

1 MARINE DEBRIS OCCURRENCE AND TREATMENT: A REVIEW

2 Iñiguez, M.E.; Conesa*, J.A.; Fullana, A.

3 Chemical Engineering Department. University of Alicante. P.O. Box 99, 03080 Alicante (Spain).

4 Phone: +(34) 96 590 38 67 Fax: +(34) 96 590 38 26

5 * Corresponding author email: ja.conesa@ua.es

6

7 **Abstract**

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

20 **1. Introduction**

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

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

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

31 Litter can easily be mistaken as food by animals and cause health complications or even
32 death. Many studies have investigated the ingestion of plastic items by marine animals,
33 including fish [13], cetaceans [14], turtles [15] or seabirds [16, 17]. Fishing gear can become
34 ocean pollutant as a result of accidental losses or dumping. Entanglement in abandoned fishing
35 gear is another important threat not only for marine mammals [18, 19], but also for benthic biota
36 [20].

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

49 [Figure 1]

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

53 **1.1. Plastics in marine debris**

54 Plastics are synthetic organic polymers that are malleable and can be molded into solid
55 objects of diverse shapes. In addition, they are strong, lightweight, durable and inexpensive
56 [27], properties that make them suitable for the manufacture of a wide range of products.

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

65 Plastics have existed only for around a century [33], but since the development of the
66 plastics industry, plastic products are the most abundant around the globe, hence representing
67 60-80% of the total marine debris [34]. A compilation on the proportion of plastics found in the
68 marine debris was done 15 years ago [4]. Table 1 presents new data on the same subject
69 published from then. An average value of > 65 % of plastics in the rubbish is found, denoting the
70 importance of controlling the plastic deposition in all places around marine environment, such
71 harbors, beaches, and those from the fishing and recreational activity.

72 [Table 1]

73 **1.2. Composition of the plastic marine debris**

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

76 37]. Table 2 presents the data found in literature about the distribution of different types of
77 plastics in the marine litter collected. It is important to note the very important and unexpected
78 amounts of cellulose acetate (CA) used in cigarette filter manufacture that has been signaled as
79 a very important problem in oceans.

80 [Table 2]

81 **2. Quantities of collected marine debris**

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

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

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

96 **2.1. General marine debris**

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

100 In recent years, several initiatives have been carried out by various organizations for the
101 collection of marine debris in different coastal areas. One of the most significant studies

102 worldwide was “The UNEP Global Initiative on Marine Litter”, a cooperative activity of
103 UNEP/GPA and the Regional Seas Program (RSP). In this project it was carried out the
104 collection of marine debris of twelve Regional Seas: Baltic Sea, Black Sea, Caspian, East Asian
105 Seas, Eastern Africa, Mediterranean, Northeast Atlantic, Northwest Pacific, Red Sea and Gulf of
106 Aden, South Asian Seas, Southeast Pacific, and Wider Caribbean, between 1989 and 2007.
107 The total debris items collected were 103,247,609 [3].

108 Other similar projects are focused only in specific areas. At the surface of the
109 Mediterranean Sea were estimated from 1.2 to 2000 items per km² [47]. The amount of marine
110 debris located on sandy beaches, rocky shores and in coastal waters of the Coastal System of
111 Coquimbo between summer 2002 and autumn 2005 were 6,906, 1,149 and 267 items,
112 respectively. [48]. In 2003 and 2004, 54-94 items per km² of marine debris were recollected in
113 the Pacific coast of northern Japan. In 2011, due to the Tohoku earthquake and tsunami, 233-
114 232 items per km² were quantified [49]. The abundance of marine debris observed during
115 transects in the Straits of Malacca and Bay of Bengal during May-June 2012 was 17,740 and
116 18,211 items, respectively [50]. In 2012, in South Korea, 42,595 tons of marine debris were
117 collected from coasts, water column and seabeds. [45]. During the winter in 2013, the
118 abundance of marine debris were investigated in the Western Indian Ocean on remote
119 Alphonse Island, where a total of 4,743 items from 1 km of windward beach were removed [51,
120 52].

121 **2.2. Plastic debris**

122 Plastics can be found in a lot of products (shopping bags, food packaging, facial cleansers,
123 household items...). The global annual production of plastics is around 280 million tons [53,
124 54]. Recent surveys estimate that between 4.8 and 12.7 million tons of plastic waste ends up in
125 the world's oceans every year [55].

126 In a recent study [55] the waste estimates for the top 20 countries mismanaging plastic
127 wastes is presented. These 20 countries or regions accumulate 83% of mismanaged plastic
128 waste that could end up in the ocean. Among the 20 most polluting countries, China is the first

129 one, USA is the number 20 and the EU as a whole is located in the number 18. Therefore, it is
130 estimated that the reduction of this waste by 50% would result in a decrease of around 40% of
131 the plastic inputs to the ocean.

132 The 192 countries with coast in the Atlantic, Pacific, Indian, Mediterranean and the Black
133 Sea generated 2,500 million tons of solid waste in 2010, of which 270 million were plastic
134 waste. Coastal areas generated 99.5 million tons of plastic waste, of which 31.9 million were
135 mismanaged waste, i.e., more than 30 %. Of these, around 8 million tons entered the ocean in
136 2010 [55].

