0.17 - 0.48	25,9	-	
Jakarta Bay (Indonesia)		16	1,09	13,7	-	
Minh Chau Island (Vietnam)		26	1.07 - 1.23	163	-	
Foul Bay (Australia)		16	0.14 - 0.19	6,69	-	
Bay of Maputo (Mozambique)		9	36.4 - 37.1	4,49	-	
South Durban (South Africa)		41	33,9	2,43	-	
Belgian Coast	Plastic litter and beached pellets	31 - 236	-	-	1076 – 3007	[99]
central pacific gyre, Pacific Ocean and Caribbean Sea, remote beaches at Marbella Beach and Thinh Long,	PE and PP plastic fragments	1 - 436	-	0 - 198	0 - 9297	[100]

Tonking Bay and urban beaches at Odaiba, Kugenuma and Seal Beach						
San Diego, California (8 beaches)	Plastic debris	n.a. - 47	-	n.a. - 76	30 - 1900	[101]

n.a. → Not available

[a] → median of five pools

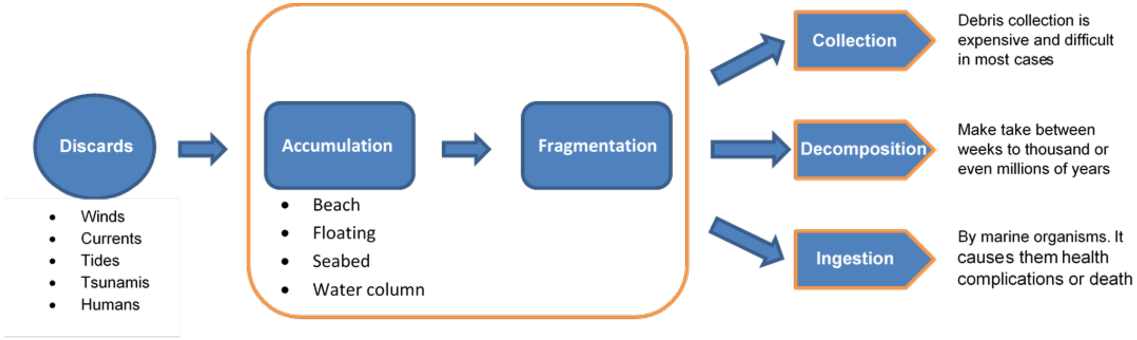

Figure 1. Typical lifecycle of marine debris