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

141 **3. Extraction and disposal of marine debris**

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

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

150 **3.1. Floating marine debris**

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

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

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

168 **3.2. Marine debris accumulated in the seabed**

169 **3.2.1. Probing equipment**

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

174 An equipment called "Tow-Sled" suitable for drilling in the seas, with moderate depths
175 (between 500-1000 m) has been developed in Korea. It is a kind of sleigh equipped with lights,
176 cameras and long-range acoustic positioning system, which provides information on the
177 amount, type and location of marine debris. This system is attached to the boat with a steel
178 cable, and moves towed by it thanks to two skates solder on each side of the equipment base
179 [63].

180 **3.2.2. Recovery equipment**

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

187 **4. Pollutants contained in the marine debris**

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

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

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

209 **5. Marine debris treatment**

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

214 **5.1. Pre-treatment**

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

221 **5.2. Treatments**

222 **5.2.1. Fuel production from marine debris (RDF)**

223 Marine debris has high calorific value (4000 – 6700 kcal/kg). This feature makes it suitable
224 for using as fuel. The analysis of the physical properties of refused-derived fuel (RDF) show that
225 marine debris contains a high percentage of carbon and hydrogen (C: 73.58%, H: 6.304%, N:
226 0.338%, S: 0.391%, others: 19.387%). Most of this debris are plastics, which can be
227 transformed into RDF.

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

233 **5.2.2. Marine debris recycling**

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

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

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

253 **5.2.3. Incineration of marine debris**

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

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

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

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

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

288 **6. Plans and actions adopted in related to marine debris**

289 **6.1. Internationally**

290 The Ocean Conservancy launched the International Coastal Cleanup (ICC) plan in 1986. In
291 this plan 97 countries and regions participated, and large amount of marine debris was
292 collected [73]. The target of this plan was to obtain information about the type and quantity in
293 which these residues are found in the marine environment. Since 1993, Brazil, Norway, United
294 Kingdom, Chile, Australia, Uruguay and the United States have been performing a marine
295 debris survey program associated to the Convention on the Conservation of Antarctic Marine
296 Living Resources (CCAMLR) [74]. Since 1996, the Environmental Protection Agency (EPA) of
297 the United States has been assessing the state of marine debris in the Gulf of Mexico, using a
298 standardized recording sheet [75]. Taiwan began to make plans related to marine debris
299 collection in 1997, when the government adopted Coastal Environment Cleanup Operation
300 Guidelines [76]. Korea began to develop plans and actions to removed marine debris in 2003
301 [63]. The Honolulu Strategy was approved in 2011 by the United Nations Environment Program
302 (UNEP). The UNEP suggested that member nations adopt those measures [77].

303 **6.2. Nationally**

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

313 An important measure that is having good result is the restriction on the use of plastic bags.
314 It is intended that people use only the necessary bags. Consequently, governments decided to
315 face in new bagging fees instead of allowing supermarkets to provide free bags. Taiwan has

316 reduced the consumption of plastic bags on a 58.34% with this initiative [78]. Other countries,
317 as is the case of France, have banned the use of plastic bags in stores from January 2016.

318 **7. Suggestions and further changes to reduce marine debris**

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

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

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

331 **8. Conclusions**

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

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

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615 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-antarctic 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]

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617

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

LOCALITY	LITTER TYPE	Percentage of debris items represented by plastics					Reference
		CA	PE	PP	PET	PS	
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]

619 *during 2005/2006/2007 ICC

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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 Zealand'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]	

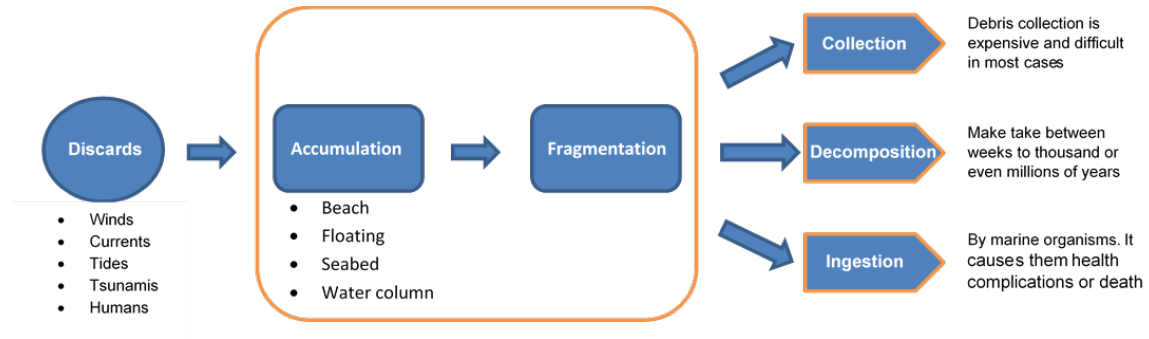
Tonking Bay and urban beaches at Odaiba, Kugenuma and Seal Beach						
San Diego, California (8 beaches)	Plastic debris	n.a. - 47	-	n.a. - 76	30 - 1900	[101]

623 n.a. → Not available

624 ^a → median of five pools

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Figure 1. Typical lifecycle of marine debris